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10TH INTERNATIONAL RANGELAND CONGRESS

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PREFACE

The Future Management of Grazing and Wild Lands in a High-Tech World

Dr. Bruce Coulman & Duane McCartney, IRC Co-Chairs

Every four years, the leading educators, researchers and rangeland managers from around the world gather to exchange knowledge, gain new ideas and network for future collaboration in the overall management of the world's extensive grazing and wild lands. Previous International Rangeland Congresses have been held in Denver USA, Adelaide, Australia, New Delhi India, Montpellier France, Salt Lake City USA, Townsville, Australia, Durban South Africa, Hohhot, China, and Rosario Argentina.

The 10th International Rangeland Congress "The Future Management of the Grazing and Wild Lands in a High Tech World" was held in Saskatoon, Saskatchewan, Canada from July 16 to 22, 2016. Over 450 presentations from delegates representing 58 countries were made through a series of plenary, oral and poster sessions. Over 215 volunteers were involved in the development and hosting of the Congress.

Pre-congress workshops included the topics of: rangeland hydrology and erosion modeling; multifunctionality of pastoralism; future of sage-grouse in western North America; species at risk in Canada; sustainable Chinese grasslands; and rangeland soil health estimates.

During the congress, two plenary presentations were held each day followed by five concurrent oral and poster sessions on thirty different topics. The main topics included: (1) State of Canadian and Global Rangeland and Pasture Resource; (2) Ecological Good and Services of Rangeland and Pasturelands; (3) The People of the Rangelands; (4) Multiple Use of Rangelands; (5) Range and Forage of High Latitudes and Altitudes; (6) Climate Change in Rangelands; and (7) Grazing Land Assessment and Management in a High-Tech World.

Delegates participated in three and four day pre-congress tours covering ecological and tourism sites in southern and central Saskatchewan and a seven day tour of Southern Saskatchewan and Alberta, including the Rocky Mountains. Nine different one-day mid-congress tours featured visits to historical sites, the University of Saskatchewan, the Western Beef Development Centre, the Western College of Veterinary Medicine, local industry, dairy farms, research centers, and tours of local grazing and farm lands.

The plenary, oral and poster presentations are featured in these proceedings and are organized by topic. We gratefully acknowledge the dedication of Kathy Larson, beef economist with the Western Beef Development Centre as head editor and general secretary of the overall congress, Dr. Mike Schellenberg, plant ecologist, and Dr. Walter Willms range ecologist (retired) Agriculture and Agri Food Canada, Co-Chairs of the Program Committee Dr. Alan Iwaasa, animal nutritionist with Agriculture and Agri Food Canada and Dr. Bart Lardner, beef cattle researcher with the Western Beef Development Centre, Co-Chairs of the paper submission and review process.

The knowledge summarized in these proceedings is a compendium of the current information for managing the world's range and wild lands and will have great influence on how we manage these lands for future generations.

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Plenary Papers

A Brief Tour of Canada's Rangeland and Pasture Resources

Edward Bork

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Key words: aspen parkland, boreal forest, ecological goods and services, mixed grass prairie, montane, northern temperate grassland

Introduction

Western Canada, including the provinces of British Columbia, Alberta, Saskatchewan and Manitoba, contains vast areas of rangeland and pasture that provide a wide array of benefits for Canadians, including forage for livestock (Fig. 1). These four provinces contain 96% (~19 M ha) of Canada's rangelands and 82% (~3.5 M ha) of the country's seeded pasture used by the beef and dairy industries (McCartney and Horton 1997). Much larger areas are used by free-ranging wildlife as only about 8% of Canada is used for agricultural purposes. Across western Canada, as many as 3.7 M beef cows call this area home and comprise more than 80% of the national breeding herd. In Alberta, which is home to about 40% of Canada's beef mother herd and close to 60% of cattle in the finishing (i.e., confined feedlot) sector, the beef industry continues to be the single largest agricultural commodity, with primary sales of nearly $4B Cdn, a value exceeding that of conventional cropping activities such as wheat and canola production. Grazing resources across Western Canada include a combination of native rangeland (i.e., areas not previously cultivated and composed largely of mosaics of endemic grassland together with various shrub and forest ecosystems), and in the prairie provinces (Alberta, Saskatchewan and Manitoba) substantial areas of introduced (i.e., seeded) pasture. In combination, native grassland and pasture provide diverse habitat for many wildlife species, including both consumptive (i.e., hunted) species, such as moose, elk, bison, bighorn sheep, pronghorn antelope, mule deer and white-tailed deer, as well as non-consumptive species, including several rare and endangered species.

The goal of this paper is not to provide a detailed review of the statistics associated with livestock production or range and pasture resources in Canada, as this has been done previously (e.g. Horton 1994; McCartney and Horton 1997). Similarly, a detailed review of the husbandry practices in beef cattle production – the primary livestock industry in Western Canada, has been described elsewhere (Sheppard et al. 2015). Instead, this paper provides a brief introduction to the contrasting rangeland ecosystems found in the region, including their biophysical characteristics and unique management challenges.

A Diversity of Ecosystems

Tallgrass prairie

Native Tallgrass Prairie (TGP) once covered about 0.6 M ha of southern Manitoba but is now relegated to isolated pockets (only ~0.5% remains) interspersed among widespread fertile cultivated fields managed for annual crop production (Chliboyko 2010). Historically diverse in both flora and fauna, these remnants contain a substantial contribution of warm-season (i.e. tropical) grasses and consist of relatively productive grasslands that evolved with high rainfall (>500 mm) and frequent fire (every 2-4 years). Historical fires were critical to prevent excess litter accumulation, facilitate nutrient cycling, initiate plant renewal, and control the encroachment of woody species. Similar to other regions, First Nations were an important mechanism regulating the occurrence of periodic fire, which was used for many purposes, including improving hunting opportunities, enhancing berry production, and providing a buffer zone of protection from wildfire, among others. Today, management of remaining TGP strives to conserve and maintain the biodiversity of this unique habitat type and often relies on the timely use of disturbance included prescribed fire.

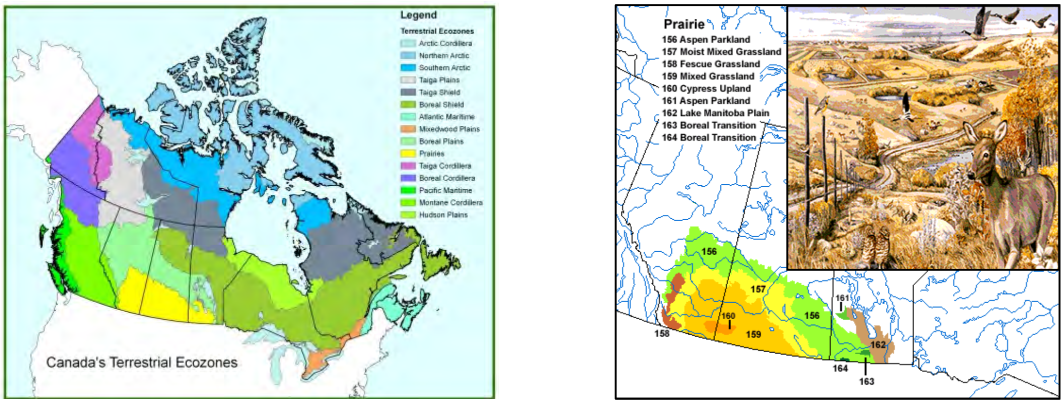

Figure 1. Canada's terrestrial ecozones (left) and embedded prairie environments (right).

Northern mixedgrass prairie

The Northern Mixedgrass Prairie (NMGP) is one of the largest grassland regions remaining in western Canada, and is represented by relatively low precipitation (~350 mm), high evapo-transpiration, and large seasonal moisture deficits (i.e. precipitation to evapo-transpiration ratios of ~0.4), particularly after mid-July (Willms and Jefferson 1993). Soils have relatively low fertility (<4% organic matter) and combined with dry conditions, lead to low statured grasslands with high root:shoot ratios where up to 85% of phytomass is belowground (Figure 2). While more than half of the NMGP is now cropped, this natural subregion continues to have the largest area of intact native grassland remaining (e.g. 43% in Alberta) Those that do remain provide habitat for many rare, threatened and endangered wildlife species, such as sage grouse, burrowing owls, ferruginous hawks, and Ordz kangaroo rat, all of which have been found to be closely tied to the conservation of native grassland habitats. Livestock production in the NMGP is typically conservative, with low stocking rates used to maintain plant vigor and ensure ample litter persists to protect soils and maintain healthy hydrologic function. Where past cropping practices have been proven unfeasible due to the restrictive climate and/or poor soil, these lands have been planted into introduced forages such as crested wheatgrass or Russian wild rye. Introduced forages were particularly important during the extended droughts of the 1930s and 40s as a mechanism to stabilize soils and provide emergency forage, and today extend the grazing season by providing early spring and fall grazing opportunities. While relatively productive for forage, these introduced pastures are less conducive to maintaining soil fertility and health, including ecosystem carbon stores, and pose a risk of invasion into adjacent native grasslands.

Foothills fescue

The Foothills Fescue (FF) is situated in SW Alberta and forms a transition zone from the NMGP into elevated Montane grasslands. While many native FF grasslands have been converted into cropland or introduced forage, others remain due to physical constraints that prevent conversion into alternate land uses. With elevated rainfall and cooler temperatures, grassland productivity is up to 6-fold greater in the FF than in the more arid plains to the east, producing as much as 3000 kg/ha of herbage annually (Figure 2). Under light to moderate grazing, highly diverse native bunchgrass communities occupy deep, well developed soils with organic matter levels that can exceed 10%. However, heavy grazing commonly results in the loss of deep-rooted bunchgrasses and lead to their replacement with shallow-rooted exotics (Dormaar and Willms 1990). Native grasslands dominated by foothills rough fescue and other strongly tufted bunchgrasses are highly valued by ranchers for dormant season grazing due to their ability to cure on the stem and retain favorable forage quality during fall and winter. Abundant production and long periods of snow-free conditions created by the regular occurrence of warm chinook winds during winter allow for extended access to stockpiled forage during the dormant season, thereby markedly lowering livestock production costs for the ranches that operate in the FF. Similar to other native grasslands across the Canadian plains, moderate livestock grazing is well

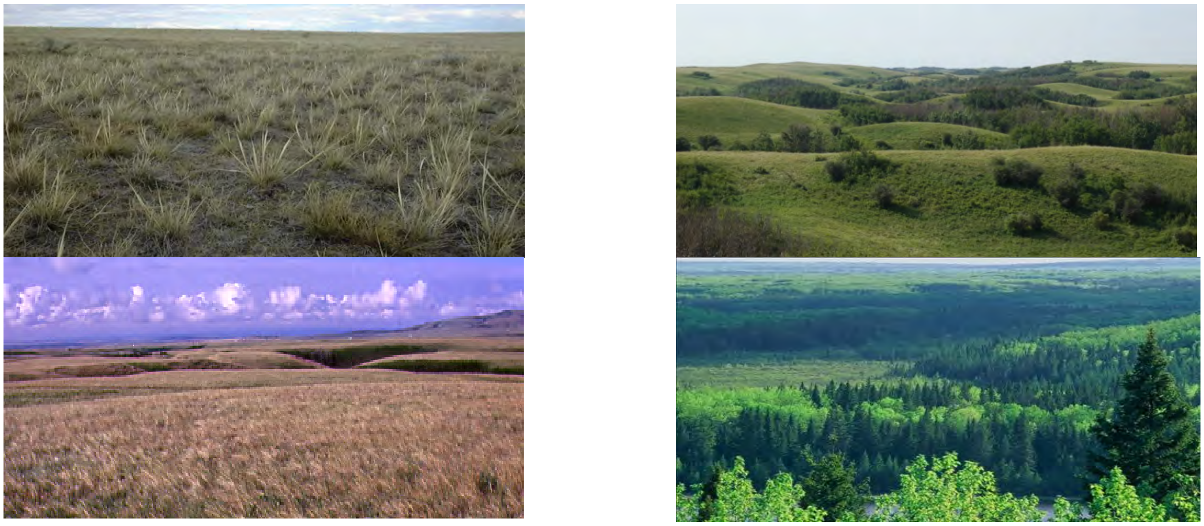

Figure 2. Examples of rangelands in the Northern Mixedgrass Prairie (upper left), Foothills Fescue (lower left), Aspen Parkland (upper right), and Boreal Forest (lower right) regions of western Canada.

known to increase plant species diversity in the FF, in large part due to the release of mid-seral grasses and forbs that are otherwise suppressed by highly competitive dominant grasses in the absence of grazing. Recently, the FF has experienced an increase in the occurrence and severity of wildfire, in turn imposing significant negative impacts on grasslands and the ranching families that rely on them.

Aspen parkland

The Aspen Parkland (AP) is aptly described as an 'ecological tension zone' forming a broad, arch-shaped transition zone from prairie grasslands in the south, to Boreal forest in the north or Montane environments in SW Alberta, and extends across all 3 prairie provinces. Much of this region is in cropland today, of which a substantial portion has been converted into intensively managed hayland and introduced pasture to support a thriving cow/calf industry. Introduced forage swards are dominated by aggressive agronomic species such as smooth brome, meadow brome, timothy, and alfalfa, among many others. These forages are used to provide large hay reserves and extend the grazing season, a necessity in the AP given that overwinter periods can be up to 6+ months long and high feed costs pose a significant economic constraint to ranching profitability in the region (McCartney 1993). Today, less than 10% of the AP continues to remain in a non-cultivated state, making native grasslands therein some of most threatened ecosystems in western Canada. Where they remain, native grasslands are typically relegated to rolling moraine ('knob and kettle') geological deposits and consist of a complex mosaic of grassland, trembling aspen forest groves, western snowberry and silverberry shrublands, as well as numerous intermittent wetland communities (Figure 2). Landscape diversity in this region is particularly high, providing heterogeneous habitat for wildlife and wide ranging opportunities for livestock grazing. Precipitation in the AP peaks during June and July and greatly aids summer plant growth, leading to favorable forage productivities and associated grazing opportunities. While plains rough fescue communities are becoming sparsely distributed due to extensive fragmentation and localized overgrazing, those that remain continue to be valued for late-season grazing by ranchers, in part due to the ability of native grasses to cure on the stem and provide favorable crude protein at that time of the year. Grasslands in the AP are also under ongoing threat of decline due to expansion of aspen forest, which can increase from less than 5% landscape cover to more than 60% after 50 years of fire suppression, and in some areas has resulted in near wholesale loss of grassland habitats. Moreover, forest increases lead to declines of more than 80% in herbage yields and can trigger soil degradation of the well-humified, fertile Black Chernozemic soils found under grasslands. As a result, integrated approaches to forest control are often employed involving some combination of herbicides, prescribed fire, controlled (i.e. 'mob style') livestock grazing, and even mechanical control.

Boreal forest
The Boreal Forest (BF) covers much of the northern prairie provinces in Canada, and provides abundant habitat for many wild ungulates, as well as livestock grazing (Figure 2). While much lower in herbaceous production compared to grasslands (by ~75%), its large area makes this region important nonetheless for livestock grazing and poses unique management challenges for livestock producers (Willoughby et al. 2006). On private lands, many forests have been replaced with high yielding agronomic forages with the intent of not only boosting production, but also building soil fertility within the Gray Luvisolic soils commonly found there. On public land, the BF is strategically managed to optimize multiple uses, which include commercial forestry, energy and resource extraction, recreation and wildlife management, as well as livestock grazing. Sustainable grazing of deciduous forests often consists of a light, once over grazing regime late in the growing season to ensure palatable forbs and shrubs are able to attain peak biomass and maintain their vigor. Livestock management in this region faces many challenges not found in the grassland biome, such as coping with a very short growing season, ensuring adequate access for animals through dense forests to distribute grazing pressure, and dealing with an increased risk of livestock depredation losses. Additionally, livestock grazing must be closely integrated with other land uses on public land. For example, where cattle grazing and deciduous forest harvest occur simultaneously, changes in the timing, intensity and pattern of grazing may be needed to ensure satisfactory forest regeneration, while at the same time logging impacts may reduce subsequent cattle access to forage via abundant woody debris and high density aspen regeneration.

Mountain rangelands
Mountainous areas of Alberta and British Columbia include Montane, Foothill, Sub-alpine and Alpine ecosystems containing high biodiversity with significant habitat for wildlife and livestock, with much of the latter occurring on public land (e.g. Wikeem et al. 1993). Livestock grazing in this region often emulates patterns of wildlife use by following a transhumance pattern, where livestock occupy high-country ranges in mid to late summer and lower Montane environments with numerous intermittent grasslands at low elevation in the winter and early spring. This temporal pattern of use allows relatively close alignment between the demand of animals for sufficient forage biomass and quality, particularly during calving and subsequent lactation, with ongoing spatial patterns of progressive green-up across these topographically rugged landscapes. However, this also necessitates careful monitoring and adjustment of livestock grazing activities to accommodate other land uses, including the needs of wildlife. In some situations, livestock grazing may be deliberately conducted to improve wild ungulate grazing opportunities through facilitative grazing, whereby the timing and intensity of cattle use are adjusted to provide high quality regrowth for dormant season foraging by wildlife. Despite their relatively small size, Montane grasslands are some of the most heavily used in Western Canada and are the focus of much attention by rangeland managers (Willoughby et al. 2005). Recreational activity is particularly high, and in the case of off-highway vehicle (OHV) use, can cause substantial degradation to remaining grasslands and sensitive riparian areas. Similarly, energy extraction has had a significant impact on these rangelands, both through direct disturbance and by fragmenting remaining grasslands, which can lead to weed invasions along the extensive network of disturbed corridors. Where intensively disturbed, native grassland revegetation is problematic due to the slow establishment of native grasses and abundance of highly competitive weedy species of introduced origin commonly residing in the seed bank. It is also worth noting that many areas of the Montane and FF sub-regions are under significant threat of fragmentation as the expansion of sub-urban areas in the form of 'ranchettes' progresses into many grasslands historically used for livestock grazing and wildlife habitat. In these areas, the use of conservation easements has been growing as an alternative mechanism to ensure the long-term co-existence of both agricultural use and grassland conservation.

Rangeland Stewardship

Land ownership

Most of Canada's land base exists under the public domain, whereby it is explicitly managed at the Provincial level for the benefit of all Canadians. For example, approximately 60% of Alberta is so called 'crown land', a number that swells to more than 90% in British Columbia. Under the public land model, resources are deliberately managed for a wide range of outcomes of benefit to society. This process encourages input from the public at various levels of administration, and in the case of rangelands grazed by livestock, often necessitates Coordinated Resource Management Planning (CRMP), a structured process encouraging input from citizens and public stakeholders into ongoing land management. In contrast, private lands are managed by a single or small number of stakeholders with a direct interest in the land base, and while typically financially motivated, they also exhibit other complex behaviors that reflect other motivations such as maintaining a healthy environment, quality of life and family traditions. Notably, private ownership is particularly common in regions containing better quality soils, placing remaining native grasslands within them (such as the Parkland) at greater risk of conversion to either cropland or urban-industrial uses. Despite this, private lands are often a key source of innovation in management and stewardship, a process aided by conservation outreach organizations such as applied research agencies or non-government organizations such as Ducks Unlimited. While there are few examples of public land under the control of the Federal government in Canada, one important and recent exception was land within the Prairie Farm Rehabilitation Administration (PRFA), which had a significant mandate to manage and maintain public rangeland in Saskatchewan. However, the recent dissolution of the PFRA and divestment of these lands from the Federal government has created significant controversy over the fate of these lands, including their potential privatization, with associated concerns over how this will impact interests of the general public.

Emergence of ecological goods and services

Rangelands of Western Canada have had a long history of herbivory, having evolved post-glaciation with significant populations of native ungulates. Shortly following European settlement in the late 1800's and the widespread reduction in wildlife through overharvest, rangelands became the primary source of fodder for a rapidly developing livestock industry. Cattle and sheep provided meat and hides to support a growing population in eastern Canada, and within many ecosystems functionally 'replaced' native ungulates as the primary form of herbivory. Similarly, horses reintroduced to the plains were widely used as a source of draught power to plow the land, transport people and goods, and aid development. While native grasslands today continue to provide an important source of forage for the livestock industry, stocking levels have declined markedly on public land, consistent with our interest in having these areas managed for multiple uses, including grassland ecological integrity. In addition, there has been a rapid emergence in the recognition of grasslands for their ability to provide Ecological Goods and Services (EG&S), which extend far beyond the sole production of forage and livestock. EG&S represent benefits to all of society from the existence and maintenance of grasslands, and includes critical ecosystem functions such as the provision of wildlife habitat, maintenance of biodiversity, storage and purification of water, support of pollinator populations, the storage of carbon and associated reduction in greenhouse gases (GHGs). While the historical use of rangelands for livestock production continues today on rangelands across Western Canada, the last few decades have seen a marked increase in attempts to enhance our understanding of the magnitude of EG&S benefits, and also promote the development of market instruments supporting EG&Ss. This information has the potential to not only add social license to the cattle industry to continue to use rangelands (particularly public lands) for livestock production, but perhaps more importantly, will lay a foundation for directly rewarding landowners for maintaining and enhancing these EG&Ss. This trend is also distinctly reflected in the current research investments by funding agencies such as the Alberta Livestock and Meat Agency (ALMA), Alberta Innovates-Biosolutions (AI-Bio), and the Climate Change and Emissions Management Corporation (CCEMC). While results of these studies are only now starting to become available, early findings point towards the retention of native grassland ecosystems for maximizing several EG&Ss, including carbon storage. Up to 40% greater carbon mass has been found in native grassland agro-ecosystems compared to neighboring areas converted to annual cropland or tame pasture. Moreover, long-term grazing has been shown to increase aboveground production, plant community diversity, as well as soil carbon, under select environmental conditions (unpublished data).

Summary
Western Canada contains widespread rangelands and pasture resources that differ greatly in climate, soils, vegetation composition, and their associated potential to support various land uses, including livestock grazing. Moreover, these lands differ in their stewardship models, occurring under both private and public management. While the primary historical use of these areas may have been for forage and associated livestock production, these lands are increasingly being recognized for their key role in providing a broad diversity of ecological goods and services, further increasing the importance of their sustainable management. Future conservation of native grasslands across the region will rely on developing a better understanding of the benefits society receives from these agro-ecosystems, and the development of market mechanisms that encourage their retention and enhancement.

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Global Range Resources: A Perspective on Their Use

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Introduction

Rangelands are among the most important terrestrial ecosystems in the world, occupying 40% of the world's terrestrial area (World Resources Institute 2000; based on IGBP data) twice the area used for crops (FAO 1998) and supply nearly three quarters of the world's energy requirement. China has a large series of rangeland resources, covering about 400 m hectares, 40% of land area in China, three times that of cultivated lands (FAO 1998). Rangeland is usually defined as uncultivated land that will provide the necessities of life for domestic and wild grazing and browsing animals, this includes grasslands, savannas, shrublands, woodlands, wetlands and deserts (Allen et al. 2011). Rangelands have a variety of additional functions, including tourism, hunting, fishing, forestry and natural resources protection. Rangelands include tallgrass and shortgrass prairies, savannas, steppes, desert grasslands and shrublands, woodlands, tundras, wetland, and meadow. China has used different definitions for "rangeland", or "grassland" since the late 1950s. Pasture lands are distinguished from rangelands in these definitions by being cultivated lands used to maintain forage species, with agronomic inputs such as fertilization or irrigation. However these definitions are very blurred, both rangelands and grasslands are terms often used for the same ecosystems. Since range management has become much more intensive during the last 50 years, "rangeland" often includes pasture land and integration with sown forages. We will use a broad definition in this paper.

Rangeland Functions

Rangelands play a critical role in providing habitat for animals, grazing for livestock, wildlife and thence the resource exploited by predators, a large part of world food production for man, and a range of environmental goods and services. Rangelands are the primary habitat for many wild animals whose economic and environmental values are increasingly recognized (wolf, hare, roe deer, hazel grouse, pheasant, etc.) and for plants with edible values or medicinal properties (fiddlehead, daylily, white mushroom, common sow thistle, *Allium* sp., lily, sea-buckthorn, honey plants) while others (*Phragmites*, Chinese *Miscanthus*) are used to make paper, or as an energy source, or for producing alcohol.

The environmental services provided by rangelands are now becoming more important as increasing human populations exploit all available resources to the point where now the world's environment is potentially unstable. Global warming is acknowledged as a major threat and rangelands have a role in carbon sequestration as well as dust and water erosion management, though this has to be balanced against the greenhouse gas production (particularly methane) from ruminants. This is one of the major challenges for current research. The extensive clearing of rangelands for cropping and other uses, plus over-exploitation through over-stocking have often been the causes of much deterioration of the rangelands and greatly reduced environmental function. Programs now exist in many countries to rehabilitate these degraded systems. The extensive nature of rangelands mean they not only can be important for the provision of environmental services within them and to surrounding areas, but they also provide a barrier that can help manage water, dust and other problems coming from outside the rangeland.

In China, the vast rangelands of the northeast great Hinggan mountains, through the Inner Mongolia steppe, the loess plateau, to the mountains of XinJiang, all provide an important ecological barrier.

Some rangelands have been cultivated for pastures and crops to directly or indirectly feed ruminants for human food. However in those countries with large areas of rangelands a significant proportion of the red meat, wool, cashmere and other fibres, skins and some milk still comes from natural systems. India has the largest cattle population in the world who graze whatever they can find and do not receive much supplements. China has the largest goat population and Australia and China have the largest number of sheep and these have been largely grazed on natural rangelands. Australia is the leading producer of wool, the USA is the leading producer of beef, though in the USA most of these animals are finished in feedlots, while China leads in mutton production worldwide, mainly in areas of lower productivity. In China, the rangelands provide the traditional animal production systems, though the use of more intense pastures and feedlots is increasing. Usually there is no supplementary feeding in most regions of China during the summer time, enabling those animal products to be marketed as ‘natural’ or ‘organic’. Supplements are though being used more through winter to improve the efficiency of livestock production. Across the world, the trend is to improve the efficiency of livestock production and that means more sown forages and more crops for supplements are used to improve productivity, finish meat animals for markets, sustain milk production from cows, sheep, goats, and to intensify animal production to feed an ever-increasing human population. As people become more affluent, most demand more red meat. The rangelands now have specialised roles for producing ‘natural’ animal products, often with stronger flavours and also for breeding the animals that will be used more intensively for milk and meat. In the developing world though, rangelands remain central to all aspects of livestock production. Addressing the inefficiencies of livestock production of small holders in rangelands will be a large part of the opportunity to address increasing demands for red meat (Michalk *et al.* 2015).

Rangeland Types and Resources

Grasslands, steppes, savannas, desert shrublands, forests, meadows and tundra are the basic rangeland types around the world. Each of these rangeland types contains several plant associations that utilise the varying, soil, climatic and other resources and then provide environmental and other services.

Steppe refers to a series of geographical biome regions across Eurasia. Much of the annual precipitation generally occurs over 60-120 days, often in summer when temperatures are ideal for plant growth. In winter, temperatures remain below freezing preventing plant growth. The grassland is continuous without trees or large shrubs, apart from those near rivers and lakes. Net annual forage production is between 400-4000 kg/ha; meadow steppe, typical steppe, and desert steppe are the most common subtypes. Steppes are widely distributed from Europe to east Asia and some parts of north and south America, in regions now relatively close to large human populations. To face the challenge of producing more meat and milk to meet increasing demands using fewer resources, different management models and grassland-based livestock production systems are used and being researched. Much relevant research relevant to the development of the steppe production systems has occurred in Australia and Europe. Legume-based grassland–livestock systems have been promoted to increase the yield, forage nutritive value and animal health, at the same time reducing dependence on fossil fuels and industrial N-fertilizer (García et al. 2013, Lüscher et al. 2014). Rotational grazing systems have proved to be efficient and better for managing environmental services in many countries, such as New Zealand, Australia, the UK, Japan and France, rather than the continuous grazing systems used in China and Mongolia in areas where various pressures reduce the ability of herders to move their livestock(Adachi and Tsuda 2013, McGlone et al. 2014). Degradation is now a major problem in China, Mongolia, Central Asia and parts of Africa where increasing human and livestock populations, often exacerbated by adverse climatic events, has lead to over-grazing, poor animal production and reduced household incomes (Han et al. 2008). Government policies and research programs aim to now reduce stocking rates and achieve a better balance between feed supply and demand (Kemp et al. 2013).

Prairies usually occur in a relative moist climate compared to the steppe, on very fertile soils, high in organic matter and loamy in texture, thus making them highly attractive for cultivation, arguably their main cause of degradation. Fire is important in prairie management when grazing pressure is low to generate higher quality forage and influence the diversity and spatial patterns of vegetation (Fuhlendorf & Engle 2001; (Ratajczak et al. 2014, Valkó et al. 2014). Prairies are usually dominated by perennial grasses, and maintain plant species through regeneration mostly from the belowground bud bank (Klimesˇová and Klimeš 2007). Canada and the United States have most of the prairies, only limited areas occur in other countries. In Canada, sustainable management, community-based grazing systems have developed over the years and conservative stocking rates typically apply. Ranchers, governments, and researchers have considerable experience using a combination of flexible rest and graze periods, and varying the intensity of grazing to optimise management of plants and animals (Fuhlendorf et al. 2012, Yu et al. 2014, Brown et al. 2015). Laws to protect rangelands regulate stocking rate. Remote sensing survey, bio-energy crops, and more effective grass-crop rotations are now used (Miller et al. 2013). The need to continually reduce energy costs and the impact of climate change on livestock in rangelands is a continuing focus for ranchers and researchers (Holechek 2014, Steiguer et al. 2014).

Savannas are distributed on both sides of the equator in all continents around latitude 30^0N/S. The annual average temperatures are 15-35℃ and annual rainfall 300-1500mm with 80 ~ 90% falling in the rainy season of 2-4 months. These conditions mean that C4 grasses commonly dominate the rangeland e.g. *Themeda* in Africa and Australia. Savannas are very common in Australia and Africa, being the major ecosystem type across much of those continents. Recent studies demonstrated that either conservative stocking with year-round grazing, or a grazing system that includes some wet-season resting helps maintain the rangeland in a desirable state or helps the transition to a more desirable state for pastoral production and rangeland condition (Ash et al. 2011). Similar results were found in South Africa’s savanna rangelands, rotational grazing having a positive effect on soil characteristics (Sandhage-Hofmann et al. 2015). Savannas though are no longer solely producing the most beef cattle, they are increasingly used for breeding animals that are then finished on better pastures elsewhere or in feedlots, while in Australia they provide live cattle exports to Asia for finishing there.

Rangeland Management Perspectives

The primary objectives of rangeland management are ideally, to achieve sustainable management of the pastoral resources and to optimise livestock production. These objectives are now applied within the context that: (1) rangeland is a renewable resource, (2) rangeland can provide food and fibre at lower cost than farmland, (3) rangeland productivity is highly variable and determined by soil, topography and climate, (4) rangelands provide many products and services e.g. food, wildlife habitat, bioenergy crop, greenhouse gases mitigation, green-tourism, carbon sequestration, erosion control etc., that need management, as does fire, (5) the decision process of rangeland management involves social, economic, cultural and technical factors. Actual practices vary across the world, as part of a spectrum of common elements, as in the examples below.

Extensive rangeland of low productivity with common grazing

Across these different rangeland types, desired livestock outputs have varied considerably, which then influences management practices. In many herder societies in low productivity regions, the aim is to maximise survival of animals while achieving enough production of food and fibre for their household and to have a small surplus of some products for sale or trade (Kemp & Michalk 2011). Today more herders are becoming livestock producers where a higher proportion of their livestock and livestock products will be traded, this is applying in China, but still limited in parts of Africa. Where the aim is to maximise survival, higher stocking rates typically apply, as the number of livestock is the households ‘bank’ and the condition of animals is less important. This increases the risk of over-grazing as herders wish to retain animals and markets are poorly developed for their disposal in drought. In effect, herders are often oscillating between survival and production. In good seasons they produce more animal product for trade, while in poor seasons they revert to survival. In average years in typical regions (Mongolia, China (desert steppe), Saudi Arabia, Algeria and Syria) 1 ha only supports 1-2 sheep unit or less. Common grazing is practiced and as herders aim to maximise animal number, degradation is common – first with changes in botanical composition then in extreme cases with desertification. In recent years, community-based rangeland management has been proposed as a promising option to reduce rural poverty and resource degradation in Mongolia. However, that approach is still evolving and no firm conclusions are yet available (Ulambayar et al. 2015). The situation is complicated by herders often having no rights to land.

Low to medium productive rangeland in more advanced economies
In Canada, Australia and USA, there are large areas of low to medium productive land where individuals have land rights and more control over managing the rangeland, especially the number of grazing animals. These managers are focused more on maximising their output of saleable product. They are focused on production where animal production per head is more important than animal number and lower stocking rates with a greater standing herbage mass, is a common aim. In advanced economies rangeland managers have learnt that a focus on animals, more so than the pastoral resource means a greater risk of over-grazing in poor seasons. They now aim to reduce livestock numbers early as pastoral resources decline, to reduce any possible damage to the rangeland. In Australia over the last forty years, pastoralists have learnt to maintain higher grassland biomass through short-term droughts than applied previously by earlier sale of surplus stock and other flexible management system (*e.g.* agistment of animals in good seasons and fencing and water infrastructure to control total grazing pressure). Only after a few years of drought is bare ground common. A consequence of better management in dry years is that recovery from drought is often quicker with more desirable plant species. In big droughts farms minimise livestock numbers for extended periods, waiting for a return to good seasons. Good rangeland management seeks to achieve a sustainable balance between forage supply (maximising the content of desirable species) and animal demand (Kemp et al 2013). Such concepts are now part of the Chinese national policies and are important in the management of semi-arid rangelands in Australia, South Africa, USA and elsewhere. Rangeland managers in these circumstances have better options for disposal of livestock. They may specialise in breeding meat animals that then move to areas growing forage crops or to a feedlot, for finishing either locally (sometimes on another farm the manager has in another district) or in other regions (Australia exports live cattle to Asia). The animal production systems in these countries are more integrated and involve more growth of forages and crops to improve the efficiency of production.

Highly intensive rangeland-livestock industries
In some developed countries (across Europe, North and South America, New Zealand, and parts of Australia) there is a long history of producing livestock on highly productive pastoral resources. Various methods (over-sowing, fertiliser) are used to foster productive, desirable, introduced, native and naturalised species. Many of these intensive pastures are on land cleared from forests, while other natural rangelands (alpine meadows, grasslands on poorer soils) are used at a lower intensity for animal production. In addition, forages and crops are sown to supplement pastures when needed to increase livestock production. Pastoral managers in these environments aim to achieve near maximal livestock production per head, especially when producing milk or meat from sheep and cattle. Their stocking rates depend upon first achieving their production goals per head and if the forage supply is insufficient they use additional forages or energy supplements. New Zealand has led the way in maximising the returns from intensive grasslands. They developed rationing systems where the feed intake of animals in some seasons (typically winter and when climatic conditions limit pasture growth below expected rates) is managed on a daily basis to be at an optimum level for the animals and results in most of the available, high quality, forage to be consumed. Very high stocking rates are used (2000 sheep units/ha) to eliminate any selectivity by animals. Very short graze periods (12-48h) are combined with long rest periods (30-120

days, depending upon temperatures and expected rainfall) to maximise pasture growth rates. This combination of grazing methods can enable an overall increase in stocking rate of up to 25% more than applies with more general rotational grazing systems. These techniques have not been used in less productive environments, but they may prove to be useful in some circumstances where, for example, the aim is to reduce less-desirable plant species and rehabilitate rangelands to a more productive state. In New Zealand, weedy pastures have been converted to highly productive *Lolium perenne / Trifolium repens* swards with these grazing tactics.

Rangeland utilization

While rangelands encompass a range of systems used by grazing livestock, the main focus is usually on the 'natural' end of the spectrum and how to achieve sustainable production as those areas cannot be readily re-planted. As mentioned, the management of such systems needs to consider a range of environmental services and functions provided by such rangelands while aiming to manage them sustainably. The general goal is to manage the plant/animal system, rather than simply focusing on animal production. In these systems, degradation is often first evident as a shift in species composition rather than in cover or standing herbage mass. Sheep and cattle can lose 10% or more of their body weights before visible signs are evident. By that stage, the more palatable plant species could have significant grazing pressure that may lead to composition shift. Monitoring the state of plants generally provides a better measure of when to move animals to new areas of the rangeland for grazing. Research needs to define the appropriate level of utilisation that maintains desirable plant species in the rangeland and helps optimise animal performance. Rules can be set whereby the state of plants can be used as an indicator of system 'health'.

In a study on the typical steppe in northern China (Zhang et al. 2015) it was found that maintaining the herbage mass at or above 1t DM/ha through summer, resulted in the more desirable plant species remaining dominant and the main less-desirable species remained <10% of total herbage mass. Analysis of a range of grazing treatments indicated this target could be met where the grazing days were 400 sheep units days/ha/yr. That proved to be a more useful measure than stocking rates as a target of sheep grazing days could be met by high or low stocking rates (within reasonable limits) and varying the duration of grazing until the total was reached. This target was equivalent to about half the district stocking rate and agreed with other modelling done (Kemp et al. 2013). Maintaining the grassland at 1t DM/ha had the best outcome for systems level greenhouse gas sequestration of (4 t CO_2e/ha).

In northern Australia, an alternative approach (Ash et al. 2011) has been to estimate the proportion of herbage that can be sustainably utilised through the 9-month dry season. This varied from 20-30% depending upon the pattern of grazing used. This is the total percent of herbage that 'disappears' over a specified period. The amount actually eaten by cattle may only be half of that i.e. 10-15%. The typical steppe study mentioned found that the utilisation rate, at the optimum sheep grazing days, was about 20% i.e. the amount of forage consumed by the sheep. In practice that probably means about 40% of the forage would be removed as another 20% would be lost through senescence, micro and meso-herbivore activities etc. In the New Zealand, case outlined above the amount of forage utilised could be 70-80% depending upon pasture growth rates. In general, it seems that a sustainable utilisation rate would decline as the productivity of a rangeland declines, due to a buffer need to maintain cover through dry periods, though this is likely to also vary depending upon seasonality of growth and if utilisation refers to the growing or non-growing season. Research could usefully investigate such a relationship as an alternative to setting stocking rates which only consider animal demand and not the forage supply, whereas utilisation rates includes both terms.

Rangeland managers will often be primarily interested in output of livestock products, but they are also conscious of the resource base and the environmental services these ecosystems provide. Research needs to find those common measures such as herbage mass (in grassland systems) which correlate with productivity and environmental services, and can be used to achieve sustainable management.

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Rangeland Goods and Services: Identifying Challenges and Developing Strategies for Continued Provisioning

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Introduction

Rangelands are dominated by a diverse assemblage of native vegetation – grasses, forbs and shrubs that cover 40% of the Earth's land area – and grazing by ruminant herbivores is a major land use. However, there is increasing awareness of the diverse benefits that rangelands provide to human societies. Ecosystem services (ES) are broadly defined as the benefits that people receive from ecosystems. The concept was popularized by the Millennium Ecosystem Assessment (MEA 2005) – a comprehensive assessment of the status of the Earth's ecosystems that was conducted by 1,300 scientist from 95 countries. The MEA classified ESs into four broad categories based on their ecological function and contribution to human well-being. Biodiversity is broadly considered to provide the foundation for all ESs. These categories are:

1) provisioning – goods and services directly used by society e.g., crops, livestock, water and timber.
2) regulating – ecological processes contributing to the regulation of ecosystem function e.g., climate, water and pests and diseases.
3) cultural – non-material benefits attained through spiritual enrichment, reflection, and aesthetic experiences e.g., recreation, ecotourism and cultural values.
4) supporting – services necessary for the production of other ES categories e.g., primary production, nutrient cycling, and pollination.

The rangeland profession has traditionally emphasized the sustainable production of a small set of provisioning services such that the concept of ESs has been slow to develop. A comprehensive assessment of seven widely implemented rangeland conservation practices in the U.S. found insufficient evidence to determine if ecological benefits had accrued from them because of minimal monitoring of practice outcomes (Briske 2011). This indicates that the potential value of ESs as a framework for rangeland application is yet to be determined. The broad goal of this paper is to evaluate the strengths and weakness of the ES framework to assess its potential value for rangeland application. The specific objectives are to: 1) describe rangeland ESs, 2) evaluate trends in supply and demand of ESs, 3) identify the primary challenges to continued provisioning, and 4) outline strategies to promote continued provisioning of ecosystem services desired by society.

Trends in Ecosystem Services

Supply of services

The MEA concluded that 16 of the 24 ESs evaluated have declined globally since 1950, including biodiversity, fresh water, erosion prevention, and climate regulation. Rangelands were included as the largest proportion of the drylands category in this assessment. A subsequent global scale modelling assessment has substantiated the MEA conclusions for rangelands by concluding that intensive livestock grazing increases carbon emissions, decreases biodiversity, and increases erosion (Petz et al. 2014). It has been estimated that 10-20% of global rangelands are current degraded to varying degrees and that approximately 15% have undergone conversion to cropland between 1950 and 2000 (Herrero and Thornton 2013). A decrease in total area and intensified use of remaining rangelands has the potential to a further reduce the supply of ESs. In contrast to these documented reductions in rangeland ESs, livestock production as been increasing for the past 50 years (Alkemade et al. 2013). This has been supported by a shift toward intensive production systems where greater than 10% of livestock feed originates from croplands.

Demand for services
Demand for ESs is driven by increasing human population and affluence, and preference for specific categories of ESs. A 70% increase in food production will be required to meet the demand of 9 billion humans at mid-century. Globally the demand for forage has increased to support the addition of 600M livestock in the past 30 years and livestock numbers are projected to continue to increase to supply the increasing global demand for meat (Herrero and Thornton 2013). In contrast, demand for forage production on U.S. rangelands has decreased 14% in the period 1979 to 2009 partially in response to the desire for more diverse ESs (Anadon et al. 2014). An increase in affluence and free time in developed nations has been associated with an increasing demand for cultural services (Havstad et al. 2007).

Tradeoffs among services:
Tradeoffs occur when land use is modified to increase production of desired ESs, but simultaneously decreases the provision of others. A major category of tradeoff occurs when land use decisions optimize provisioning services at the expense of supporting and regulating services. This category of tradeoffs occurs on rangelands throughout the globe. For example, long-term cattle production and economic profit was greatest in the Great Plains of the U.S. when rangeland was maintained in fair-good range condition, rather than excellent condition (Dunn et al. 2010). In this situation a tradeoff occurred among ESs valued by the public – biodiversity and hydrological function - and ESs that contributed to ranch income - forage and livestock production. Tradeoffs among ESs are further increased by the implementation of intensive production systems and conversion to cropland.

Challenges to Future Provisioning of Services

Increasing demand for all categories of ESs, a shift in demand among service categories, and decreasing availability of global ESs creates a major challenge for their continued provisioning. Given that rangelands are human dominated systems, these challenges represent both ecological and social considerations.

Ecological considerations
An understanding of four ecological topics are required to sustainably manage ESs: 1) species that are most important to the supply of ESs, 2) structure and processes of ecological systems that maintain function, 3) influence of key environmental variables, and 4) spatio-temporal scale over which providers and services operate (Kremen 2005). The structure and function of many rangeland systems are well understood, but this knowledge has not been specifically developed or organized to assess ESs, other than specific provisioning services (Briske 2011). The expansiveness and heterogeneity of rangelands greatly magnifies the challenge of acquiring sufficient ecological understanding to effectively manage ESs.

1. Key species provisioning ecosystem services. Ecosystem function is primarily determined by the traits of plants species that make the greatest contribution to production. Specific processes are affected by a combination of traits while key traits are simultaneously involved in the control of multiple processes (de Bello et al. 2010). Consequently, existing vegetation classifications of dominant and subordinate species, functional plant traits, and functional plant groups are all relevant to the provision of ESs because they emphasize the magnitude of resource use and the type of ecological process performed.

2. Ecological structure and mechanism underpinning ESs. Functional and response diversity, and landscape connectivity are critical to the provision of ESs (Mitchell et al. 2013). Functional

diversity indicates that multiple species carry out similar ecological functions while response diversity describes how functionally similar species possess unique tolerances to disturbances. Collectively, these attributes are assumed to maintain ecosystem function and the provision of ESs in response to diverse disturbance regimes. A global analysis of land use intensification found that both functional and response diversity were significantly reduced, although the relationship varied with land use intensity (Laliberte et al. 2010). Functional diversity decreased more rapidly than response diversity with increasing grazing intensity and it further suggests that functional and structural thresholds are not necessarily closely coupled (Chillo and Ojeda 2014). The redistribution of resources from source areas (patches of bare ground) to sinks within landscapes is an important ecological process in arid and semiarid rangelands that contributes to increased function and heterogeneity (Ludwig et al. 2005). Modification of these processes by natural or human means could greatly alter the supply and category of ESs by increasing runoff and soil erosion.

3. Influence of key environmental variables. Multiple variables or disturbances may modify the structure and function of rangeland systems to modify the supply and category of ESs. The potential consequences of increasing climate variability and woody plant encroachment are briefly described below.
    a. Climatic variability, extremes and change. The specific consequences of increasing climatic variability will be numerous and varied, including modification to plant community composition and species range distributions, forage quality and quantity, invasive plant species, parasites and diseases, and fire regimes (Polley et al. 2013). The consequences of climate variability to ESs are further complicated by large geographic variation in exposure and sensitivity of rangelands. Unique exposures to climate change will produce distinct geographic consequences that will create both adversity and opportunity for the supply of ESs. The ability of management and adaptation to maintain the supply of ESs in response to increasing climate variability is not well known, but limits do exists and the supply of ESs may be reduced and undergo geographic relocation in some situations.
    b. Wood plant encroachment. Encroachment of woody plants into grasslands and savannas is a global phenomenon that is taking place at a rate of 0.5-2.0% per year (Anadon et al. 2014). The majority (33/43) of ecological processes evaluated in a global meta-analysis of woody plant encroachment showed variable responses with only 20% of them producing consistent trends (Eldridge et al. 2011). Soil organic carbon, total nitrogen, available phosphorus and root biomass consistently increased with woody plant encroachment, while grass cover and soil pH consistently decreased. The common perception that ESs are reduced by woody plant encroachment may be a consequence of a narrow emphasis on the provisioning services of forage and livestock production (Eldridge et al. 2011). However, woody plant encroachment does contribute to major tradeoffs among ES categories. A 1% increase in woody plant cover decreases livestock production by 0.6 – 1.6 reproductive cows/km^2 in productive rangelands (Anadon et al. 2014). This translates to a 2.5% reduction in livestock production in the U.S. based on average livestock densities of 27 reproductive cows/km^2. However, in marginally productive rangelands, woody plant encroachment may actually increase livestock production.

4. Spatial and temporal scale considerations. Scale introduces additional complexity in the assessment and management of both the supply and demand for ESs. For example, C storage on rangelands represents a global regulating service, yet C sequestration it is highly heterogeneous based on regional vegetation and climate (Chan et al. 2006). Demand for many ESs frequently scales proportionately with human population density. Water demand is highest in agricultural and urban areas, which often does not coincide with a high regional availability of water.

Socio-economic considerations

The major social challenge to continued provision of multiple ESs is that markets value goods, specifically select provisioning services, but not the ecosystem processes that supply them. In contrast, regulating, cultural and supporting services have great value to the public at large, but their values do not accrue to the individuals or organizations who make land management decisions (Woodward et al. 2014). Consequently, self-regulating feedbacks between provisioning and other ES categories are weak or absent. Economists consider provisioning services to create benefits that are internal to existing markets, while the remaining services are external to them and considered to be of minimal value.

1. Value and valuation of non-market ESs. The economic notion of value is fundamentally linked to the concept of sacrifice. If society is not willing to make sacrifices to obtain or protect a service or ecosystem, then it is deemed to have little value. In cases where the necessary sacrifices are not made, it may reflect a failure of the market to correctly reveal the true interests of society. Markets are generally effective at providing incentives for provisioning services. For example, a livestock producer has a clear stewardship incentive because if rangeland is degraded it directly affects future prosperity. Market incentives do not always promote effective stewardship and many historical examples of poor natural resource management exist. However, established mechanisms exist for governments to minimize losses of provisioning services, including legislation, tradable rights, and common property governance (Ostrom 1990).

   In contrast to provisioning ESs, the benefits of other ES categories tend to accrue primarily to people other than those who directly control the land. For example, an urban center within a rangeland region may benefit from numerous regulating services – water purification and flood control – but markets do not necessarily provide a mechanism to ensure that these benefits will continue. The value of these ESs only becomes evident when they are no longer provided and sacrifices are imposed on the public. A central challenge to the valuation of rangeland ESs is that are often diffuse – locally sparse, but large in aggregate. Economists refer to this at the paradox of value (Simpson, 1998). Essential goods are available at low cost, while goods of little intrinsic value command a higher value – water is less valuable than diamonds because it is much more available. This can explain why we have witnessed such significant losses in non-market services in recent decades without greater public concern. Increasing recognition of the value of ESs in addition to provisioning services has created a situation where the narrow interests of land managers for provisioning services no longer coincided with broader societal interests (Simpson 1998). When will society recognize that non-market services have become sufficiently scarce increase their value?

2. Incentives. If policy makers are to alter the management of rangelands, land management incentives will have to be modified. Incentives currently involve the compensation of land managers for the loss of provisioning services when attempting to increase the supply of non-market ESs. In other cases, policies that create perverse incentives that lead to overvaluation of provisioning services at the expense of other ESs categories must be corrected. For example, grasslands are being converted to cropland at a rapid rate in the U.S. Approximately 5.7 million acres of grassland have been converted to cropland since 2000 and 22% of this land had not been recently cultivated (Lark et al. 2015). These perverse incentives could be minimized by greater enforcement of the Renewable Fuels Standard and restriction of federal crop insurance that incentivizes conversion of marginal lands to croplands. Sod Saver legislation has recently been enacted in six northern plains states to reduce the rate of grassland conversion to cropland.

Strategies for Continued Provisioning of Ecosystem Services

Knowledge of rangeland ESs

Minimal documentation of the consequences of management practices on the supply and tradeoffs among diverse categories of ESs represents a major challenge to an objective assessment of the ESs framework for rangeland application (Briske 2011). However, knowledge of ecological patterns and processes in rangeland ecosystems has advanced substantially in the past 25 years. Much of this newly acquired knowledge has been created in response to the investigation of ecological resilience. Resilience attempts to describe how ecosystems can be dynamic, but yet persist as stable states in response to disturbances. The prevailing interpretation is that ecological resilience is established by controlling variables and feedback mechanisms that constrain community dynamics within 'basins of attraction' (Walker et al. 2004). Given that controlling variables and feedback mechanisms are ecological processes, knowledge of them may contribute to an increased understanding ESs, which are the outcomes of ecological processes. A major effort will be required to retrieve, organize and interpret existing ecological knowledge within a framework that supports ESs, if it is to be used to guide rangeland management and policy.

Incentives

Several mechanisms to increase the supply of diverse ESs from rangelands follow in order of increasing intrusiveness: 1) land tenure systems, 2) land trusts and conservation easements, 3) common resource governance, 4) conservation incentives, 5) market-based conservation (payment for ESs), 6) coordinated land use planning, and laws and regulations (Ostrom 1990). Their relative effectiveness, both independently and in combination, must be evaluated under various ecological and socio-economic conditions.

Conclusions and Implications

The ability to supply diverse ESs from rangelands is constrained by a limited understanding of ES responses and tradeoffs to management practices and natural disturbances. If ESs are to provide a basis for managing rangelands, several important actions will be required. First, existing ecological knowledge will need to be organized into a management relevant framework capable of supporting ESs. Second, data on rangeland ESs responses to management and natural disturbances need to be monitored and archived. Third, knowledge of ESs must be incorporated into management and policy guidelines to support effective decision-making by increasing synergies and decreasing tradeoffs among various categories of ESs. Strategies to sustainably meet the growing demand for ESs will require an integrated, multidisciplinary approach that expands the scope of rangeland management to include knowledge of ecological processes, natural resource policies and socioeconomic values, and institutions. The central socio-economic challenge is the development of novel incentives that can realign the interests of land managers at local scales with those of the public at regional and global scales.

Adoption of an ES framework may allow for a more complete accounting of diverse ESs that are characteristic of the expansiveness and heterogeneity of global rangelands. Provisioning services - food, fiber, fuel - remain of vital importance, especially to humans in developing nations that possess large amounts of rangeland. However, in the context of global stewardship and human well-being, the aggregate value of diffuse non-market services may be of equal or greater value than provisioning services. The production of provisioning services on rangelands is greatly constrained by resource scarcity and variability compared to more resource rich regions. A major caveat to the valuation of rangeland ESs is that they are diffuse and broadly distributed throughout remote regions – a circumstance that is counter to the successful application of concentrated non-market services adjacent to urban centers. This will require that a global entity be designated to administer and develop market structures to trade these diffuse services in aggregate on continental or global scales. Although the utility of the ES framework remains a work in progress, we conclude that it may utility for global rangeland application and recommend that it should be explored as a mechanisms to guide management decisions and policy recommendations.

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Toward a Culture of Range: The Role of Society in Protecting Rangeland Ecological Goods and Services

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Residual Rangelands

Societies think of rangelands, native grasslands and shrublands—if they think of them at all—as a residual category. They are what's left over after you subtract cities, farmland, waterbodies, forests and mountains—a kind of null set. And where native grasslands do figure in to regional economies, they are typically secondary or even tertiary sectors. So they don't get much attention.

Most people would recognize a visual difference between say a spruce forest and a ponderosa pine forest, but only a few would detect a difference between, a stand of native bunchgrass and a crested wheatgrass field, or be able to distinguish needleandthread grass from quackgrass. The average person does not think of a native grassland as an ecosystem, or as a habitat, the way they do a forest or a wetland. So not only are rangelands a residual category in the minds of most, they are also damnably hard to describe. Let's face it, even we range people ourselves have difficulty characterizing them. In the Canadian Okanagan where I live, you can hear any number of terms applied to the same grassland.

Antelopebrush/needleandthread. Shrub-steppe. Pacific Northwest Bunchgrass. Intermountain Bunchgrass. Bunchgrass Biogeoclimatic Zone. Good condition, fair condition, poor condition. High seral, midseral, low seral. Grassland, rangeland, shrubland. And so on.

When I say "we," I am primarily referring to those of us living in western North America. That is my experiential frame of reference, since I've known or worked in the grasslands of California, Oregon, Washington, Montana, Saskatchewan and British Columbia.

So before we even begin to talk about society's role in protecting the ecological goods and services of grasslands, we need to get grasslands out of that residual category and develop an actual public conception—a mental picture—of what they are.

Nature—the Perennial Loser

It is my belief that the root cause of most environmental problems is our collective detachment from nature. We either see nature as an inexhaustible cornucopia, or we don't see it at all; it's simply there as an inconsequential backdrop for the ongoing human drama. In our hierarchy of values, contemporary culture gives nature a low priority and, as I've already pointed out, grasslands are on the far outer fringes of the public's awareness of nature.

Within mainstream North American culture we maintain a very curious duality in our attitudes toward nature. Our scientists study it, we document its services and we create parks in its honor, but we basically pay it lip service, and any time nature and short term economics enter on to the same playing field, nature is the perennial loser. And furthermore, when we consider any other society that *does* have close and intimate ties to nature, we automatically categorize that society as a primitive one.

Perhaps these are the two modes of the human condition; primitive but immersed in nature, or technology-driven and either at war with or oblivious to nature.

There are some historical reasons for why society here in the West does not have a strong connection to our grassland landscapes. The very earliest European settlements only reach back to around the mid-1800s. Two centuries or less is not a long time to get to know and appreciate local ecosystems. In the southern Interior of British Columbia, many of our low-elevation, valley-bottom grasslands were permanently altered by overgrazing, fire suppression and alien species invasion long before the first botanists had a chance to characterize them.

Very shortly after European settlement of the West, we were swept up into a veritable technological roller-coaster ride, which started with railroads and telegraphs and tractors, is currently passing through android tablets, drones and GMOs, and we are probably just now approaching the crest before the steepest descent of that roller-coaster, in that breathless moment just before we take the techno-plunge and our hair goes straight back, right over our surgically implanted cellphones.

So we have gone from the first vestiges of pioneer settlement to a hyper-urban, technologically driven society in two hundred years—that's not a long time to get to come to terms with ecosystems, particularly the complex and fragile ones that our grasslands are. And as anyone involved in ecosystem restoration can tell you, it is very difficult to reach back in time to understand pre-European contact ecosystem states and processes.

Cowboy Culture

The only tangible cultural connection we have with grasslands is via the lore of the cowboy, as expressed through books, images, movies and clothing. A few of you may know of the book *Smoky the Cowhorse*, by Will James, a classic western novel published in 1926, and it was a best seller for several years after that. I devoured that book as a boy, just as my father had devoured it when he was a boy. Because James was also a painter, and a damn good one at that, both my dad and I were able to project our boyhood selves right into those sagebrush-studded landscapes. That book was seminal, coming as it did at the tail end of the old Wild West, and of the Open Range era. Smoky was the bridge between the decline of the *actual* cowboy as a common—and often very unglamorous—profession, and the spectacular rise of the *mythic* cowboy and his romantic image in popular culture.

By the way, I have to mention a Canadian and a Saskatchewan connection here. Even though Will James identified himself as a quintessential Montana cowboy, his real name was Alphonse Dufault, he was born in Quebec, and he spent his formative years in southwestern Saskatchewan, near Val Marie.

But back to my thesis. There is much that was positive in the cowboy image; self-reliance, a closeness to nature; an understanding of natural cycles and an intimate connection to animals. Of course there were the negative aspects as well; gun violence, alienation from women, a toxic strain of Malheur libertarianism, and a general contempt for settled society. By the 1960s the cowboy image was starting to fade from the public consciousness. It had its last gasp in the phenomenally successful Marlboro Man advertising campaign, which ended with virtually all the men whose images were used in the campaign dead of lung cancer.

So where do we go from here? Now that the cowboy is for all intents and purposes, erased from the public's imagination, what cultural device can we use to connect people to grasslands?

Information *vs.* Story

The traditional answer to this question, and the one I have built most of my career around, is information. I have done environmental education and nature extension for a couple of decades now, long enough to learn a very hard lesson: information sucks. If you are trying to pull people into caring about local species and ecosystems by simply giving them information, you will absolutely captivate about 4 ½ percent of the population. The rest won't give a damn, or worse yet, they'll think you've been out in the sun too long without a hat. If you truly want to alert the public to the importance of ecological goods and services, you need to brand those goods and services, wrap them, and package them, and give them a unique identity, much the same way a successful winemaker does.

As a sometime nature writer, I've also discovered that sheer information itself is also not enough to carry a narrative, or make a book. The information has to be part of a story.

I once had the opportunity to visit Mitlenatch Island, a tiny uninhabited islet off the coast of Vancouver Island in British Columbia. Mitlenatch is one of those ridiculously well supplied little pieces of nature. It has sea birds, shore birds, raptors, seals and sea lions, and flowering plants of every description. It is so well endowed, it is like the Marilyn Monroe of the natural world. And yet when I wrote about it, all the species information seemed totally flat and unaffecting. It was only when I wrote the ecology of Mitlenatch into the story of how I got there, with a rollicking and bacchanalian oyster farmer, and the deal I had to cut with him to take me there, a deal which involved the midnight firing of spud guns, did the nature of Mitlenatch finally come alive for me on the page.

Making the Cultural Connection

To be real for us, nature has to be more than just information, more than just facts, more than just science. Nature needs context, and packaging. Nature needs story. Think of Farley Mowat's *Never Cry Wolf*. Nature cries out for music. Think of Vivaldi's *Four Seasons* or Beethoven's magnificent Sixth, the Pastoral Symphony. Nature craves images of itself, as in the photographs of Ansel Adams. Nature needs art. Think of Robert Bateman's paintings. Or closer to home, the wonderful landscape paintings of the late Saskatchewan artist, Allen Sapp. These cultural artifices contextualize, editorialize, and memorialize species, ecosystems and landscapes, and make them memorable to us. The artistic images persist long after the viewing or the reading or the listening; they hang in our minds, and manifest at odd moments. They refer, they correlate and they convey. They link forward and backward in time. And there is reciprocity: both nature and the artist are transformed in the act of creation.

These cultural linkages to nature are at the core of the genius of indigenous peoples' knowledge; that knowledge is all carried within the enfolding womb of story, and ritual, and culture.

And the nice thing about the cultural packaging of nature is that it's recyclable, does not require bubble packs, and has no best-before date.

The upshot of this is, if culture and the arts can help us take a collective second look at bitterbrush or western wheatgrass or rough fescue, then those natural elements stand a far better chance of remaining in our consciousness when it comes time to make decisions about how we live.

The conservation movement, of which I consider myself a part, is often accused of being elitist. I don't think that's true. I don't think we're elitist, I think we're just dumb, because we have relied almost solely on information, to the neglect of packaging, story, and culture. And we have very studiously avoided any connection between conservation and popular culture. Certainly governments have a role here, but may I remind you that governments are creatures of the voting public; if we voters don't care about grasslands, neither will governments.

We use science to document the use and overuse of natural resources, and we generally employ science when we attempt to stem the overuse. But the huge irony is that the solution to the overuse of natural capital does not lie primarily with science, or even with rationality; it lies in the social, cultural, and spiritual realms. The ultimate solution to overuse, and the road towards a sustainable, conserver society, lies in a fundamental re-tooling of our social and cultural values so that nature plays a more prominent role.

So now to return to the original question, "what is the role of society in protecting and providing rangeland ecological goods and services," we must first get society to recognize grasslands as ecosystems, and we can do that by employing culture, art and even spirituality in innovative ways. As a non-religious person and a redneck to boot, I have to use the term spirituality very carefully. For me, and I suspect for a few of you as well, a grassland is often as close to church as I get. I like the solitude that grasslands provide. For me, they are the least cluttered, and most transparent door into nature. So here might be yet another inducement to get the public involved in grasslands: make them understand that you could combine pilates, crystal power, yoga, aromatherapy, transcendental meditation and Rolfing all into one, and still not get the same spiritual satisfaction you get from a long walk in a fescue grassland.

Other Solutions

I do wholeheartedly subscribe to William Jordan's thesis on the importance of ecological restoration to the human psyche and soul, and that ER is an effective way of getting people engaged with nature. But successful ER projects are typically small, close to large urban centres, and are ones that show rapid and positive results. Grasslands and rangelands are typically large, away from cities, and the timelines for their restoration are often measured in decades, not years.

Speaking of large urban centres, I do believe that suburbanization and urban sprawl are major drivers of the loss and degradation of native grasslands in many parts of western North America. Grassland advocates need to learn the language of, and become familiar with, urban planners and municipal politicians. As Marcy Houle says, ranchers and environmentalists often derive great satisfaction from fighting with each other, while the real enemy—suburbanization—is ignored.

One last thing that I think we can do, as individuals and consumers, is to go the extra mile to seek out grass-fed beef, instead of picking up whatever is available on the shelves of the local Piggly Wiggly. I do remember when grass-fed and organic beef first hit the markets some fifteen years ago, and at the time I thought yes, this will work! People are now paying more attention to where their food comes from and how it is produced, and both ranchers and rangelands can benefit from this. And yet, fifteen years later, I'm ready to pay premium price for labeled grass-fed beef cuts, but I can only find them in a few high-end specialty stores in big cities. I don't really know why this is, but somehow, we have missed out on a brilliant, ecologically positive marketing opportunity, one that would also help connect urbanites to rangelands.

I wish I had more concrete solutions to the problem at hand, but I don't, so I'll close with a quote. I've always been a fan of the writer Wallace Stegner, another individual with a Saskatchewan connection, and if I were to teach a college range course, I would make his book *Wolf Willow* required reading. So here is the quote:

> One cannot be pessimistic about the West. This is the native home of hope. When it fully learns that cooperation, not rugged individualism, is the quality that most characterizes and preserves it, then it will have achieved itself and outlived its origins. Then it has a chance to create a society to match its scenery.

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Pastoralists in the 21st century: "Lo-Tech" meets "Hi-Tech"

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Introduction

In the 21st century, we live in a hi-tech world. "Hi-tech" is a fuzzy term, at the opposite end of the spectrum to "lo-tech", referring to working mainly with knowledge, skills and simple tools, often hand-made or mechanical. Hi-tech is the most advanced technology available, often involving computer electronics and information and communication technologies (ICT). Examples of currently cutting-edge hi-tech involve mobile phones, satellites, biotechnology, alternative energy or new forms of vehicles, also remotely controlled. Many of these have direct or indirect impact on pastoralists. How do these technological changes affect pastoralists in an essentially lo-tech production system?

"Pastoralism" is a form of land use in which grazing livestock make productive use of natural vegetation in marginal areas that are too dry, high, steep and/or infertile for crops. Traditionally, it is labour-intensive with little mechanisation, involves multiple animal species and produces a wide range of outputs: milk, meat, fibre, manure, leather etc. Vegetation growth in the rangelands depends on rainfall and varies greatly between years. Pastoralists capitalise on this poorly predictable heterogeneity over time and space. They constantly deal with uncertain conditions, and have few options to influence them.

In our hi-tech, information-rich world, there is no reliable information about the number of pastoralists; estimates vary by a factor of ten (Krätli *et al* 2013b). But it is safe to say that well over 90% of the maybe 100–200 million pastoralists in the world live outside of North America, Europe and Australasia. They produce food (meat and milk) with few external inputs in areas where ways of producing food make little sense in economic or ecological terms. To achieve food security with human population growth and climate change, the non-arable areas used for pastoralism will become even more important for the world than they are today. Here, the pastoralists are used to dealing with high climatic variation – primarily through their mobility – and can continue to produce food.

In the last two or three decades, pastoralists even in the most remote areas of Africa are meeting the hi-tech world. Here, we look at how hi-tech has impacted on pastoralism and how pastoralists have embraced hi-tech. We focus on Africa, Australia and Central Asia, as these are areas where we have worked and observed and learned.

Some Impacts of External Hi-Tech on Pastoralism

Industrialised production marginalises local pastoral products

Hi-tech applied in industrialised livestock systems, such as in Europe or North America, has led to cheaper and more uniform animal products that are transported to all parts of the globe. This marginalises produce coming from more remote areas of extensive livestock production, especially in low-income countries. The industrialised production is costly in terms of fossil energy use and impact on the environment and climate, but – under the current framework conditions – much cheaper than it should be in terms of money.

Hi-tech food-safety control excludes poorer pastoralists from markets

New technologies in animal health and food safety allow tighter control in high-income countries and are doubtless necessary for huge production and processing units so as to decrease risks for human and animal health. However, when the controls required for such mass production are enforced in low-income countries, poor producers cannot access formal markets and poor consumers cannot afford the products from the industrialised production. This has negative implications for human nutrition and health, as animal products are vital sources of protein (Roesel & Grace 2015). Intermediate-level technology plus a policy favouring the processing of smaller quantities of pastoral products sold to small-scale butchers and milk processors could bring greater benefits to poor producers and consumers and the local labour market than applying the highest levels of technology available.

Technological development leads to competing uses of land

New technologies to extract minerals and water have led investors deeper into pastoral areas. Irrigated mechanised farming has expanded into land that was once used only by pastoralists for food production. With rising demand for energy, large solar- and wind-power parks and bio-energy plantations have been installed. The technology consumes non-renewable resources and requires highly trained external experts to operate it. Hi-tech, when initially applied, usually means high risk, as the chances for success (and impacts) are unknown. However, it can also bring high profits quickly, which is what interests investors. Through such "development", many pastoral groups lost access to land and water resources they had been using for generations, with no compensation because of unclear rights to communal resources. Especially where irrigated farming is introduced in the name of increasing food production, pastoralists are excluded from key grazing and watering sites they need at critical times of the year to be able to maintain their production system. If these vital links in the pastoral seasonal cycle are broken, the drier areas (unfit for cropping, irrigated or otherwise) can no longer be used at other times of the year to produce animal-based food.

Some Impacts of Hi-Tech within Pastoral Systems

Pastoralists are not isolated from new technologies. For example, those in Africa have long had market links with cities and other countries, and some have worked abroad for some years, e.g. in the Arab States. They are aware of many new technologies and readily apply those that improve how they produce and sell their products and improve their lives as pastoralists. Many of these innovations were adopted spontaneously, without donor support, and some innovations were developed by pastoralists themselves.

Mobile phones and money

A new technology rapidly welcomed by pastoralists is the mobile phone. Most governments were loath to make the large investments needed to provide landlines for phones and energy supply in the sparsely populated pastoral areas. Mobile phone coverage, coupled with small-scale mobile units to generate electricity using solar or wind power, suits pastoralism perfectly and has brought about a revolution in communications and commerce in the rangelands.

Worldwide, pastoralists – men, women, young and old – now use mobile phones to obtain information about conditions for moving herds: weather, pasture and water availability, disease, conflict etc along routes. They stay in touch with family members and herders in their base and mobile camps, and can make herd management and marketing decisions from a distance. Mobile phones help pastoralists grasp new market opportunities, e.g. in camel meat and milk (Debsu *et al* 2016). In Kenya, a study last year found that 93% of Maasai herders rely on cellphones for some aspects of pastoral work (Butt 2015). In Mongolia, about 90% of the herders use cellphones and almost as many have small solar panels to recharge the phones and provide electricity for light, radio and TV. The Mongolian government values pastoralism and supports the spread of such solar power units throughout the rangelands (Hay 2015).

A major technology leap for pastoralists in Kenya was Safaricom's introduction of the electronic money-transfer system M-Pesa (Kiswahili for mobile money). Pastoralists can pay for inputs or receive payments for livestock by phone, saving time and money needed to travel to towns and avoiding risks of theft when carrying cash over long distances. They can receive remittances from family members living in towns or abroad. M-Pesa kiosks are scattered throughout Kenya, also in towns and settlements in the rangelands, to deposit or withdraw money. M-Pesa has facilitated money flows for the vast majority of pastoralists in Kenya who do not have bank accounts. It now has more subscribers and transfers more money than all Kenyan commercial banks together (Reinke & Speradini 2012).

The combination mobile phones + mobile money has widened the pastoralists' scope of commerce and led to an upsurge of micro-enterprises in the rangelands, especially on the initiative of youth with some formal education, selling, repairing and recharging phones and running kiosks to sell SIM cards. Some development projects support this by training youth and women in "solar entrepreneurship" to be able to sell, install and repair solar panels for recharging phones and lighting homes and schools (Obi 2015, Waruru 2013). The cellphone has also raised motivation for literacy, to be able to use SMS, which is less expensive than phone calls. Young pastoralists are earning money by teaching older pastoralists how to operate mobile phones and how to use SMS (e.g. in northern Benin, Georges Djohy, pers. comm.).

Computerised market information systems

In Africa, computerised information systems were started by projects to give early warning of disaster in pastoral areas but were then expanded to livestock market information to assist pastoralists in management decisions. Market data are available via cellphone and online, can be downloaded and printed for herders without Internet access and are posted at markets. Thus far, reports (e.g. Debsu *et al* 2016, Jama *et al* 2006) suggest that, in the rangelands, traders rather herders are using this information, while the main users are in the cities: project and government staff who track livestock trade and plan interventions. At least in East Africa, all market information systems continue to receive donor funding, in many cases several years after the system was set up (Zoltner & Steffan 2013). Operating costs are too high for governments in low-income countries. Moreover, herders are often wary of the motivations of public bodies trying to collect information. They may have more trust in systems operated by pastoral organisations, but these are not likely to be self-sustainable in terms of raising enough revenue to cover costs.

Motor vehicles

In the Americas and Australia, it is common practice to transport animals by vehicle and to use motorbikes to herd stock. With the import of cheap Chinese motorbikes, also many African herders use this form of transport – ideal for areas with animal tracks but no roads – to check on herds kept in remote areas and to bring animals to seasonal pastures or markets, often across national borders.

Pastoralists are increasingly using trucks to transport feed and water to animals, or to transport them to urban markets or ports. Groups of poorer herders combine the proceeds from selling a few animals to be able to hire a truck to transport the remaining animals to better pasture during drought. Pastoralists in many parts of Africa and Asia often hire tankers to bring water to underground cisterns or containers for watering herds where there is good pasture but no natural water source or well. Pastoralists in Sudan use camels to transport large empty rubber containers to grazing sites and then phone a tanker driver to come and fill up the "bladders". These water-related innovations by pastoralists are examples of endogenous solutions specific to the logic of pastoral production. They match access to water with the selective and transient use of pasture, rather than attracting masses of animals to a single and static borehole—a standard technology of governments and development projects (Krätli *et al* 2013a).

In high-income countries where the ratio of livestock to pastoralists is high and the ratio of people to land area low, unmanned remotely piloted aerial vehicles (drones) with heat sensors are used to find stock and reduce the cost of rounding them up, often done by helicopter in Australia. Drones can also be used to check fences and waterpoints. This technology is still in an experimental phase—also by some techie livestock owners in high-income countries—but is unlikely to be useful for the majority of pastoralists in the world, who know where their animals are, do not use fences and can use their social networks and cellphones to check on waterpoints at much less expense.

Animal healthcare
Technological advances related to veterinary drugs and vaccines are highly valued by pastoralists, who will travel long distance to obtain what they need to treat or protect their animals. Some pastoral groups in Africa and Asia operate their own animal health services, through community-based agents linked with government or private veterinary services. However, the easier availability of drugs can lead to widespread inappropriate use and speed up development of disease agents resistant to the drugs. Especially bacteria resistant to antibiotics are a reason for concern.

The wide popularity of mobile phones among pastoralists in Africa also makes it possible to monitor health and demographic data for both livestock and humans and thus help control diseases. In Chad, for example, groups of pastoralists were contacted regularly by mobile phone to gather information on birth, death and health status of the community and herds. This surveillance can be combined with One Health services for pastoral people and livestock (Jean-Richard *et al* 2014).

Satellite-based information systems on pastoral resources
A combination of cellphones and satellite imagery holds potential for pastoralists worldwide to obtain information on pastoral resources. In some cases, such as Kenya, herders collect information on the status of vegetation on the ground using a geo-localised app. Their reports make the satellite-based forage maps more precise (Steele 2015). The data are used primarily by government and development agencies for early-warning and planning purposes.

Elsewhere in eastern Africa, some NGOs are exploring how herders can use such information systems for their own decision-making. In Ethiopia, Lay Volunteer International Association found that pastoral men and women could easily interpret geo-referenced maps; these, combined with participatory mapping tools, allowed herders to depict their land and water use to support negotiations over resource use with other stakeholders (Rossi & Rizzi 2010). Project Concern International works with herders in Ethiopia and Tanzania in combining lo-tech scouting and oral communication about pasture conditions with hi-tech satellite-derived vegetation data to help herders decide where to take their herds in different seasons (Maratea 2014). In West Africa, maps based on satellite data are used to identify stock corridors between seasonal grazing areas and across borders to coastal markets, with pastoralists involved in groundtruthing and negotiations with local crop farmers (Maxwell 2013).

In the far north of Europe, indigenous herders are also exploring these new technologies. The World Reindeer Herders Association approached researchers in Norway to build the herders' competence in using satellite-generated data and GIS as tools for monitoring forage quality, ice and snow features, fire scars and infrastructure development. The herders are integrating their local knowledge with scientific data and developing their own monitoring systems so that they can adjust herd movements to avoid dangers and take advantage of better pastures along migration routes (Maynard *et al* 2008).

An example of hi-tech for empowerment of pastoralists comes from Tanzania and Kenya, where satellite images are used for a mapping system that enables pastoralists to demonstrate, in a 'language' that policymakers and planners understand, the logic behind the pastoral livelihood strategies. This work, supported by the International Institute for Environment and Development (IIED), takes place in a context of administrative devolution, where district governments have authority over local planning and development. Pastoralists are using the maps to improve dialogue with government so that it will invest in appropriate support to pastoralism as a viable production system (Hill *et al* 2015).

Satellite-based insurance systems
First in Mongolia and now in eastern Africa, some pastoralists are working with donors, researchers and insurance firms to test livestock insurance based on assessment of vegetative cover using satellite data (Chelan'ga *et al.* 2015). Experiences thus far suggest that, with remote-sensed data on rangeland conditions

over time, ground-truthing and time series of data on herd mortality, it is possible to predict mortality rates (Little & McPeak 2014). The insurance payouts are made on predicted, not actual mortality. Stimulating demand for the insurance is a challenge when herders discover that they may lose no stock to drought and still get a payout, but may also lose stock and not be compensated because the insurance system did not predict stock mortality. It is still uncertain whether index-based livestock insurance can be a profitable commercial product for private insurance firms or whether it will meet the same fate as market information system projects.

Digital identification of animals

In Botswana, cattle theft has been much reduced since the government introduced a livestock identification and traceback system, using a microchip encased in a bolus in the rumen and radio frequency technology (Mooketsi 2013). This system is now being tested elsewhere in Africa. Not only can animals be traced when stolen or lost, the digital identification system also traces the provenance of stock, which is useful for penetrating the EU market that requires such data. However, problems in Botswana because of equipment failure and non-visibility of the bolus led the government to switch to digital eartags. Another disadvantage of this technology from the perspective of herders is that it allows the government to monitor animal holdings and movements. Moreover, such hi-tech systems make pastoralists dependent on equipment, e.g. electronic microchip readers, using hard- and software that only specialists can understand and fix and—if it doesn't work—sell you something new. The costs are prohibitive in the countries where most of the world's pastoralists live, but one government obviously values the benefits of this approach: Uruguay now has a computerised cattle traceability system that covers the whole country, using numbered and chip-readable eartags. The hi-tech cowboys are said to be as skilled with computers as they are with horses. The government financed this traceability system to reinforce Uruguay's reputation as an exporter of prime beef (Davies 2014).

Modern weapons

One aspect of technological "advance" that has highly affected herders' lives is the development of high-power weapons, now used in livestock raids and conflicts. The wide availability of such weapons (especially small arms) has exacerbated conflicts in the African rangelands and led to more stock theft, more human deaths, no-go grazing areas between rival groups and concentration of animals in more secure areas near settlements (Little *et al* 2011). It is an introduced technology that some herders as well as large-scale livestock traders and rustlers are using to their advantage and obliges all herders to arm themselves for protection.

Discussion and Outlook

Technological threats and potentials

Hi-tech is influencing 21st-century pastoralists in both good and bad ways. Application of advanced technology in intensive livestock systems elsewhere, together with policies that favour this technology, is changing the framework conditions for pastoralism in low-income countries, above all with regard to marketing, also domestic markets. Application of hi-tech in extractive industries and irrigated farming in parts of the rangelands is depleting non-renewable resources and ousting pastoralists from strategic grazing areas, thus threatening the entire pastoral system. Especially in countries with common property regimes for pasture, herders generally have no say over these alternative uses of the land and do not benefit from them. Often, external investors can profit from extractive industries or irrigated farming for only a short period, until the resources are depleted or the high production cost or environmental damage ends the venture. But, in that short period, they can destroy the resource use system that pastoralists have used in the larger area for generations, including the knowledge and skills to continue doing so.

Some pastoral groups have been resilient and adaptive in embracing modern technologies that improve their production systems and lives. The potentials of hi-tech must be seen through the lens of pastoralists. The hi-tech world tends to hubris: as if technology can solve all problems. This comes from a mindset of man's control over nature—in agriculture: growing food under as highly controlled conditions as possible. This mindset does not fit the logic of pastoralists: making strategic use of dispersed and ephemeral grazing resources. Pastoralism is a form of low-external-input and sustainable agriculture. It makes efficient use of scarce resources—above all, water—with minimal use of fossil-based inputs. It produces nutritious high-protein food from plants that cannot be eaten directly by humans and in areas where food cannot be grown without high levels of external inputs. It is an efficient and environmentally sustainable way of making the existing resources productive for human beings. It requires high herd mobility, rapid and flexible reaction to changes in weather and other local conditions, and keeping as many options open as possible. Successful herd mobility relies on collecting real-time information on pasture and water availability and quality, disease outbreaks, areas of conflicts, etc. as well as cultivating wide and reliable social networks and engaging in frequent negotiation.

As far as the actual grazing is concerned, the main management options that make economic sense in most of the world's rangelands are lo-tech but highly knowledge intensive: distribution of animals in time and space, use of different types and species of animals, influencing growth and composition of vegetation through fire or mechanical means, e.g. cutting, and applying indigenous knowledge of plant and animal behaviour. Efforts at intensifying this extensive production system make it essentially non-pastoral. However, pastoralists have recognised some hi-tech innovations that can support them in making decisions about moving herds, in managing animal health and in marketing pastoral products. Above all, cellphones have made it possible to obtain such information very quickly, especially if used with trusted contact persons or scouts. This is a clear technology choice made by pastoralists worldwide, where hi-tech enriches socio-economic networks.

To improve the lives of pastoralists, appropriate and affordable innovations are needed above all to improve the quality of life in the rangelands: providing services that suit the pastoral mode of production rather than attracting people to settle in towns. Here again, mobile technologies are key – to provide safe water for people and livestock, to improve human and animal health, to enable long-distance and life-long learning by children and adults, and to generate renewable energy to support these services.

Beyond technology

Some forms of hi-tech can provide useful tools that visualise bio-technical factors, but using, e.g., satellite-based data can throw additional light on only some aspects of pastoralism, which includes also social, cultural, political and economic dimensions. Many of the challenges faced by pastoralists are related to policy, economics, insecurity and access to resources. Hi-tech can be useful if it can support related negotiations, e.g. to secure land-use rights or stock migration and trade corridors.

Hi-tech does not always lead to economic efficiency, environmental protection or social equity; indeed, many forms of hi-tech in the rangelands work against these. That is why pastoralist development must go beyond physical technologies to explore institutional innovation. For example, this is needed in large parts of Africa to counter tendencies that hard technologies and the political and economic interests behind them lead to greater individualisation and weaken the local institutions that govern the use of rangeland resources, e.g. agreements on seasonal resting of pastures or closure of large-volume boreholes to minimise environmental degradation and socio-economic inequities.

The most important hi-tech contribution for pastoralists has been the revolution in generating, processing and sharing information, but what is crucial for pastoralists is their capacity to use this information and to influence how others are using it. Many ways of using ICT and satellite data in pastoral areas allow governments to track resource dynamics, anticipate crises and "manage" the rangelands from afar. It is not the technology that determines how rangelands are used but rather the decision-making systems and institutions of the stakeholders – those who are in the rangelands and those who are not.

In most of Africa, pastoralists have been marginalised ever since colonisation. It was different in the

American West and Australasia, where the colonising ranchers once played an important role in national politics and identity. Those days are gone. The Australian station owners are no longer "kings in grass castles"; they now have little political say, and most city dwellers – including new citizens from Asian and Arab countries – do not identify with them (Walker 2015). In terms of their status in their countries, the "traditional" and "modern" pastoralists now have more in common than before. They need to join forces to show how they contribute to economy and society – not only by producing healthy food but also through environmental protection, carbon sequestration, tourism and security – so as to justify investment in the rangelands. In these efforts, Internet platforms such as WISP (World Initiative for Sustainable Pastoralism), CELEP (Coalition of European Lobbies for Eastern African Pastoralism) and FAO's Pastoralist Knowledge Hub can connect pastoralists and their advocates worldwide. ICT can help pastoralists build new alliances, using websites, blogs, films etc as tools to lobby for recognition of pastoralism as a production system with a future (also in Europe, e.g. Herzog *et al* 2016) and for pastoral resource-use rights. Especially training of youth in ICT could help them use hi-tech for this purpose.

What does the future hold?

The fact remains that, in dry rangelands, pastoralists manage to produce food for themselves and others in their own countries and abroad at low cost and – where they can move their herds – in an ecologically sound way. There are 100–200 million people with these unique skills who live from pastoralism, mainly in low-income countries. On a 10,000 ha property in Australia with 1000 cattle, one family may earn a living; in a similar climate in East Africa, pastoralists may keep twice as many animals on the same area which supports – albeit on a lower level of wealth – 20–30 families. "Development" that ousts these people from the rangelands will push them into urban poverty, aid dependency or overseas migration.

Whether in Africa, Mongolia, Australia or the Americas, ICT and transport innovations make pastoralists much more strongly and quickly connected with the rest of the world than in the past. Better connectivity will doubtless lead to further changes in how they organise their lives and work. In all pastoral areas, one can see satellite dishes as receivers and solar panels to generate energy for radios, TVs, computers and cellphones. At a petrol station in southern Ethiopia, I found myself sitting among herders watching a live screening of a World Cup soccer game. ICT brings entertainment, easier communication and more efficient commerce and makes life in the rangelands more attractive, also for youth. Will this reduce rural exodus? Will more people opt to stay in or return to the rangelands to be pastoralists and/or to run businesses to serve local people and well as people in the cities? Or will the flood of information about life elsewhere motivate even higher rural exodus? One observer of the ICT revolution in Mongolia sees evidence that pastoralists are enjoying the benefits of "modernity on the move". He claims that the wide availability of cellphones and mobile charging stations is reversing urbanisation: some pastoralists have abandoned the urban congestion and scramble for low-level service jobs and gone back to the range, as they now see pastoralism as a viable lifestyle (Hay 2015).

Although today, hi-tech in the North still impacts negatively on the terms of trade for most pastoralists in the South, the economics can change as people and governments become more aware of the health and ecological impacts of "factory animals" versus local grass-grown meat and milk. As more consumers demand healthy and environmentally friendly food, pastoralists in North and South are recognising a niche for selling organic produce. Although today, pastoralists in many countries are still threatened by hi-tech projects that are not economic and waste scarce resources, there is growing awareness of the non-sustainability of these interventions. With greater understanding of pastoralists' valuable role in producing nutritious food from ephemeral resources, conserving biodiversity and maintaining society in remote areas, hi-tech options that suit a mobile production system and are applied in a socially responsible way could indeed modernise pastoral life and help ensure its future.

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Resource Extraction and Mining Problems in Asia and Mongolia

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Asia is the largest of the world's continents, covering approximately 30% of the Earth's land area. It is also the world's most populous continent, with roughly 60% of the total population (4.4 billion). The border between the two continents is debated. However, most geographers define Asia's western border as an indirect line that follows the Ural Mountains, the Caucasus Mountains, and the Caspian and Black seas. Asia is bordered by the Arctic, Pacific, and Indian oceans. Today, Asia is home to the citizens of 48 countries, two of them (Russia and Turkey) having part of their land in Europe.

Natural Resource Extraction in Asia
Asia's stake in world markets has grown dramatically in the last half-century. Today, Asian countries rank as some of the top producers of many agricultural, forest, fishing, mining, and industrial products (National Geographic Society, 2012). This increased production has brought both extreme wealth and negative environmental impacts to the continent.

Hardier grains, such as barley, buckwheat, millet, oats, and wheat, are grown in the central and southern areas of this zone, where permanent frosts inhibit plant growth. Animal husbandry is also very important in this zone. In Mongolia, for example, 75% of agricultural land is allocated to the rearing of livestock. In 2010, Asia harvested almost 570 tonnes of rice, accounting for more than 50% of the continent's total cereal production—and roughly 90% of total global rice production.

Timber industry
Forestry, the management of trees and other vegetation in forests, is an important but threatened industry in a select group of Asian countries. China is a major exporter of wood products, ranking first globally in wood-based panel production, paper, and wood furniture. During the past 10 years, Asia has increased its forest cover by 30 million hectares to create forest plantations where trees can be intensively managed for higher-yield production.

Asia represents the most important region for fisheries and aquaculture production in the world
Asia's marine fishing areas produced roughly 50% of the global fish capture. Six of the top 10 world producers of fish are found in Asia. Asia also produced about 90% of the world's aquaculture-raised fish. A recent study by the National Geographic Society places China and Japan as the world's leading consumers of seafood, at roughly 695 million and 583 million tonnes annually.

Mining
Extractive activities are an important part of the economies of many Asian countries (. China, India, Russia, and Indonesia are the continent's most productive mining economies. These countries extract many of the same minerals. China is the world's largest producer of aluminum, gold, tin, and coal. India is also a major producer of aluminum and iron ore, along with other minerals such as barite, chromium and manganese. Russia is a major producer of coal, tungsten, diamonds, iron, and steel. Countries on the Arabian Peninsula have the world's largest deposits of oil and natural gas. In 2010, Saudi Arabia was the world's largest manufacturer of petroleum liquids, producing 10.07 million barrels of liquid fuels every day. It also has the world's largest oil reserves, at roughly 250 billion barrels. Saudi Arabia's economy is heavily dependent on

oil exports, which account for 80 to 90% of the country's total revenues. Saudi Arabia, Iran, and the United Arab Emirates accounted for roughly 57% of global liquid fuels production in 2010.

Another major player in Asia's liquid fuels industry is Russia. Russia has oil reserves in Siberia, and massive natural gas reserves throughout the Arctic. Russia is the world's largest producer of natural gas, and the largest supplier of natural gas to Europe. Russia has not aggressively drilled in the Arctic Ocean, but engineers say the area holds millions of barrels of oil and gas reserves. A surge of economic investment, primarily funded by the oil, technology, and pharmaceutical industries, has fueled the development of medium-sized cities into important metropolitan areas. Two urban areas that demonstrate this are Hyderabad, India, and Dubai, United Arab Emirates.

Gold and coal
China has recently become the world's largest gold producer. For the year 2015 gold output rose 490 tones and became the world's largest. On the other hand, gold output in China has risen by 70% for the past decade. It burns 24% of the world's coal. China has been by far the biggest coal producing country over the last three decades. The country produced about 3.6 billion tonnes of coal in 2012 accounting for over 47% of the world's total coal output. China has 114 billion tonnes of coal, enough to last 75 years if consumption rates remain the same. Coal-fired power plants are the biggest source of human-made carbon dioxide emissions, making it the single greatest threat facing our climate. Apart from climate change, coal also causes irreparable damage to the environment, people's health and communities around the world. From mining to combustion, coal is the dirtiest fossil fuel on the planet, producing air and water pollution and liquid and solid waste.

Coal is the single biggest source of climate-changing pollution. Coal mining destroys ecosystems and releases toxic levels of minerals and gases into water and air. The impacts of air pollution are far reaching: for example, mercury pollution from coal-fired power plants can travel thousands of kilometers. Burning coal creates millions of tonnes of waste products that contain toxic levels of heavy metals and minerals. Coal consumption increases at a rate of 10% a year.

Copper in Asia
Again China is the biggest producer of copper in Asia. In 2014 China produced 1.760 thousand tonnes of copper per year and Chile 5.750.000 tonnes. Other biggest copper producers in Asia are Russia (742.000t), Kazakhstan (494.000t), Iran (494.00t) and Mongolia, which is the seventeenth biggest producer in the world (122.000t).

Diamonds
Russia is one of the world's largest producers of gem quality diamonds. Russia accounts for 21% of global diamonds produced. Russia's main diamond mining enterprise is Almazy Rossii-Sakha, which mines over 98% of the country's diamond output in the Sakha/Yakutsk Republic. Alrosa Group, one of the biggest producers of diamonds in the world, plans to mine US$1.636 billion worth of the gems this year, including US$1.500 billion by the group's flagship company ZAO Alrosa.

Mining Problems in Mongolia
The mining giants have given a major boost to its economy; in 2014, Mongolia's GDP is slated to spike by 15.3%, the highest growth rate in the world. In 2012, minerals comprised 30% of the GDP and more than 80% of exports, according to the Mongolian Research Group of the Centre for Social Responsibility in Mining.

Largest mines in Mongolia (Report from: Rheinbraun Engineering und Wasser Gmbh. 2003)
The Oyu Tolgoi mine is a combined open pit and underground mining project in the south Gobi desert near to the Chinese border. The site was discovered in 2001 and is being developed as a joint venture between Turquoise Hill Resources with 66% ownership and the Government of Mongolia with 34%. The mine began construction as of 2010 is the largest financial undertaking in Mongolia's history; it is

expected to produce 455,000 tonnes of copper annually. Oyu Tolgoi LLC, the world's largest copper deposit and official site of strategic importance in Mongolia. It is expected to produce 30% of Mongolia's GDP by the time it reaches full production in 2021, according to the International Monetary Fund.

The Erdenet City was built in 1974 to exploit Asia's largest deposit of copper ore and has the fourth largest copper mine in the world. The "Erdenet Mining Corporation" is a joint Mongolian-Russian venture, and accounts for a majority of Mongolia's hard currency income. Erdenet mines 22.23 million tonnes of ore per year, producing 126,700 tonnes of copper and 1954 tonnes of molybdenum. The mine accounts for 13.5% of Mongolia's GDP and 7% of tax revenue. About 8.000 people are employed in the mine.

Borundur is the biggest fluorspar mining and fluorspar concentrate production. The underground mine, open pit and mineral processing plant, which is the only mineral processing plant in the country, are operated by the Mongolrostsvetmet JV company. All fluorspar products are exported to the Russia, the Ukraine, and other countries by rail. In 2014 there were 40,000 heads of livestock in Borundur . However, they do not have enough pasture land due to mining.

The Baganuur mine is the "biggest coal mining company in Mongolia." The mine has produced approximately 75 million tonnes of brown coal since it was opened.

Boroo Gold Mine is an open-pit gold mining site located in northern Mongolia. The Gatsuurt gold mine is near by the Boroo Gold Mine. The mine is owned by the Canadian mining company Centerra Gold Inc. It began commercial production in March 2004 and produced more than 1.5 million ounces (47 tonnes) of gold through the end of 2010. The Boroo mine was the first hard-rock gold mine established in Mongolia.

The Erds Coal Mine is a coal mine located in eastern Mongolia. The mine has coal reserves amounting to 807 million tonnes of coking coal, one of the largest coal reserves in Asia and the world. The mine has an annual production capacity of 0.1 million tonnes of coal.

Tavan Tolgoi ("Five Hill") is one of the world's largest untapped coking and thermal coal deposits, located in southern Mongolia. It has a total estimated resource of 6.4 billion tonnes, one quarter of which is high quality coking coal. More recently, private investors, responding to an improved investment climate, have concentrated almost exclusively on six high-value export metals: gold, copper, zinc and uranium, plus fluorspar and coal.

Gold production mainly comes from placer operations, but output is stagnating as large readily accessible rich deposits are depleted. Exploration by an estimated 200-plus placer drilling rigs is now compensating for the decline with new discoveries.

Artisanal and Small-scale (ASM) Gold Mining
Unlike many other developing countries, ASM is not part of traditional subsistence economy in Mongolia (World Bank, 2006). There is a wide range of opinions about the number of artisanal and small-scale miners in Mongolia, stemming from the large size of the country, the lack of a full survey, the practical difficulties of counting ASM at any given site, and the substantial seasonal fluctuations in numbers and geographical distribution.

According to government estimates, there are about 30,000 informal gold miners. For fluorspar, there is consensus that several thousand ASM operations have become active in fluorspar mining and processing in the last four years.

Also, there are perhaps no more than a thousand informal miners engaged in mining of materials serving local needs, such as salt, clay, and sand. Possibly another 500 informal miners are engaged in illegal mining and export of fossils, semi-precious stones, meteorites, and mineral specimens.

Environmental Impact of Mining

Changes in hydrological regimes

Informal ASM gold mining can and often does degrade or destroy placer reserves, notably by removing pay gravel before and during formal placer mining. This renders full-scale mining more complicated, more risky, and less profitable (and sometimes unprofitable). The environmental impacts of ASM are also significant and represent a growing concern in Mongolia (Grayson and Murray, 2003).

Air pollution

Lower air quality from ASM's is posing a growing health threat. Dust generated by placer ASM's - from shoveling, scraping chiseling, bagging, and spillages in a confined space with poor ventilation - causes eye injury, bronchial complaints, and silicosis. Even more dangerous is the smoke from fires to melt permafrost, particularly black smoke from tires. The sheer volume of smoke is known to be exerting a strong negative impact on the health of the miners and livestock.

Water pollution

ASM's are considered the main cause of substantial deterioration in water quality in several rivers across the country. Thousands of placer mines are aggravating the situation by using fire to melt the permafrost. Local loss of permafrost prevents the spring thaw getting to the main river, with water now pouring through gaps in the once continuous permafrost seal.

Mercury pollution

Pollution from mercury is a substantial problem, particularly in the Boroo River due to informal mercury mining; the overall resulting health impacts are believed to be serious, however, to date no systematic testing has been done, and no specific measures have been put in place to address this problem. Not only is mercury polluting rivers, but it is also found in high quantity in the soil. A 2002 study documented high mercury levels in contaminated soils at the site of the disused Boroo gold recovery factory. Rangelands with mercury-contaminated soil is used for grazing by sheep, goats, horses, and cattle.

Cyanide pollution

Cyanides are used as part of the gold extraction process. In 2007 in the Khongor village near Darhan city, mass contamination by cyanides occurred when ASM miners used cyanides in open air. Also in the Gobi region, cyanide poisoning of wild and domestic animals happened several times. The biggest user of cyanides in Mongolia was Boroo Gold.

Arsenic pollution

Gold mining and processing are also known to enhance the release of arsenic and its uptake by humans and livestock. According to an investigation of arsenic (occurrence and sources in ground, surface, waste and drinking water in northern Mongolia reported by Pfeiffer et al. (2015), the highest concentration of arsenic was detected in the effluent of a gold mine (up to 2,820 $\mu g\ L^{-1}$). Five of 54 drinking water samples and 16 of 184 river samples were found to contain As levels above the World Health Organization (WHO) maximum permissible limit (10 $\mu g\ L^{-1}$), with a maximum of 300 $\mu g\ L^{-1}$ As.

Social impacts

Mining companies could be a valuable component of a diversified rural livelihood economy. This is arguably true of the small industrial cities built to serve the soums (smallest administration unit in Mongolia) in which 200 placer gold mines are operated by 128 companies. When asked, company managers claim it makes management much easier, as it stifles emergence of local networks around the mines, and ensures simpler discipline and better work ethics. Rural people see the placer mines as being destructive of nature, grazing, and winter shelters and contributing little to the local economy.

Risks to health and environment

Mongolia's semi-arid South Gobi region is dotted with large-scale mining projects, proof of a veritable gold rush. Recent mining driven economic growth is causing threats to the environment and to the livelihood of herders. Mining is not compatible with the Mongolian culture of cherishing the environment and ecology. In semi-arid areas like South Gobi, the extreme dust generated from poorly planned dirt roads built for mining operations is compromising the health of local people, as well as their herds of horses, goats, sheep, yaks and camels. The creation of these roads, which cart truckloads of minerals to neighboring China and run through areas where many animals graze, also leads to high degradation of pasturelands. Furthermore, mining can impact the quantity and quality of surface water and groundwater. It often discharges sediment particles, threatening fish species and the invertebrates that rely on them for food. Mining-related infrastructure projects are affecting the health and habitat of animals crucial to Mongolia's nomadic herders.

In conclusion: about Centerra Gold's Gatsuurt project in Mongolia

The project area, which contains 50 tonnes of gold, is situated on Sacred Mount Noyon. This mountain is the source of eight small rivers in the area that have been contaminated and will have an impact on Baikal Lake. The local population is against the Gatsuurt mine because the concentration of arsenic in gold rocks in this region are very high (46,000 mg kg^{-1}) exceeding almost 5000 times of WHO standard. The levels of arsenic in ground wells and surface waters in this region has been substantiated by a 2014 environmental study. A team of Mongolian and German researchers investigated the incidence of arsenic in ground, surface, waste and drinking water in Northern Mongolia, concluding that concentrations of arsenic in the tailing ponds (Boroo and Gatsuurt mines) will contaminate the environment for many years. The previous miner's tailing pond is a reminder of their potential impact.

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Energy Extraction Effects on North American Rangelands: Impacts on the Delivery of Ecosystem Services

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Key words: land use change, biofuels, unconventional oil and gas, wind energy, Sustainable Rangeland Roundtable.

Introduction

Sustainable energy development is fundamental to resolving challenges facing humanity, including food security. During most of the 20th century, agriculture in North America was characterized by abundant, low-cost energy derived from external fossil fuels (Smil, 2000). There is broad agreement that more diverse sources of domestic energy are needed for countries to progress towards energy independence and security (Resources for the Future, 2005). Achieving this goal necessitates greater use of renewable energy resources, such as biomass, wind, solar radiation, and geothermal energy, as well as domestic oil and gas resources extracted through unconventional means. In North America, many untapped renewable energy and unconventional oil and gas resources occur on rangelands. Therefore, the push to develop untapped domestic fuels is impacting rangelands and the ecosystem services they provide because exploiting these resources affects the natural capital and biophysical processes that produce ecosystem services.

While biofuels can enhance some ecosystem services (e.g., increased forage production through reduced competition from woody plants harvested for bioenergy), they may compromise other critical services (e.g., biodiverse habitats) (Gasparatos et al., 2011). Wind energy is generally perceived to be a persistent clean energy source, which has led to significant subsidies for wind farm development throughout North America; however, wind energy development also presents substantial challenges to wildlife (e.g., migratory birds and bats) due to impacts with wind turbines and habitat destruction (Arnett et al., 2007, Loss et al., 2015). With respect to unconventional oil and gas development, advanced extraction techniques have led to an average of 50,000 new wells annually throughout central North America since 2000, which has turned many rangelands into industrial landscapes (Allred et al. 2015). This has led to substantial tradeoffs between energy development benefits and degraded rangeland ecosystem services including a loss of approximately five million animal unit month (AUM) equivalents of herbaceous biomass and degraded and fragmented landscapes leading to severed migratory pathways, increased wildlife mortality, and more invasive species.

Evaluating the nature and magnitude of energy development impacts is, however, hindered by the complex and multi-scale interactions between biophysical and socioeconomic factors that affect the functionality of ecosystems. Due to their complexity, such interactions are frequently discounted or ignored (Nicholson et al., 2009) because the scale and focus of most land use decision-making discourages comprehensive assessment of tradeoffs resulting from development (Allred et al. 2015). Another challenge for understanding processes that affect natural resources is that such knowledge is hindered by the inconsistent use of concepts and terms by diverse scientific disciplines to describe complex social-ecological systems (Ostrom, 2009). To address these challenges, the Sustainable Rangeland Roundtable (SRR) in the US developed the Integrated Social, Economic and Ecological Conceptual (ISEEC) framework to disentangle the complexity of interactions affecting the delivery and use of rangeland-based ecosystem services (Fox et al., 2009). This framework provides a useful tool for systematically identifying interactions that affect the integrity of rangelands used for energy production and indicators needed to monitor and evaluate these effects (Kreuter et al., 2012; 2016).

In this paper we describe the ISEEC framework in the context of energy development on rangelands and identify indicators to comprehensively assess the effects of energy development on ecosystems services provided by North American rangelands and knowledge gaps that provide guidance for future research. We focus on biofuels, wind energy, and unconventional oil and gas because the development of these energy sources has the potential to affect large areas of rangelands. We exclude solar and geothermal energy because the areas for such developments tend to be geographically more restricted. The paper is organized in four parts: (1) Description of *overarching elements of the ISEEC framework*; (2) *Application of the ISEEC framework* to systematically identify biophysical-socioeconomic linkages that affect the delivery of ecosystem services which may be affected by development of biofuels, wind energy, and unconventional oil and gas resources; (3) Demonstration of how identification of these linkages can facilitate *selection of appropriate indicators* to monitor the impacts of energy resources development; and (4) Identification of *critical knowledge gaps*.

(1) Overarching elements of the ISEEC Framework

The Millennium Ecosystem Assessment identified four categories of ecosystem services that benefit human well-being: provisioning, regulating, cultural, and supporting services (MEA, 2005). These four categories can be further grouped into extractable marketable goods (provisioning services) and *in situ* non-market services (regulating, cultural, and supporting). This lumping of *in situ* services is useful because there is frequently overlap between regulating, cultural, and supporting services, as they all provide benefits only in the place they occur (i.e., their benefits cannot be exported) and they generally represent public goods that require indirect valuation techniques because they lack market price signals. The ISEEC framework uses these two broad categories of ecosystem services to link the biophysical and socio-economic components of a rangeland-based social-ecological system (SES) (Figure 1). The state of the SES is categorized by its biophysical condition and natural capital and its socio-economic capital and human condition. Biophysical processes determine the ability of rangelands to deliver ecosystem services and socio-economic processes create the context in which ecosystem services are used. These processes act on biophysical and socio-economic states at time t_0 to produce different states at time t_1. Interactions occur through delivery and use of extractable goods, in situ delivery and use of services, and external negative and positive effects of human economic activity and market or regulations driven interventions.

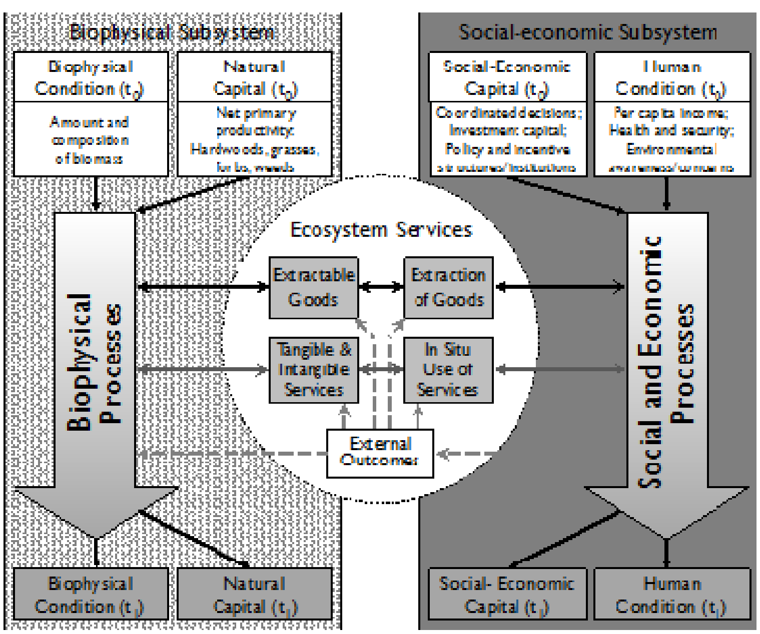
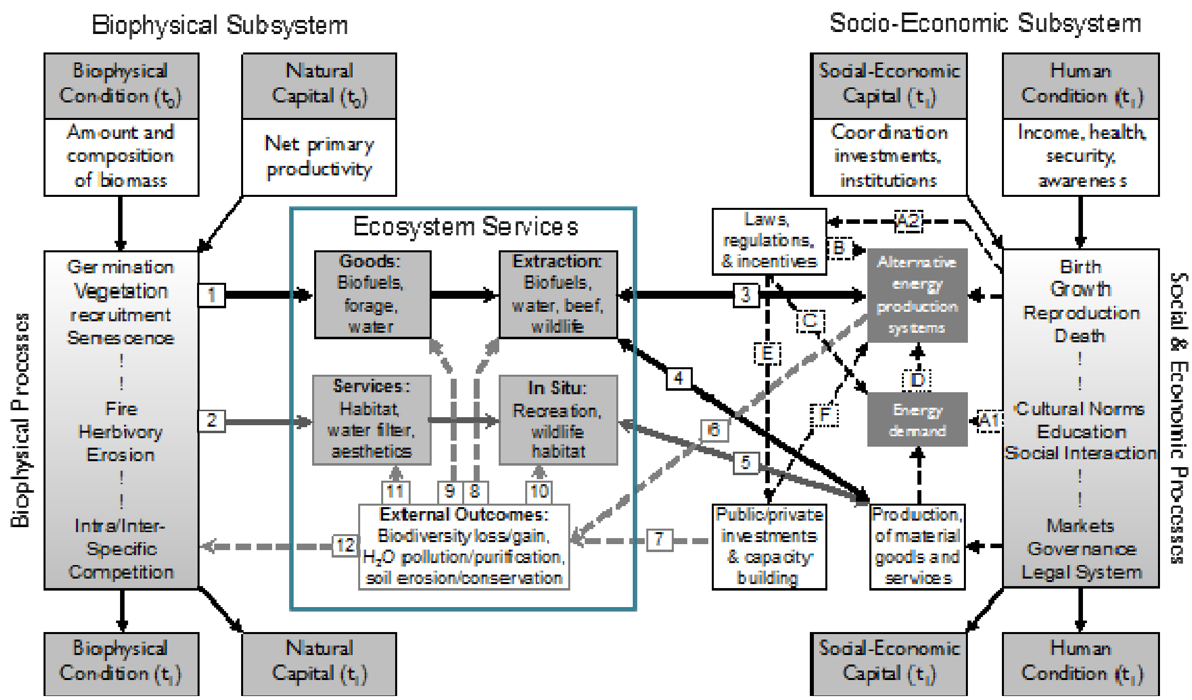


Figure 1. Components and linkages within the ISEEC framework for rangeland-based SESs (from Kreuter et al., 2016)

Application of the ISEEC Framework

Expanding detail within the ISSEC framework enables us to focus on key linkages pertaining to development of alternative energy sources on rangelands (Figure 2). Links [1] and [2] represent the biophysical processes that produce extractable goods (provisioning services) and *in situ* services (regulating and cultural services). Demand for energy resources (biofuels, wind, and oil and gas) and other goods and services is driven by factors including attitudes towards energy development, which are influenced by cultural norms, education, and legal systems [A1 & A2]. These produce laws, regulations, and incentives for development of alternative energy resources [B] and affect energy demand [C], which together affect alternative energy development [D]. These factors lead to public and private investments in novel energy production technology [E], which increases capacity for energy production [F]. Drivers for energy development influence rangelands through extraction of biofuels and vegetation impacts by energy infrastructure [3] and extraction of other goods, such as forage [4]. *In situ* use of ecosystem services is represented by link [5], which is influenced by social factors affecting development of facilities that enhance use of these services (e.g., tourism facilities). External outcomes of using ecosystem goods for energy production may include soil erosion, water pollution, green house gas emissions, biodiversity loss, etc. [6], but these can effects can be negative or positive depending on investments in energy infrastructure or effective mitigation measures [7]. These feedbacks can influence use and delivery of extractable goods ([8] and [9]), *in situ* ecosystem



services ([10] and [11]) and processes that lead to provision of these goods and services [12].

Figure 2. ISEEC framework for energy development effects on rangeland ecosystems (numbered black solid arrows refer to extractable goods, numbered dark grey solid arrows refer to *in situ* services, numbered light grey dashed arrows relate to feedback effects, and alphabetized black dashed arrows refer to social divers; from Kreuter et al., 2016).

Selection of Appropriate Indicators

Having established key links affecting the delivery and use of ecosystem services from rangelands subjected to alternative energy development, the next step is to monitor changes in these links to determine the effects of such changes on biophysical and socioeconomic processes over time. The need for monitoring rangeland resources to identify changes in plant communities, determining tradeoffs among alternative uses, and responding effectively to changing rangeland conditions has long been recognized by managers (Campbell, 1948). However, indicators used to inventory and monitor rangeland resources have primarily focused on biophysical attributes, generally ignoring socioeconomic changes on rangelands, and were not standardized, thus making it impossible to conduct integrated large scale assessments of changes to rangelands. This deficiency led SRR to identify 64 indicators for monitoring rangeland sustainability at large scales (Maczko et al., 2004). Many of these indicators can be applied to monitor changes in linkages identified in Figure 2 as shown in Table 1.

Table 1. Indicators for monitoring changes in biophysical-social-economic linkages affecting ecosystem goods and services in energy development on rangelands.

Linkage*	Description	Indicator **
1, 2	Plant composition Plant biomass	[12] Spatial extent of vegetation communities [14] Fragmentation of rangeland plant communities [20] Population status and geographic range of rangeland species [21] Above ground plant biomass
3, 4	Biofuel utilization Other rangeland goods utilization	[27] Value of forage harvested from rangeland by livestock [28] Value of production of non-livestock rangeland products [32] Return on investment in livestock, wildlife, water, biofuel, etc.
5	Rangeland services utilization	[32] Return on investment in hunting, recreation, etc. [33] Area of rangelands under conservation ownership
6	Direct biofuel harvesting impacts	[01] Soil area with significantly diminished org. matter or C/N ratio [04] Area with significant change in bare ground [05] Area with accelerated soil erosion [12] Spatial extent of vegetation communities [20] Population and geographic range of rangeland dependent-species
7	Public/private investment and capacity building	[32] Return on investment in livestock, wildlife, water, biofuel, etc. [33] Area of rangelands under conservation ownership [56] Extent to which government agencies and NGOs affect conservation/management of rangelands [57] Extent to which economic policies support conservation/management of rangelands [59] Professional education/technical assistance support [60] Conservation/rangeland management support [63] Resources for monitoring rangeland condition [64] Conservation/management research/development support
8, 9, 10, 11, 12	Soil condition Water quality Biodiversity	[01] Soil area with significantly diminished org. matter or C/N ratio [04] Area with significant change in bare ground [05] Area with accelerated soil erosion [06] Percent water bodies with significant changes biotic composition [07] Percent surface water with significant deterioration of chemical, physical, and biological properties from acceptable levels [12] Spatial extent of vegetation communities [14] Fragmentation of rangeland plant communities [20] Population and range of rangeland dependent species

* Numbers in the first column indicate the corresponding link in Figure 2.

** Indicators for monitoring sustainability of rangeland ecosystems identified by SRR with (number in brackets represent the SRR indicator number) (source: Maczko et al., 2008)

Critical Knowledge Gaps

To successfully conduct a compressive assessment of energy development impacts on rangelands through the use of an integration tool, such as the ISEEC framework, several knowledge gaps need to be addressed. Knowledge gaps to fully characterized linkages identified in Figure 2 include the following (Kreuter et al., 2016): Factors underlying the formation of perceptions about the energy industry and alternative energy sources ([A1], [A2]) (Theodori, 2013); development of energy from rangeland-based biofuels faces several challenges including efficient harvesting and coordinated harvest and utilization of both woody and grass based biomass ([B], [E], [F]) and more data are needed concerning the ecological effects of repeated harvesting of re-sprouting woody plants ([3], [4], [6] through [12]) (Ansley et al., 2013); the cumulative impact of wind farm developments and placement of turbine sites that minimize impacts on birds and bats ([3], [4], [6] through [12]) (Arnett et al., 2007; Loss et al., 2015); effects of using various water sources for hydraulic fracturing on surface vegetation and water availability for communities where water is being withdrawn, and impacts of unconventional oil and gas development on wildlife ([2], [5] through [12]) (Jackson et al., 2014; Souther et al., 2014); emission of greenhouse gases associated with unconventional energy production on rangelands ([7] through [12]) (Conant et al., 2001); comparative efficacy of various reclamation techniques for different disturbance types ([7] through [12]) (ESRD 2013); and broader implications of energy reform legislation that enables energy development to take priority over other land uses and to seize land and water from local communities ([A2], [B], [E], [7] through [12]) (Souther et al., 2014).

Conclusions and Implications

While substantial knowledge exists about alternative energy production and the effects of their development on rangelands, there are still numerous knowledge gaps that must be filled to obtain a comprehensive understanding of these energy exploitation impacts. Decision makers and citizens need better ways to sift through the conflicting claims and conclusions available from an increasing number of information sources regarding the development of alternative energy sources to meet national goals of energy independence and security. To fill current knowledge gaps, the next step is to develop a multi-disciplinary research team and secure funding for research that incorporates standardized indicators, such as the ones developed by SRR to obtain data before, during, and after development of these energy sources. Active synthesis and consolidation of reliable objective data is also necessary to improve large scale monitoring and integration of these data into land use planning and policy across spatial scales and jurisdictional boundaries is necessary to achieve energy polices that minimize ecosystem service losses in rangeland ecosystems (Allred et al., 2015; Brunson et al., 2016). The key implication is that decision makers and scientists must work together to ensure that the best available information guides the development of energy polices that do not compromise critical ecosystem services upon which human well-being depends.

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Rangelands of Subarctic and Arctic North America and Europe: Ecosystems, Wildlife and Management

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Key words: arctic ecosystems, subarctic ecosystems, range productivity, range management

Introduction

Rangelands are usually associated with temperate and tropical grasslands, shrublands and savannahs occurring in North and South America, Africa, Australia and Eurasia. An internet search on the general theme of rangelands led to thousands of hits mostly related to this physiognomic concept and geographic distribution. A search of the terms "subarctic rangelands" and "arctic rangelands" turned up a relatively small number of directly relevant sites, and near the top of the list was a link to this talk at this conference. So, I have some responsibility through this overview to provide a starting point for those interested in high-latitude range resources.

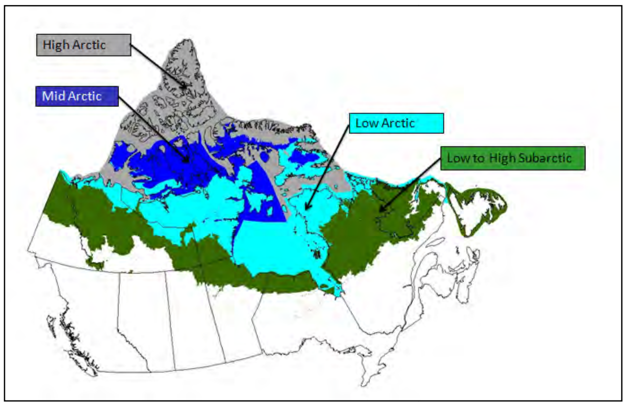
The definition of rangelands benefits from a perspective of who and what is using them; Arctic and Subarctic rangelands are of considerable importance from ecological, economic and cultural perspectives. Although my initial focus was to restrict the review to ecosystem characteristics (climate, vegetation composition and productivity), I broadened the review to include wildlife, managed grazing animals, and range management. The geographic area that this review covers includes the subarctic and arctic landscapes of North America (Canada and the United States) and mainland Europe (Norway, Sweden, and Finland). Three terms central to the review are defined as follows.

1. *Rangelands*: The Society for Range Management definition is inclusive — "Land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangeland includes natural grasslands, savannas, shrublands, deserts, tundra, alpine communities, marshes and meadows." (Society for Range Management, 1998). In the context of this review, because grazing animals are distributed across most Arctic and Subarctic ecosystems, almost the entire Arctic and Subarctic area can be considered as rangeland; in addition to vascular plants, lichens are also a critical vegetation component.
2. *Arctic:* Arctic ecosystems include treeless tundra and polar deserts underlain by continuous permafrost above a latitudinal tree line that is loosely correlated with a minimum 10^{o}C isotherm during the warmest month. Figures 1a through 1c indicate the extent of Arctic landscapes in North America and Europe; Figure 1d provides an estimate of standing biomass for Arctic tundra and polar desert ecosystems.
3. *Subarctic*: Subarctic landscapes include conifer-dominated woodlands and discontinuous tundra below tree line mostly underlain by continuous permafrost. Figures 1a through 1c indicate the extent of subarctic landscapes across North America and Europe based on a synthesis of ecosystem classification data. For Europe, I considered the Northern Boreal Zone as equivalent to Subarctic ecoregions in Canada and Alaska based on available descriptions of permafrost and vegetation characteristics and general agreement with the global classification prepared by Walter (1979).

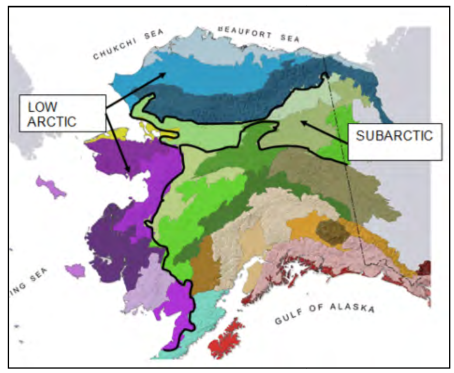
Materials and Methods

This overview generally follows guidelines for review articles provided by *Environmental Research Reviews* (http://iopscience.iop.org/1748-9326/page/Environmental%20Research%20Reviews). I initially undertook mainly web-based searches on the keywords given at the beginning of this paper and then expanded the scope as the reviewed articles suggested other paths of inquiry. Because the purpose of this review is to provide an overview of a broad subject area and is not a metadata analysis of quantitative data pertaining to range productivity, I did not critically review statistical methods or outcomes in articles that reported quantitative data.

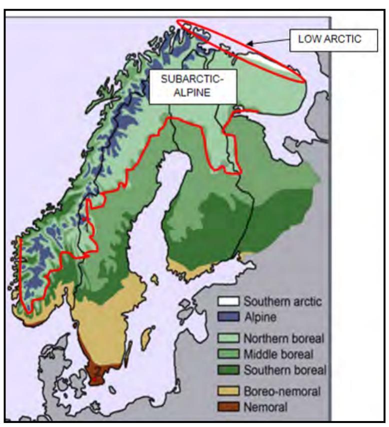
1a. Canadian Arctic and Subarctic Regions
(source: Ecoregions Working Group 1989; Ecosystem Classification Group 2008, 2009, 2010, 2012, 2013)



1b. Alaskan Arctic and Subarctic Regions
(source: Nowacki *et al,* 2001)



1c. Scandinavian and western Russian Arctic and Subarctic Regions (above red line and within red oval)
(source: Moen, 1999)



1d. Arctic ecosystem productivity- total phytomass. Red oval is extent of Arctic in mainland Norway
(source: CAVM Team, 2003)

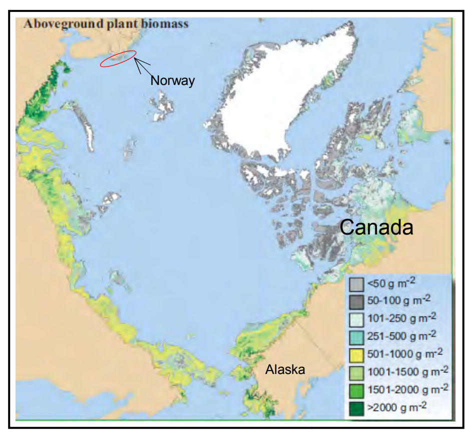


Figure 1. Subarctic and Arctic ecosystem distribution in North America and Scandinavia (1a through 1c); estimated circumpolar arctic standing biomass (1d).

Results and Discussion

Ecosystems

Global Subarctic and Arctic ecosystem distribution is mainly controlled by regional climatic patterns and topography. From the southern limits of the Subarctic northward to the High Arctic, annual solar radiation decreases as the angle of insolation becomes more oblique, contributing directly to a decrease in average annual and monthly temperatures, to a much shorter growing season, and to the development of continuous permafrost. Below a mean July isotherm of approximately 10°C, trees usually germinate and grow only in scattered pockets, finally giving way to treeless tundra; the tree line is a dynamic boundary responsive to both climate change and soil conditions that can be tens of kilometres wide and marks the transition from Subarctic to Arctic. Cold air holds less moisture, and annual precipitation decreases correspondingly; the High Arctic is a polar desert and receives perhaps 100 to 150 mm of precipitation annually, mainly as snow. Islands in the far north are often surrounded by pack ice year-round that increases albedo and further contributes to cold and dry conditions.

Elevation influences local to regional climates. The average midsummer (July) temperature decreases at an approximate rate of two degrees per 333 metres elevation gain (CAVM Team, 2003). Hilly terrain south of tree line often produces a broad transition zone of tundra on exposed upper slopes and coniferous woodlands on lower slopes. More pronounced elevational changes in mountainous areas result in clearly defined and rapid transitions between coniferous forests and arctic-alpine tundra in Subarctic areas, or between tundra and virtually barren terrain in Arctic areas or at very high elevations southward.

Figure 1 shows that Arctic ecosystems are extensive across northern North America but limited to the extreme north of Norway in Europe. Warmer temperatures and higher precipitation in Europe compared to North America at the same latitudes are partly attributable to three factors: global atmospheric patterns that draw Arctic air far south in North America and bring mild subtropical air north across the eastern Atlantic Ocean and western Europe; seasonal release and absorption of heat by the ocean; and the Gulf Stream/North Atlantic current (Seager, 2006). Average mean annual temperature (MAT) and mean annual precipitation (MAP) figures for Subarctic and Arctic areas in North America and Scandinavia are:

- High Arctic (North America): MAT -16 to -21^{0}C (July +4^{0}C); MAP 90-150mm[a]
- Mid Arctic (North America): MAT -14 to -16^{0}C (July +6 to +8^{0}C); MAP 130-150mm[a]
- Low Arctic (North America): MAT -11 to -14^{0}C (July +7 to +9^{0}C); MAP 130-150mm[a]
- Southern Arctic (Norway): MAT -3 to -2^{0}C; MAP 400-500mm[b]
- Subarctic (North America): MAT -5 to -13^{0}C; MAP 230-430mm[a]
- Subarctic (Sweden): MAT 0 to -2^{0}C; MAP 400-500mm[c]

a. Ecosystem Classification Group 2008,2009,2010,2012,2013
b. http://met.no/English/Climate_in_Norway/ accessed Oct. 26 2015
c. http://en.tutiempo.net/climate/sweden/2/ accessed Oct. 26 2015

Soils throughout the Arctic and most of the Subarctic are permanently frozen and exhibit various permafrost related features. Patterned ground is widespread and is the result of freeze-thaw cycles; on organic and fine textured soils, the surface thaws to a depth of 30-100 cm and saturated surface horizons are common. In the southern Arctic and the Subarctic, thick peat deposits accumulate in wet areas, then permafrost develops and pushes the peat upward elevating the surface layers above the water table. The resulting surface-dry conditions combined with brief cold growing seasons promote the development of thick lichen, bryophyte and dwarf shrub layers. Slow rates of decomposition and cryoturbation (the mixing effect of permafrost activity) result in the accumulation of large amounts of organic matter over thousands of years in Arctic and Subarctic soils and they are globally important storehouses of carbon (Tarnocai *et al,* 2009).

Regional vegetation patterns and net primary productivity are linked closely to climate and terrain, with species diversity, cover and biomass increasing southward. The Circumpolar Arctic Vegetation Map (CAVM Team, 2003) is the most comprehensive and integrated readily available source of information for Arctic ecosystems. Nowacki *et al.* (2001) provide information on Alaskan Arctic and Subarctic landscapes. Ecosystem publications for the Northwest Territories (Ecosystem Classification Group, 2008, 2009, 2010, 2012, 2013) provide detailed information on Arctic and Subarctic ecosystems that is applicable to Yukon Territory, Quebec and Nunavut at the level of interpretation reported in this overview.

- The coldest parts of the High Arctic on the most northerly and westerly Canadian islands (Figure 1a) are polar deserts. Much of the area is barren; blackish cryptogamic crusts with sparse lichen, moss, forb and graminoid cover only a few cm high grow in areas where snowmelt seepage occurs, and shrubs are absent. Total phytomass is less than 30 g/m^2.
- At lower latitudes in the High Arctic and Mid-Arctic (Figure 1a), forbs and graminoids form continuous patches in sheltered and low-elevation positions and prostrate dwarf shrubs reach heights of 10 to 20 cm. Total phytomass is 50-300 g/m^2.
- In the Low Arctic (Figure 1a,b,c) , graminoid and shrub tundra is dominant, averaging 20-50 cm in height with nearly continuous cover and shrubs more than 80 cm tall in favourable locations. Total phytomass is 250-400 g/m^2.
- In the Subarctic (the Northern Boreal of Sweden, Finland and Norway)(Figure 1a,b,c), open coniferous woodlands dominated by *Picea* spp. and *Pinus* spp. (the latter occurring only in Europe near latitudinal tree line) are interspersed with shrub tundra near tree line, while to the south forest cover becomes more continuous and deciduous trees form part of the canopy. In Norway and Sweden, mountain birch (*Betula pubescens* ssp. *czerepanovii*) forms the tree line at high elevations and latitudes, one of the only places in the world where deciduous trees form tree line (https://en.wikipedia.org/wiki/Geography_of_Norway#North_Boreal). Lichens, mosses and shrubs are important components of the forest floor. Several authors cited in Kumpula *et al* (2000) reported lichen biomass values of between 800 to 1100 g/m^2 in Canada, Finland and Norway.

The phytomass values reported above and shown in Figure 1d are general and illustrate regional trends. Phytomass available to grazing animals in the Arctic and Subarctic is partly determined by seasonal and annual climatic variations — primarily rainfall, snow cover and temperature — that determine the growth and availability of forage (Behnke, 2000). It is also determined by site conditions such as exposure to sun and wind, depth to permafrost, depth to bedrock, soil drainage and chemistry, snow deposition patterns and groundwater and surface water availability, and by factors affecting plant cover such as fire, grazing, trampling and industrial activities.

Wildlife and semi-domesticated grazing animals

The Arctic and Subarctic provide year-round or seasonal range for both resident and migrant birds and mammals. A few birds are grazers; the lesser snow goose (*Chen caerulescens caerulescens*) is currently the most abundant waterfowl species in the western Arctic of North America with population levels that cause severe overgrazing of the tundra in places (Ecosystem Classification Group 2013, p. 96). Dall's sheep (*Ovis dallii*), related to the bighorn sheep of central North America, roam throughout the mountainous subarctic-alpine areas of the Northwest Territories, Yukon Territory and Alaska.

The most important and widespread grazing mammals are muskox (*Ovibos moschatus*) native to North America and caribou, native to both North America and Europe and referred to as reindeer in Europe. Both caribou and reindeer belong to the same genus and species (*Rangifer tarandus*); the European reindeer is *R. tarandus*. The barren-ground caribou of mainland North America is *R.tarandus* ssp. *groenlandicus*; the smaller Peary caribou of the High Arctic is *R. tarandus* ssp. *pearyi* and is designated a Species at Risk by the Northwest Territories (Government of Northwest Territories, 2015).

Muskox range across Arctic Canada and south into the Subarctic. Total numbers are estimated at approximately 120,000 with re-established populations in Alaska numbering about 3,000. They are primarily grazers of sedges and grasses but also feed on shrubs and forbs; their winter ranges are characterized by low snow cover to reduce the energetic costs of grazing (Gunn and Forchhammer, 2008). Populations fluctuate significantly and declines are related to icing and deep hard snow that limits forage availability, to hunting, and to predation (CAFF 2013, p. 92).

Barren-ground caribou number approximately 650,000 to 750,000 in North America (Government of Northwest Territories, 2015); semi-domesticated reindeer in Subarctic and Southern Arctic Scandinavia probably number about 600,000. Most caribou migrate significant distances (up to 5,000 km/year) and graze on lichens, shrubs (especially *Betula* spp. and *Salix* spp.), graminoids, forbs and mosses (Henttonen and Tikhonov, 2008). In Scandinavia where semi-domesticated reindeer herds are managed, reindeer migrations are often monitored and guided by reindeer herders.

Barren-ground caribou in Arctic and Subarctic Canada and Alaska occur in 11 named herds with defined geographic ranges; some are restricted to the Arctic and have both their winter and summer ranges there, but most have their calving grounds and summer ranges on the tundra and their winter ranges in Subarctic areas where their primary winter forage, reindeer lichen (*Cladina stellaris, C. mitis, C. rangiferina, Cladonia unciatus*) grows in mats under open spruce woodlands. Both caribou and reindeer can detect lichens under snow cover and paw through deep snow for food. Excessively deep snow and icing events (e.g., freezing rain) limits forage availability as will year to year variations in summer climate. Predation, harvesting and grazing intensity are also important.

Population fluctuations can be extreme. The Bathurst herd (Northwest Territories) has ranged from an estimated population maximum of 470,000 (1986) to a low of 32,000 (2009) (Boulanger and Adamczewski, 2015). The late winter calf/cow ratio is an important predictor of population change and summer range indicators derived from long term remote sensed time series of vegetation change and climate explain 59 percent of the variation in calf/cow ratio two years later; heavy hunting pressure when the population is already in decline contributes to an accelerated decline (Chen *et al*., 2014).

Range management

This overview focuses on range management associated with reindeer and caribou because these grazing animals are common to both North America and Europe. In both regions, caribou and reindeer are important sources of food and clothing and provide a cultural identity for Arctic and Subarctic peoples. Reindeer harvesting contributes significantly to local economies in Norway, Finland and Sweden.

Caribou in North America are unconfined wild populations that are managed through policy decisions regarding harvest levels (hunting), informed by population surveys and co-management boards that include members from state and territorial governments and local residents who depend upon caribou. Reindeer in Scandinavia are mainly semi-domesticated populations that have been actively herded by established family groups for hundreds of years. There are 26 major groups of herders mostly across Scandinavia (the Sami people) and Russia and Mongolia (various peoples). Two groups herd reindeer in North America (the Inupiak-Eskimo [Alaska] and Inuivialuit-Sami [Northwest Territories] from populations that originated in Europe and Russia (Library and Archives Canada Blog, 2015; International Centre for Reindeer Husbandry, 2015).

Range management generally implies an understanding of carrying capacity and stocking rate. For wild caribou herds in North America, stocking rate is a difficult concept to apply because the range of most herds is so vast and the influences of year to year and seasonal climatic changes on plant productivity are uncontrollable. Understanding population trends in herds is critical to determining those factors that can be managed (e.g., hunting and industrial development); when populations are declining or very low, they are less resilient to climate change and hunting than when they are increasing or at high numbers (Government of Northwest Territories, 2015). Understanding the key drivers of herd population change and their relationship to range productivity is also critical for predictive purposes as noted above with reference to the Bathurst herd where climatic factors provide leading indicators for herd population trends.

Where reindeer herds are actively managed, as in Arctic and Subarctic Scandinavia, range management can address issues such as pasture conversion (e.g. industrial development), predation and climate especially for those herds that do not migrate long distances. Reindeer herders have their own indicators of pasture quality that vary in space and time, combining ecology, geography, and social relations, all of which bear heavily on their patterns of pasture use (Forbes, 2006). For hundreds of years, informal traditional agreements between families and family groups that control reindeer pasture territories have allowed for flexible territorial boundaries and sharing of resources according to group needs and range condition; government policies need to take these into account (Marin, 2006).

Future directions

Northern environments are highly sensitive to climate change (Ecosystem Classification Group, 2009); increased temperatures over the last few decades have contributed to permafrost melting and the expansion of low and tall shrub growth northward. Although the impacts of high-latitude climate change on rangelands, wildlife, managed herds and humans have yet to be determined, it is essential that baseline indicators continue to be monitored in well-designed replicated studies. Regional ecological classifications have an important role to play as benchmarks for assessing change, as starting points for landscape management and as guidelines for establishing monitoring frameworks.

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Sustainable Rangelands, Sustainable Pastoralism in Yak-Herding Areas of the Greater Tibetan Plateau

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Introduction

In the vast high altitude rangelands of the Tibetan plateau, and of the surrounding mountain regions of Central Asia – from Tajikistan and Kyrgyzstan in the far west, to Mongolia and Bhutan in the east – yak husbandry has for millennia contributed to the sustenance and cultures of people living in these challenging, often marginal lands. Today, of the world's estimated 14 million domestic yak, around 90% are found in China, 4% in Mongolia, and the rest are in the Himalayan and Central Asian countries (Wiener et al. 2003).

First domesticated around 10,000 years ago, most likely in the *Changtang* region of Tibet, yak provide many fundamentals necessary for both traditional and modern lifestyles, from meat and milk products, to fiber (for clothing and habitation), yak dung (for heating and cooking) and transportation. The progenitor of this domestic animal is the wild yak, still found in some parts of the Tibetan plateau. Wild yak once numbered in the millions and roamed widely across the plateau. Now, however, only an estimated 15,000 exist in the wild – probably the most at-risk species on the Tibetan plateau today. The presence of wild yak, and its domestication, has been the single most important factor in the adaptation of people in the Tibetan plateau region. Without this unique animal, life would be impossible across vast areas of High Asia.

There is nearly complete overlap of yak husbandry and rangelands in the mountainous areas of Asia. The state of the rangelands, however, is deteriorating. Many different causes are attributed to the observed changes, including both anthropogenic and natural factors. It is also observable that different root causes of land degradation may be assumed or accepted by different people, based on their socio-political ideology or preferred development paradigm! Consequently, there are not only ecological obstacles to the maintenance and development yak-dependent livelihoods, but also ideological threats. These include so-called 'modernization' policies applied to some pastoral areas that seek to advance market-based institutional reforms such as household-level privatization and rangeland transfer mechanisms (Gongbuzeren et al., 2016) as well as the transformation of nomadic pastoralists into settled ranchers or sedentary farmers. Such policies fail to recognize the socio-cultural interactions that have co-evolved between rangeland ecosystems, livestock and herders over generations. Although benefits may be generated for individual herders, such modernization policies all too often lead to socio-cultural loss, such as when the only apparent option for 'development' is for herders to abandon their customary rangeland management systems and livelihood. There is also a loss of time-tested (i.e. proven, and sustainable) natural resource management practices.

Mountain rangelands in Asia constitute the most extensive high altitude pastoral regions worldwide. Other noteworthy zones exist in the Andes of South America, and in smaller isolated ranges or relatively high plateaus in Africa. There are also similarities with extensive rangelands and traditional resource-based livelihoods, such as practiced by Sami reindeer herders in cold northern climates. However, nowhere else in the world are high rangelands and nomadic pastoralism as extensive as on the vast Tibetan plateau and in the surrounding mountainous areas of the Himalayas and Central Asia.

High Mountains and Rangelands of the World

Globally, rangelands (drylands and grasslands) cover around 40% of the Earth's land area. Mountain regions, for their part, cover about 24% of the world (Price 2015). Both these contribute uniquely to human wellbeing, from local to global scales. Biodiversity, including ecosystems with their goods and services, also has both intrinsic and utilitarian values; neither should be overlooked. Non-economic values of biodiversity range from the aesthetic to the philosophical or religious significance of nature. Additionally, inter-generational equity also requires us to consider the value that we place on nature today in light of the needs of tomorrow. Within such a framework the multitude of ecosystem services provided by rangelands (and other habitats) have been extensively studied and are well known; based largely on the Millennium Ecosystem Assessment (MA 2005). However as Yahdjian et al (2015) have elaborated, "the value [that we attribute to] rangelands depends on both their ability to supply ecosystem services *and society's demand for such services*, [and] land-use decisions reflect balances between the supply of ecosystem services and multiple demands by stakeholders, *weighted by their political power*" (emphases added).

Of the world's rangelands, vast areas are found at high altitudes – with the largest aerial extent of high altitude rangeland being situated in Asia, centered on the Tibetan plateau. In total, around 1.3 million km^2 of the Tibetan plateau is classified as steppe (the entire plateau covers around 2.5 million km^2, or approximately one-quarter of China's total land area), including alpine meadow (45%), alpine steppe (28%), alpine desert (5%) and other vegetation types (Sheehy et al. 2006).

While most of this high altitude region has been isolated for centuries due to enormous distances, and also political decisions (often with insular policies), now nearly everywhere 'resource users' live in a truly globalized world, especially with new communication technologies. In such a world, though, all too often development approaches or political decisions are conceived for lowlands, farmlands or urban centers, and do not serve the best interests of mountain peoples – largely because different frames of reference are used, or scales of analysis employed. Yet for pastoralists and agro-pastoralists, livestock such as yak are so much more than economic assets. Therefore the basis of our assessments of human wellbeing needs to be *richer* than pure economics – and should incorporate *much more of the social dimensions* of rangeland ecosystems (see Hodges et al. 2014).

Rangelands Are Social-Ecological Systems

Living for centuries in isolation from the rest of the world, Tibetan herders' customs and practices in relation to rangeland resources have developed mostly under the influence of the land itself – and less by influence of other communities' experiences, transmitted through cultural exchanges. Conversely, the land has changed not only through ecological processes – it equally has been greatly impacted by people through their land management practices. People and land, or society and ecology, are tightly inter-related. Indeed, most rangelands of the world have developed over millennia under the influence of grazing, whether by livestock or wildlife. On the Tibetan plateau, it also is postulated that a significant portion of present-day grazing land was created long ago through the clearing (burning) of forests to improve grazing opportunities for herders and their domesticated animals, becoming rangeland subsequently maintained through grazing management (Miehe et al. 2009, Ryavec 2015).

The bottom line is simply this: There is interdependence between people and the land, and the world's vast rangelands are perhaps best regarded as *coupled social-ecological systems*. And in light of this, the conservation of rangelands must be premised not only on biodiversity and ecological issues *per se*, but also – fundamentally – by ensuring that *sustainable pastoralism* is both supported and practiced.

Figure 1. Tibetan herding family moving to summer pastures. Providing not only meat, milk, fiber and fuel (dung), but also transportation, they have long been an indispensible part of Tibetan pastoralism.

Pastoralism Is a Sustainable Food System

Traditionally, pastoralism has been the primary means by which communities have transformed rangeland and its resources into basic sustenance. Even today, pastoralism is *de facto* one of the most sustainable food systems on the planet; as it has proven itself through its very existence despite long-standing, entrenched prejudices and pressures (and opposition) over centuries from agricultural and urban populations (Krätli and Schareika 2010). The adaptive capacities of pastoralists have led them, through trial and error, to choose more flexible and responsive decision-making processes and more seasonally mobile land use patterns, allowing them to respond pragmatically to variable and often unpredictable climatic conditions. This does not mean that misuse (including overuse) of natural resources and ensuing environmental degradation does not ever occur in rangelands, mediated at least in part by pastoral communities. However, where such land degradation occurs, it tends to have been influenced significantly by *changing patterns* of natural resource use, often due to an imposition (whether active or passive) of new socio-political structures and/or to a delinking of resource and resource user boundaries and other features (or 'design principles') that are commonly associated with the sustainable management of common pool resources (Anderies et al. 2004, Ostrom 2009, 2011). Adopting integrated perspectives of rangeland systems to better understand their inter-connected social, economic and ecological realities is increasingly recognized as being of paramount importance to achieve sustainability (TEEB 2008, McGahey et al. 2014). Under management that properly links these complementary dimensions, this food production system can yet continue to serve the interests of both humanity and global biodiversity.

The UNEP and IUCN also highlight the role of pastoralists as stewards of more than a quarter of the world's land area. Pastoralism is practiced by between 200 and 500 million people, including nomadic communities, transhumant herders and agro-pastoralists. Yet despite the large numbers, four important facts about pastoralism are widely overlooked (Davies & Hagelberg 2014):

1) Mobility of livestock (and wildlife) is essential to maintain the health of dryland ecosystems – for carbon sequestration, watershed protection, and biodiversity conservation.
2) Intensive livestock systems can degrade the environment by producing high levels of carbon dioxide and methane, polluting watercourses, and causing land degradation.

3) Sustainable pastoral systems are more efficient, productive and resilient than more sedentary agricultural systems in rangelands, when all factors and environmental benefits are counted.
4) Pastoralism is a universal issue, as pastoralists in both the developing and developed countries share many environmental and economic challenges and opportunities.

Additionally, the benefits derived from sustainable use and preservation of rangelands have a regional or even global component, in particular through upstream-downstream water related linkages. Pastoralism may also be recognized not only as a means to harvest resources, but – in the language of the Millennium Assessment – it is itself a significant *cultural asset* of mountain and rangeland social-ecological systems, and also a *provider* of ecosystem services. As summed up in the UN Convention on Biological Diversity (CBD) document *Good Practice Guide: Pastoralism, Nature Conservation and Development*, pastoralism contributes "to the production and stability of ecosystem services. […] The vegetation maintained through grazing activities…captures carbon, reduces erosion, maintains soils, facilitates water holding capacity and provides [wildlife] habitat. Most pastoral systems [also] are steeped in cultural practices and indigenous knowledge, 'cultural services' which are highly valued and often irreplaceable." Thus, even beyond the provision of direct goods and services such as meat, milk and fibers, pastoralism in the high altitude rangelands of the world can be a livelihood option that benefits both the resource users themselves and the global community through climate change mitigation, disaster risk reduction, water resource availability, and biodiversity conservation.

Experiences from the Tibetan Plateau

Based on nearly two decades working in the Tibetan plateau region, and more recently in the mountains and rangelands of Kyrgyzstan and Tajikistan in Central Asia, I now wish to turn our attention to two special topics related to resource governance in rangelands, illustrated with two case studies from the headwaters of the Yangtze River near the center of the Tibetan plateau in China. These are two governance models that *overlay* older, traditional pastoral practices and social dynamics as well as an array of government policies that have been introduced in recent years (Miller 2002, Foggin 2008, Li et al. 2014, Kreutzman 2015). Out of such a layering of understandings, interactions, relationships, and mindsets—a new synthesis emerges, the living realities of today! It is such realities that I wish to introduce and summarize here. One is the outworking of community-level engagement and partnership with a recently established *nature reserve*, the other the result of new forms of *community association* (through the establishment of a community cooperative) for mutual support, empowerment, and socio-economic benefit.

I offer the following observations from a combination of roles and identities: as conservation biologist, development practitioner, research scientist, and also as colleague and friend of the many local herders as well as government authorities who welcomed us when, together with my family, we lived in the Yangtze River headwaters over a period of several years. As such, these observations will include both 'external analysis' as well as 'insider perspectives' – yet through such a synthesis, it is my hope that 'mountain voices' may be better heard, as they are essential ingredients for sustainability.

Case Study #1: Community engagement and partnerships with Protected Areas

The term 'protected area' covers a broad suite of landscapes with special natural, ecological and/or cultural significance. The IUCN defines a protected area as a "clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve long-term conservation of nature with associated ecosystem services and cultural values." The best-known form of protected areas is probably the 'national park' system – such as was developed in Canada, starting with the establishment of Banff National Park in 1885. Problematic with national parks, however, has been the erroneous view that humankind exists apart from nature; which has led to enormous injustice for many indigenous communities around the world, many of which have been excluded from their own lands in the name of conservation (Dowie 2009). Costs of enforcement are also extremely high in these cases.

On the other hand, less formal but effective conservation by local and indigenous peoples occurs in very large territories and areas – estimated to cover 13% of the world's land surface (ICCA 2016). Generally referred to as *indigenous and community conserved areas*, or ICCAs, this model includes both the active or strict protection by local communities of an area in its so-called natural state, and more passive shaping and/or maintenance of landscapes and the sustainable and biodiversity-friendly use of natural resources (Borrini-Feyerabend et al. 2007).

In today's world, many formally recognized protected areas – in rangelands and elsewhere – overlap significantly with (often much larger) ICCAs. The latter form of governance generally includes widely agreed regulations and sanctions, and generally allows for the sustainable use of rangeland resources and their conservation as well as a flourishing of nomadic pastoralist culture. In China, vast areas of the Tibetan plateau are now included within the national PA network. One of the largest PAs is the Sanjiangyuan National Nature Reserve, yet even before this was conceived, local conservation action was underway – both through traditional practices and mindsets, and the community-led development of conservation initiatives (Foggin 2005, 2014).

Finding themselves living within a newly-established nature reserve, yet having had nil or very little involvement in its planning and establishment, with initially no provision for the involvement of local communities in its management, herders residing in the Yangtze River headwaters became deeply concerned about their future. Yet through a process of multi-stakeholder dialogue in the first years of the nature reserve's existence, the management authorities came to recognize both the potential roles and multiple benefits that could be derived from developing partnerships with local communities. Thus was initiated what has become the Reserve's primary *modus operandus*, 'community co-management'. The strategic decision to adopt a *co-management approach* was for four reasons: (i) to compensate for shortage of field staff, (ii) to capitalize on herders' knowledge and abilities, (iii) to increase environmental awareness, and (iv) to reduce illegal poaching. Additionally, our own purposes (as Canadian non-profit organization) included (v) the less tangible but no-less-real value of community empowerment, along with capacity development, and (vi) a desire to demonstrate to higher-level policy makers how communities could be partners in conservation, i.e. seen as part of the solution, rather than assumed to be detrimental in areas of high biodiversity value.

In one herding community with whom I have partnered since 1998 (together with the grassroots NGO, *Upper Yangtze Conservation and Development Organization*), the snow leopard was selected as focal species for conservation, around which we concentrated our collaboration. Camera traps were used, supplemented by seasonal wildlife surveys by community rangers. Through this project, a rugged mountain range with one of the highest densities of snow leopard in the world was identified. Government authorities were able to see community co-management worked out in practice – and as a viable option for protected area management, with a variety of community development co-benefits.

Another community environmental activity undertaken in this area has been the trial development of solar-powered electric fences, to help protect herders' homes from break-ins by brown bear. Human-wildlife conflict with bears has increased in recent years, to the point where 9 out of 10 winter homes are damaged annually in some regions when herders move to their summer pastures. After initial trials undertaken by our non-profit NGO, the nature reserve managers have further extended this deterrence approach as part of their community partnership.

Figure 2. Snow leopard was selected as a focal species for trial use of community co-management in the Sanjiangyuan National Nature Reserve, with support from the NGO, Plateau Perspectives Canada.

In yet another herding community near the source of the Yangtze River, local regulations were agreed as early as 1998 to limit illegal poaching by local and external hunters – well before the creation of the Sanjiangyuan National Nature Reserve. Over time this led to the establishment of a local organization focused on wild yak preservation and other related grassland management and conservation measures. Such community ventures were subsequently incorporated into the 'contract conservation' approach also trialed by the nature reserve, within the broader 'community co-management' framework. Under this approach a contract is drawn up between the community and nature reserve authorities whereby community rangers monitor wildlife populations (in this instance, wild yak) in exchange for payments to be made into a local development fund managed by a committee with community representation.

These early experiences with co-management in pastoral areas have been endorsed at high level, with integration into protected area planning and management under the auspices of the Qinghai Forestry Department. There has been financial and technical support provided by a GEF/UNDP project, which aims to scale-up such lessons learned. Several aspects of this community-oriented approach to conservation in pastoral areas have also been extended to other Chinese provinces, through the suite of State Forestry Administration (SFA) and UNDP projects under the Main Streams of Life program, with their focus on strengthening the effectiveness of PA systems.

In such ways, protected areas have potential to strengthen community participation in natural resource management, and more fundamentally in resource governance (i.e., decision-making). At global scale, IUCN and other international bodies are now increasingly endorsing more community-oriented forms of resource governance, most notably since the World Parks Congress 2014 held in Sydney, Australia. The reach of 'local voices' into development policy is increasing too, particularly through *mountain agenda* dialogues facilitated by the UN Food & Agriculture Organization (FAO), Swiss Development Corporation (SDC) and others, which recognize the value of respecting and listening to local resource users as well as the enormous benefit thus derived from mountains for downstream populations. In the Tibetan plateau region, which constitutes around half of China's vast rangeland resources and where several large national protected areas have already been established in recent decades, co-management is a tool that may be leveraged, if thoughtfully applied, in support of conservation outcomes, community empowerment and socio-economic development.

Case Study #2: Establishment of community cooperatives and associations
Just beyond the boundary of the aforementioned nature reserve, another herding community mobilized under the encouragement of two young colleagues from our non-profit organization, leading to the development of the Kegawa Herders Cooperative (named after a local sacred mountain) and also of a community association that has successfully trialed the management of a revolving development fund. County and prefecture governments have provided enabling policy environments, but the development of these community efforts have been largely endogenous, with support from Plateau Perspectives and several national academic institutions and development organizations.

The launch of the Herders Cooperative in 2010 marked the beginning of what has become the most empowering of all development activities that Plateau Perspectives has supported – financially and technically – since it began projects in 1998. Starting with around 40 families, now approximately 92 households regularly participate in the projects and activities organized by the Cooperative. These activities include a regular monitoring of local grassland conditions, the development of handicrafts, the setup and operating of a small shop, and on-going development of a community-based tourism venture. A long-term partnership has also developed with an international sports clothing company, kora, which produces thermal underwear from fine yak wool. Through the latter project, all cooperative members have the option to sell their yak wool at guaranteed upper fair market value, supplemented annually with a donation to the community's social development fund. The Cooperative makes major decisions at annual general meetings and operates activities through working groups.

More specifically, membership in the Cooperative is voluntary, but requires some level of financial contribution. Payment of dividends (from profits generated through the year) is proportional to each member's contribution, whether financial or in-kind in the form of livestock, but voting rights are based on a principle of one person, one vote. General meetings are held to ensure that every member has a voice. The working groups established to oversee operations and to facilitate on-going communication amongst members include ecological husbandry, grassland monitoring, environmental awareness, garbage collection, tourism development, and other topics. Most recently, in late 2015, the Cooperative decided to develop its own yak herd, together with designated pastureland. Milk, butter and cheese sales are planned, targeting the expanding urban population in the county capital. Some of the profit generated from these activities is reinvested into the core fund, and some is earmarked for social needs. Most of the profit, though, is shared amongst shareholders as dividends, in proportion to each member's cumulative investment.

The 'community development revolving fund' established in a neighboring village with support from Ford Foundation, through our non-profit and with the indispensable assistance of Prof Du Fachun and his colleagues, provided yet another way to strengthen the engagement of herding communities in resource governance, business development, management and community negotiations. Through provision of short duration micro loans, several rounds of business ventures have been successfully trialed. Beyond the individual activities funded, however, the primary success of this revolving fund project has been the mobilization of community members to discuss, agree and implement joint action. For the government, this also has demonstrated the viability of community-level management of resources, including financial resources. This may become even more important in the future as various options for transfer payments are considered, in exchange for pastoral communities' protection and maintenance of critical 'ecosystems services' in the rangelands.

Through such community-operated, rangeland-based business operations, many herding families have gained access to valuable opportunities, providing not only some level of economic benefit but also a framework for resource aggregation and strengthened local governance. This empowerment is leading to greater socio-economic wellbeing, a sense of ownership of resource conditions, and a pride in local pastoralist livelihoods and culture. In the context of a world increasingly 'flattened' by globalization, which tends to advance homogeneity over diversity, *pastoralist empowerment* and a sense of identity are important ingredients for socio-economic development, for contentment, and for regional stability.

Figure 3. Kegawa Herders Cooperative 'tourism development working group' members in the field.

Concluding Remarks

Both the collaborative management of protected areas and the development of community-owned and -operated businesses with joint management of common pool resources (cf. cooperatives) bring multiple benefits for conservation and community development. In both instances, monitoring of grassland ecosystems and biodiversity is a fundamental feature of the resource management approach. Diversification of income and development opportunities also is at the heart of these endeavors. In short, sustainable pastoralism and the conservation of rangelands are complementary and reinforcing elements in a single development equation.

With ever-changing socio-political and climatic environments, resource users in rangelands need to remain constantly aware of new realities. *They always will need to adapt* – which indeed has always been amongst the strengths of pastoral peoples: flexible, mobile, and responsive to change. Through development of new social arrangements with neighbors and government, and with internal mobilization and strengthened capacities as primary resource users, pastoral communities should play a central role in decision-making for the development and conservation of the world's rangelands. On the Tibetan plateau, this has been advanced in a small way through new partnerships developed with protected areas and the empowerment of several communities to diversify their economic strategies. Decreasing local communities' dependence on narrow production systems will strengthen resilience, particularly in the face of future climate shocks (Wang et al. 2014), anticipated to be especially severe in mountain regions. Most significantly, partnering with pastoralists to conserve one of the world's greatest grazing land ecosystems – the Tibetan plateau – is already demonstrably an excellent option.

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The Resilience of Western Rangeland: Exposure to 9,000 Years of Climate Variability

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With its location in the mid-latitudes and continental interior, and on the leeward side of the western cordillera, the northern Great Plains has one of the most variable climates on earth.

The native grasslands have been exposed to nine millennia of this climatic variability and extremes, and a much larger range of climatic conditions than experienced by the recently arrived livestock producers and managers of rangeland. This paper compares the recent experience of agriculturalists, using instrumental data on weather and forage yield, to the climatic variability of the past 9000 years, using paleoclimatic and paleo-ecological records, and thereby we consider the resilience of northern grasslands and the range of climatic conditions to which it is adapted. We present an overview of the post-glacial (Holocene) climatic changes with detailed annual information for the past 500 years. We also consider climatic changes projected for the balance of the 21st century. Given this long climate context, spanning the history of this ecosystem and its near future, we then examine evidence of the ecological impacts of these variations in climate. We focus on the semiarid rangeland of southeastern Alberta and southwestern Saskatchewan where forage yield data have been collected at Onefour (Alberta) and paleo-environmental research has been conducted at nearby sites.

An Instrumental Record of Forage Yield and Weather

An exceptional record of forage yield has been maintained by Agriculture Canada at the Onefour (Alberta) Manyberries Research Station. A clipping experiment was initiated in 1930. Litter was removed in this long-term productivity trial, as without its moderating influence productivity was more dependent on weather conditions. In two papers published 30 years apart, Smoliak (1956, 1986) related forage productivity to various weather variables. Productivity was highly correlated with growing season (April-July inclusive) precipitation ($R^2 = 0.714$). For this conference paper, we ran stepwise multiple regression with the data from the first 20 years with mean temperature and pan evaporation as additional inputs. As in the original paper, only precipitation was significant in the model. In the Smoliak (1986) paper multiple regression relating growing season precipitation and mean temperature to productivity gave a multiple R^2 of 0.490. Temperature was negatively related to productivity. Adding pan evaporation into the equation did not improve the R^2. For the entire 81 years of data, precipitation was again the first variable entered and pan evaporation increased the multiple R^2 to 0.56, while temperature did not improve the relationship. Pan evaporation was negatively related to productivity.

Weather variables were regressed against year to detect consistent long-term changes (trends) from 1930 to 2014. There was no change in growing season mean daily temperature over time ($R^2 < 0.001$, linear). Precipitation increased over time ($R^2 = 0.138$, linear) and pan evaporation decreased ($R^2 = 0.110$, linear). Productivity also was regressed against year to detect if there is a long-term trend. There was a significant increase in productivity, which was best fit by a quadratic equation ($R^2 = 0.439$). Some of this change can be expected from increased precipitation and reduced evaporation (both of which could contribute to greater soil moisture). So to some extent it appears that climate change is resulting in increased productivity. During the last 30 years of the study there was much greater change in productivity than the changes in weather variables (linear plateau analysis gave a break point at 1985). This was likely due to a shift in plant community composition toward more productive grasses. It could be that a threshold in soil moisture availability had been passed so that more productive (though less drought tolerant) grasses have increased. Plant community sampling suggested that needle-and-thread and wheatgrasses (C_3 grasses) have increased while blue grama (C_4 grass) declined.

There was no evidence of warming during the growing season, but analysis of long-term weather data at Onefour suggests a moister environment. Likely increased soil moisture availability increased productivity, and the potential productivity increased further due to shifts in species composition. There are few sites with long-term productivity data, but examining historical trends in weather at more sites would show whether this trend toward a more humid growing season is widespread in the northern Great Plains.

Grasslands and the Holocene Record of Environmental Change

Grasslands were established on the southern Canadian prairies by approximately 9000 years before the present (yBP; Klassen, 1994; Sauchyn and Sauchyn, 1991; Yansa, 1998) during the most recent postglacial time. A number of high-resolution records of Holocene climate and vegetation history have been inferred from the pollen and other proxies in lake sediments at sites where the current vegetation and climate is very similar to that at the Onefour Agriculture Canada research substation. Some of the lake sediment records extend continuously to European settlement times, as indicated by the presence in the top sediment layer of *Salsola* (Russian thistle) pollen, which arrived on the northern Great Plains in the late 1800s (Jacobson and Engstrom, 1989). All of these records from grassland regions indicate droughts of greater severity and length than any of the historical droughts of the late 1800s, 1930s, and 1980s (Laird et al., 1996; 1998; Vance et al., 1993).

Species abundances and annual precipitation and evaporation at Kettle Lake, in northwestern North Dakota, are very similar to the species' productivity and climate data from the Onefour (AESRD, 2013; Clark et al., 2002; Hopkinson, 1999; W. Willms, pers. comm.). Detailed analysis of one time period, 8500-7900 yBP, in the Kettle Lake record found five drought cycles of 100-130 years in length. During these droughts, grass pollen inputs dropped to between less than 5% to about 8% of total preserved pollen in the sediments. At the same time, quartz levels spiked, indicating erosion; and charcoal amounts dropped to near zero suggesting the vegetation was too dry to support prairie fires. Intriguingly, at this site the repeated drought cycle shifted the vegetation composition permanently to more C_3 grasses; and the authors speculate that the drought tolerance of C_4 grasses was exceeded. Each drought was followed by a return to moister grassland conditions (Clark et al., 2002).

The pollen record from Harris Lake, in the Cypress Hills of Saskatchewan, and only ~100 km northeast of Onefour, is very similar; during the same period, 8500-7900 yBP, four severe and one less severe droughts are indicated by grass pollen levels of around 5% (Sauchyn and Sauchyn, 1991). Severe droughts (grass pollen levels 5-10%, up to 20%) had approximately the same timing in central Montana (Barnosky, 1989), but were later (during 7100-5000 yBP) in east-central North Dakota (Laird et al., 1996; 1998). In all studies severe droughts were documented also during the Medieval Warm Period around 1000 yBP. To put these levels of pollen inputs into context, modern pollen inputs into lake sediments across the Great Plains are very rarely as low as 5% and mostly 20% or higher even in the driest grassland regions (Williams et al., 2006). Similarly, pre-settlement grass pollen inputs in lakes in southwestern Alberta range from 13-20% or higher (Strong, 1977). Although grass pollen percentage changes cannot be translated directly into grass cover or productivity changes, the 50-85% declines in grass pollen during drought intervals, as compared to moister intervals, suggests significant impacts exceeding those observed during historical droughts. At Kettle Lake (Clark et al., 2002), the authors concluded that "drought severity during past, and possibly future, arid phases cannot be anticipated from the attenuated climate variability [of times of less severe drought, including historical droughts]…the Dust Bowl was unremarkable in the context of the last two millennia".

Climatic Variability since 1575

The major constraint on our interpretation of paleoenvironmental archives that span the Holocene is chronological control: the precise timing of events and changes. The biological proxies from soils and sediments, and especially from shallow prairie lakes, provide an ecological history of cumulative changes, averaged responses to variations in climate. Tree rings are a unique climate proxy. In seasonal climates, radial growth increments represent an absolute annual chronology and also contain information about growth-limiting environmental factors. In the semiarid northern plains, tree-ring data are available from the island forests in river valleys and on uplands (i.e., Cypress Hills, Sweetgrass Hills), and from the eastern margins of the Rocky Mountains (Sauchyn et al., 2015). In this dry climate, the availability of soil moisture is the major constraint on annual tree growth just as it limits forage productivity as described above.

In the absence of a time series of measured soil moisture, we used the Standardized Precipitation Evapotranspiration Index (SPEI; Vicente-Serrano et al., 2010) to build a tree-ring model that statistically relates annual tree growth to May-June-July (MJJ) soil moisture conditions. Methods for the measurement of tree-ring widths and statistical processing of these data are described in Sauchyn et al. (2015). The MJJ SPEI for the period 1900-2011 was derived from monthly weather data for southeastern Alberta, the region that includes the Onefour site. Applying our tree-ring model of MJJ SPEI to standardized ring-width data for the period 1575 to 2009 resulted in the proxy soil moisture record in Figure 1. Positive/negative SPEI represents above/below normal soil moisture conditions in spring and early summer. From the years with negative SPEI, it is apparent the instrumental forage yield data are from a recent period of relatively moderate drought severity, in terms of both intensity and duration. Tree rings capture the recent dry years and decades; however, there are 34 preceding years when water deficits exceeded those in the two driest years from the instrumental period: 1936 and 1961. While most years between the mid 1910s and mid 1940s had water deficits, there are droughts of similar duration but greater intensity in the tree-ring record. Notably, extreme water deficits occurred in the 13 consecutive years between 1601 and 1613. The prolonged drought of 1842 to 1873 is the most relevant here, because it is relatively recent and therefore historical observations of the landscape exist, including John Palliser's famous assertion that the southern Canadian plains will be "forever comparatively useless". He traversed the region in the mid to late 1850s.

In the context of this high-resolution drought record for the past five centuries, we now examine evidence for the impact of the most intense and prolonged droughts on the condition of the rangeland. Much of this evidence comes for the study of sand dune activity (Hugenholtz, et al. 2010; Wolfe et al., 2013). Where rangeland still exists in the Mixed Grassland Ecoregion, it is usually because the soils are too dry or the topography is too rough to support consistent annual crop production. Therefore much of the remaining rangeland coincides with the extensive area of sand dunes (Wolfe, 2001). Research on the history and chronology of these dune fields reveals that sufficient drought and disturbance (fire, bison grazing, human activity) periodically has led to the destabilization of the dune fields and shifting of the sands.

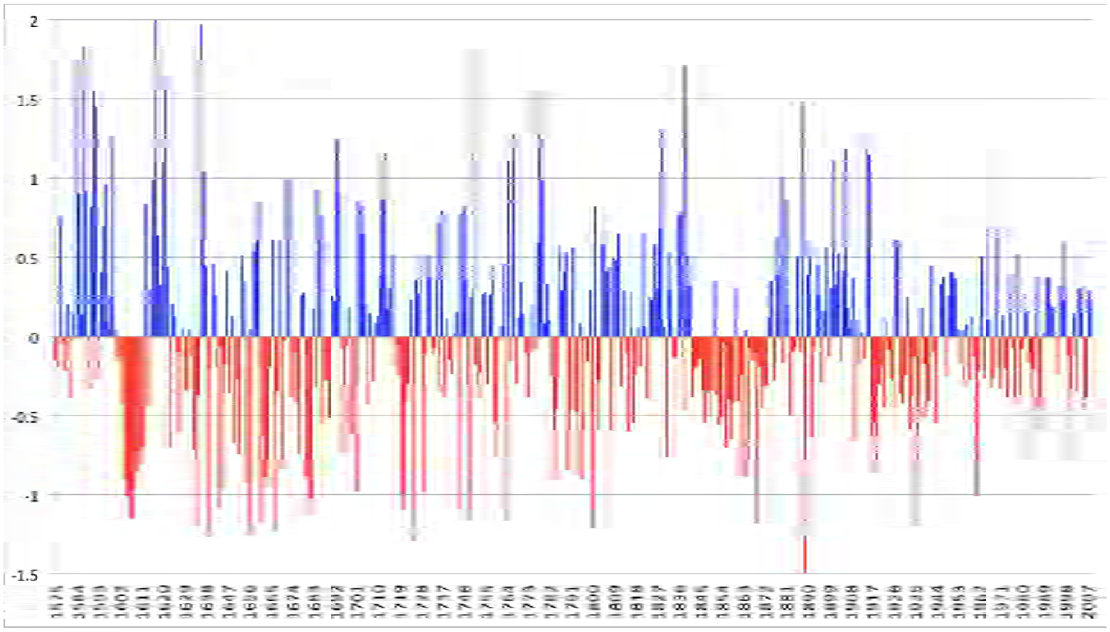

Figure 1. May-June-July Standardized Precipitation Evapotranspiration Index (SPEI) for southeastern Alberta reconstructed from tree rings for the period 1575 to 2009. The SPEI has no units. Blue bars represent positive moisture anomalies and red bars indicate water deficits.

The timing of past sand dune activity has been determined from the optical dating of now-buried sand in stable dunes. Wolfe et al. (2001) presented evidence of the destabilization of the Great Sand Hills in southwestern Saskatchewan starting in the late 18th century. They attributed this phase of sand dune activity to recurring drought in the 1700s as evident in our proxy SPEI record in Figure 1. Similarly, Wolfe et al. (2013) determined that buried sand in the Middle Sand Hills of eastern Alberta was previously exposed to light in the 1850s when John Palliser passed through this dune field and observed "miles of burning sand". In an overview of the sand dune history of the past several centuries, Hugenholtz et al. (2010) highlighted the widespread activity up to the mid 19th century, and declining activity since then in the absence of sustained severe drought, and with the demise of bison and human (aboriginal) populations (Wolfe et al. 2007; Fox et al., 2012). Our proxy SPEI record supports this recent history of the sandy rangeland in terms of a reduced severity of drought in the past 120 years.

Conclusions

Since the 1930s, growing season precipitation has been the major determinant of forage yield measured at Onefour, Alberta. Rising productivity over the past several decades may be linked to increasing soil moisture possibly in response to global warming. Paleoenvironmental data provide context for these recent observations indicating that, even though this resilient ecosystem is adapted to an extreme and variable climate, its tolerance has been periodically severely challenged. Pollen records from grassland lakes include intervals of dramatically reduced grass pollen counts coincident with other indicators of disturbed and desiccated rangeland. A record of soil moisture (SPEI) inferred from tree-rings, and research on sand dune activity, suggest that droughts of the 18th and mid 19th Centuries were of sufficient intensity and duration to cause significant instability of the prairie landscapes. Because these droughts were relatively recent in the history of the western rangeland, water deficits of this intensity and duration, with no modern analogue since the 1930s, are likely to occur again. When they do, it will be in a warmer climate.

Thorpe (2011) and Thorpe et al. (2008) examined the potential impact of anthropogenic climate change on western Canadian rangelands. They projected negative trends in grassland productivity and grazing capacity largely in response to increased water loss in summer. The bottom plot in Figure 2 shows the largest declining productivity at the driest location in close proximity to the Onefour Agricultural Research Station. The top plot in Figure 2, of the Onefour forage yield data, reveals that the historical range of forage yield in response to year-to-year variability in growing season weather is significantly larger than the projected reduction in average pasture productivity in response to global warming. Most of the observed and projected climate change for the Canadian prairies occurs in winter. Even though summers may eventually be warmer, the growing season also will be longer, with better spring soil moisture from increased winter precipitation, and possibly not as much moisture loss by evapotranspiration than simulated by models that do not account for increased atmospheric humidity in a warmer climate. Therefore, we conclude from both the forage yield and paleoecological data that the critical impact of anthropogenic climate change may not be a downward trend in pasture productivity, but rather the potential for global warming to amplify the short-term (annual to decadal scale) variability that has characterized the climate of the northern plains throughout the history of the mixed grassland ecosystem.

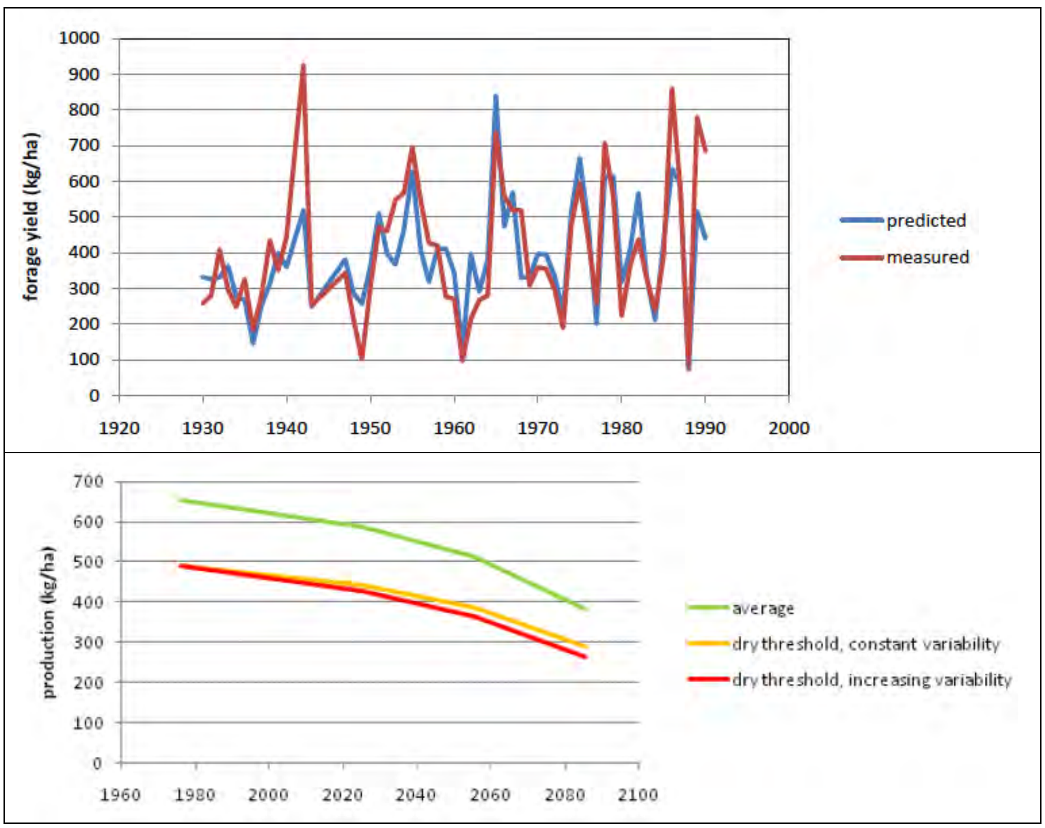

Figure 2: Top: measured forage yield (kg/ha) at Onefour Alberta and yield predicted by a rangeland productivity model (see Thorpe 2011 for details). Bottom: Future trends in forage yield projected by driving the rangeland productivity model with climate model outputs for the location where Alberta, Saskatchewan and Montana meet (Thorpe 2011).

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Global Climate of Rangelands: Past, Present, Future

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Key words: climate change, primary production, data-fusion, coordinated distributed experiments

An Approximation to Rangelands

The significance of "rangelands" for humankind is potentially best reflected in two aspects: (a) virtually every civilization has a rich lineage of creative works revolving around pastoral themes and topics and (b) the myriads of available definitions. Here the most common thread of definitions is followed, characterising "rangelands" as all land areas with predominantly native vegetation that are subject to grazing by wild and/or domestic herbivores. Given this functional definition, rangelands can be considered virtually ubiquitous: they cover roughly 50% of Earth's terrestrial landmass, are present on all continents (but Antarctica) and comprise ecosystems of diverse climatic features. Rangelands are found across continua from hot to cold, and wet to dry climates (Allen-Diaz et al., 1996): Cold and moist environments such as subpolar tundra, as well as hot and dry vegetation zone such as thornbush savannas can be regarded as rangelands. Basically, rangelands are found wherever combinations of temperature, precipitation and its seasonality, potential evapotranspiration, as well as to a lesser extent fire, edaphic and land-use features, forbid dense stands of trees (Fig. 1).

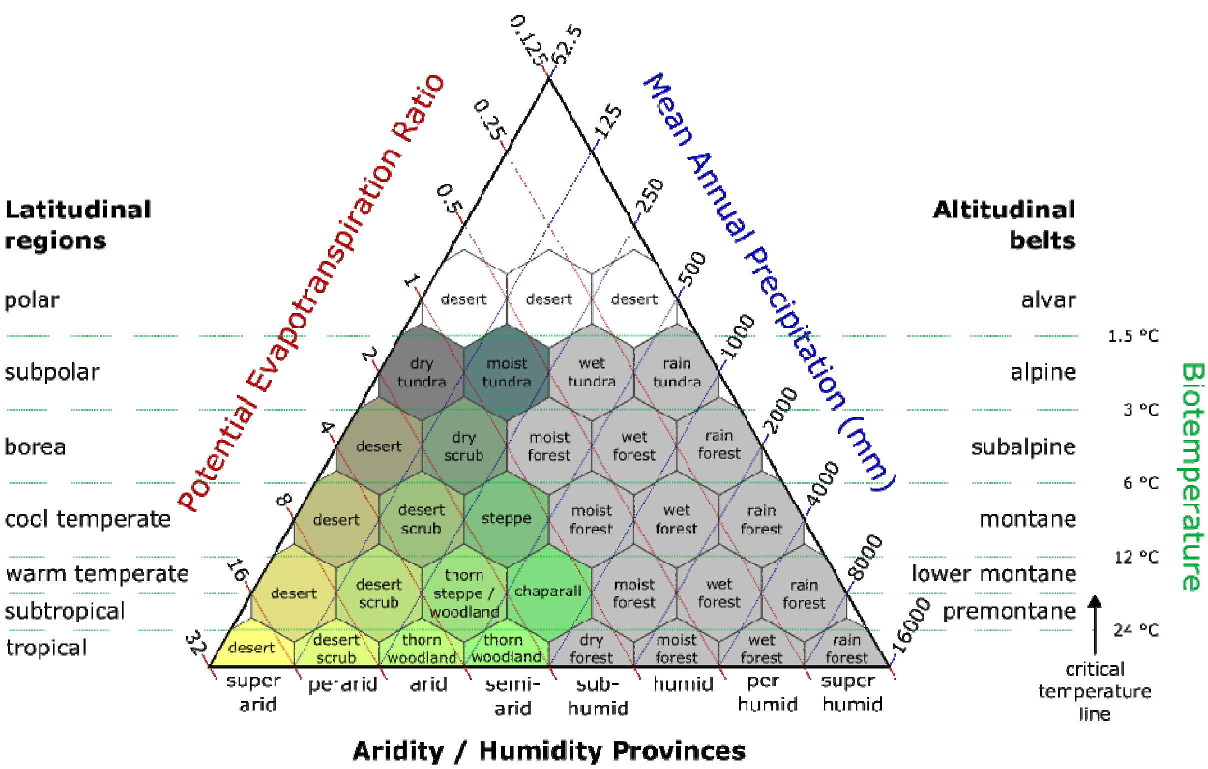

Figure 1. Vegetation Zones according to Holdridge (1947; 1964) and modified by Cramer and Leemans (1993).

Biotemperature is the mean value of all daily mean temperatures above 0°C, divided by 365. The demand of plants for moisture is represented by mean annual precipitation (MAP) and potential evapotranspiration ratio (i.e. MAP/PET). The colored (none-grey) hexagons represent vegetation zones that are considered rangelands.

On a global scale, rangelands can be considered climatically (as well as structurally) diverse, which complicates drawing inference about their ecological behaviour under future global change regimes. Given their physical extent and importance for global livelihood and food security (Briske and Heitschmidt, 1991), our understanding of how the structure and functioning of rangeland ecosystems will respond to changing climate (and land use) is still surprisingly poor (Maestre et al., 2012; Reynolds et al., 2007). Given their very definition as grazed lands, it is obvious that livelihood security in rangelands relies heavily on the provision of ecosystems services from vegetation (Gillson and Hoffman, 2007). These ecosystem services are often estimated by aboveground net primary production (ANPP) which is a core ecological currency and one of the best documented quantitative estimates for forage provision (Scurlock et al., 2002).

Rangeland Dynamics under Past and Present Climate and Land-Use Regimes

Dynamics of ANPP in response to intra- and inter-annual climate fluctuations under past and present climate regimes, as well as different land use intensities, are fairly well understood (Ruppert et al., 2012). Bearing in mind that the vast majority of rangelands are drylands, and hence characterized by water-deficiency during prolonged periods throughout the year (Asner and Heidebrecht, 2005), it is not surprising that variations in ANPP are mainly related to water availability. A large body of literature reports linear relationships of ANPP and annual precipitation (Huxman et al., 2004). Temperature, on the other hand, hardly accounts for any inter-annual variance in ANPP at a given site in most rangelands. However, temperature is highly related to biomass and litter decomposition (along with other factors, Throop and Archer, 2009) and thus indirect effects via re-nourishment of the soil are likely. Furthermore, long-term mean and maximum temperature play an important role in shaping the C_3/C_4 species composition of grass-dominated rangelands (Sims and Risser, 1988).

With all other environmental attributes being constant, also the effects of land use intensity (i.e. grazing or herbivory intensity in rangelands) can be considered fairly predictive (Milchunas and Lauenroth, 1993). The effect of grazing on ANPP has been described as a first-order effect of reduced vegetation cover due to defoliation (Wiegand et al., 2004): mechanical defoliation reduces plants' cover and photosynthetic active tissue, thus the overall carbon-fixation and rate of tissue production. Furthermore, the relative and absolute cover of bare soil might trigger other detrimental effects such as water or wind erosion, run-off and nutrient loss by volatilization that feedback on primary production as well (O'Connor et al., 2001). Obviously these effects are directly connected to the intensity, timing and frequency of grazing, with more extreme regimes (i.e. high stocking densities) being more harmful (Milchunas and Lauenroth, 1993). Nevertheless, the actual effect of grazing across different rangeland environments might fluctuate, which has frequently been related to the evolutionary history of grazing at the given sites (Milchunas et al., 1988). This explanation stresses the idea that regions, which have been subject to grazing for prolonged evolutionary time scales (as is the case for many rangelands globally), will exhibit vegetation that is well adapted to grazing disturbances (e.g. African rangelands). Furthermore, the actual impact of grazing is also moderated by the general condition of the rangeland (health or degradation status), with degraded rangelands suffering more strongly (O'Connor et al., 2001). Another aspect related to grazing is compensatory growth (i.e. regrowth after tissue loss, McNaughton, 1983). Grasses are particularly well adapted to losses in vegetative organs, as their relatively low-lying and abundant meristems can compensate tissue losses rather rapidly. In grazing-adapted ecosystems, such as most rangelands, (perennial) plant mortality after defoliation is virtually non-existent if it is not coincident with unfavorable climate conditions such as severe drought (Zimmermann et al., 2010). Furthermore, under low levels of grazing – or other sources of injuries – regrowth might even exceed the preceding tissue loss, a (highly disputed) phenomenon coined "*overcompensation*."

Altogether, grazing is a complex driver of ecosystem dynamics in rangelands, as it triggers not only direct effects on plant individuals but also on communities and their habitats, which again might feedback on primary production and other ecosystem processes and functions. Overall, the most general statement for the influence of grazing in rangelands in this context might be *dosis sola facit venenum*: Poisonousness is a question of concentration (Paracelsus, 1538).

Although effects of short-term climate fluctuations (under past and current climate regimes) as well as those of land use change are well understood when acting separately, we are still struggling to predict rangelands behaviour when both drivers change simultaneously. Particularly, when drivers operate at their maxima, i.e. climatic extreme events (drought, floods) or abrupt land-use change (i.e. initiation or cessation of grazing, or relative steep increases of grazing pressure, e.g. after a fire). This is a highly concerning finding, if we consider that both drivers *will act simultaneously* with ongoing global change and that increases in the frequency of extreme events is among the most certain projections of climate change in virtually all global rangelands.

Rangelands' Climate Change Projections

Climate change projections for rangelands exhibit considerable variability and uncertainty across scenarios and regions (Fig. 2; IPCC, 2013). Increases in average land surface temperature is probably the most consistent trend across Earth's rangelands (Fig. 2a) with more pronounced increases in relatively cold rangelands (e.g. 1° to 9°C in subpolar tundra by the end of the century) as compared to temperate and hot rangelands (here, increases are likely to mirror average global increases of 1° to 4°C by the end of the century). Changes in the global water cycle are much less consistent and often vary on sub-continental to regional scales (Fig. 2b).

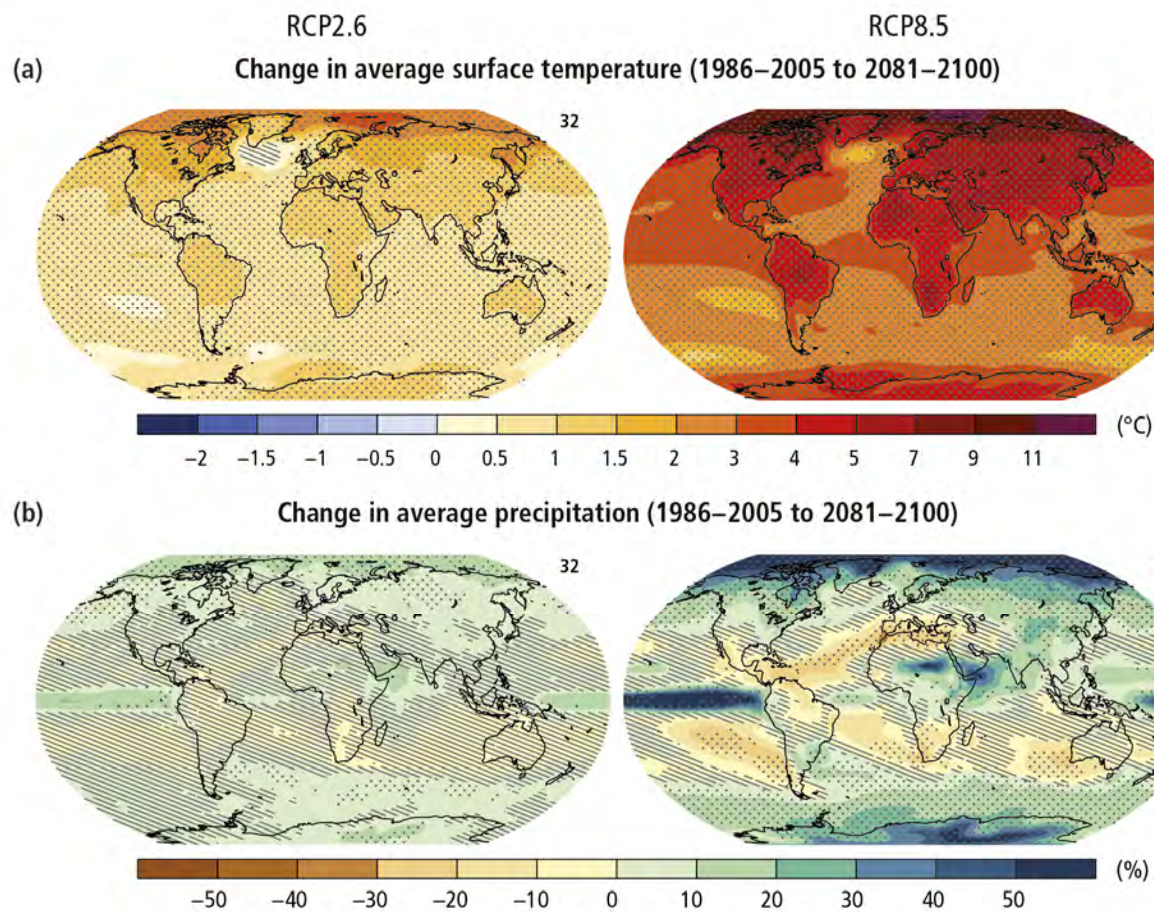

Figure 2. Change in average surface temperature (a) and change in average precipitation (b) based on multi-model mean projections for 2081–2100 relative to 1986–2005 under the RCP2.6 (left) and RCP8.5 (right) scenarios.

The number of models used to calculate the multi-model mean is indicated in the upper right corner of each panel. Stippling (i.e. dots) shows regions where the projected change is large compared to natural internal variability and where at least 90% of models agree on the sign of change. Hatching (i.e. diagonal lines) shows regions where the projected change is less than one standard deviation of the natural internal variability. Figure originally published as Figure SPM.7 in IPCC (2013).

In summary, literally all rangelands are experiencing elevated surface temperatures and the majority of rangelands may be facing reduced amounts of annual precipitation by the end of the century. Although relatively cold rangelands are expected to benefit from increased temperatures (productivity-wise), for most regions it solely means an increase in potential evapotranspiration (PET), and hence a net increase in aridity. In some regions (e.g. Mongolia) these temperature induced increases in PET may even exceed the expected additional inputs via increased precipitation and hence still lead to a net increase in aridity. Simultaneously, global and regional climate systems are becoming more variable, and extreme events, such as heavy rains and dry spells, will occur more frequently and potentially last longer (IPCC, 2013), making the overall climate system of most rangelands (even) less reliable. At the same time, large proportions of dryland areas are subject to significant human population growth and urbanization (Millennium Ecosystem Assessment, 2005), both inevitably leading to the expansion of agricultural land and an intensification of livestock production (i.e. higher stocking rates and densities; Foley et al., 2005).

Altogether, from current understanding gained from past and present conditions, projected changes of the climatic system will hamper ecosystem functioning and decrease provision with ecosystem services in most rangeland systems, while land use change will increase the pressure on the systems and act as an additional stressor. Threats of co-occurrence of these non-beneficial conditions could already be observed during the last decades: severe droughts in densely populated drylands worldwide were responsible for massive reductions in livestock and crop productivity, leading to poverty and famine. Furthermore, vegetation structure (e.g. species composition, biodiversity) and dynamics (e.g. phenology) will of course respond and gradually and/or intermittently and/or abruptly change along with ongoing climate and land use change, potentially rendering today's system knowledge inadequate or at least incomplete. Please note, that potential effects of elevated CO_2-concentrations have not even been regarded yet, although increases in CO_2 may have tremendous effects on vegetation composition and structure particularly for grassland and savanna systems (cf. "CO2-fertilization"; Buitenwerf et al., 2012).

Rangelands' Climate Change Research, Quo Vadis?

We as rangeland scientists find ourselves in an oddly fortunate position nowadays. Rising awareness of global change in the public, politically and – along with it – in the funding institutions has provided us with, potentially, unprecedented attention and research opportunities. However, these are not the times to 'lay back' and imprudently enjoy the scientific freedom that comes along with it, but rather the time to critically revisit our very personal approach to rangeland research (or more general: to plant ecology).
Historically, and also very logically, rangeland scientists often chose a rather focused and often highly regional or even local perspective. Along with this, the considered variables, employed fieldwork methods and monitoring tools often depend mainly upon 'common practice' of the research individual. Taken together, and given the high spatiotemporal variability of rangelands on a global scale, results from many studies can only be considered anecdotal and cannot be easily translated to other regions or up-scaled, thus hampering synthesis and functional insights which are so desperately needed (Reynolds et al., 2007).

In my opinion, more considerate research planning (with respect to the selection of the methodological toolbox) along with better cooperation (i.e. data sharing and pairing) between individual researchers and research institutes would have the potential to boost scientific inference tremendously – particularly in the realm of rangelands' climate change research. Here, I want to highlight two major research strategies that have great potential for maximizing inference made from individuals' research activities in this field.

Coordinated Distributed Experiments

The first strategy is increasingly adopted in ecology: Coordinated distributed experiments (CDE, Fraser et al., 2012). CDEs usually provide an experimental core protocol that is meant to be applied and repeated by as many scientists and sites as possible (potentially globally). The shared experimental layout assures comparability of results and eases joint analysis as well as spatial and temporal up-scaling of the results. NutNet (http://www.nutnet.umn.edu/) and FLUXNET (http://fluxnet.ornl.gov/) are among the best-known and most proliferate CDEs of the last decades. Very recently, two rangeland-related CDEs have been founded and are currently in an early adaption stage (i.e. Drought-Net – http://drought-net.org/ and BIODESERT, Fernando Maestre, King Juan Carlos University - Spain, pers. comm.). During my talk, I will highlight potentials of CDEs and one's personal engagement in these.

Data-Fusion and Meta-Analysis

The second strategy that I want to highlight are knowledge or data-fusion approaches. These approaches aim to synthesize available knowledge and data and can be performed in various ways. The most prominent and common approach are literature reviews. These have repeatedly proven to be versatile tools for summarizing knowledge or as opportunities to achieve functional insights as well as impetus for new research directions or even research fields. However, at the same time they have the main disadvantage of rendering merely qualitative and not quantitative results. During the last decades, a new type of data-synthesis has emerged across natural sciences: meta-analyses (Glass, 1976) or, more broadly speaking, data-fusion or -integration studies (Lenzerini, 2002). Within my talk, I want to highlight the potential of this research strategy along with anecdotal insights gathered during my past and recent work, assembling a global scale data sets of dryland ANPP (Ruppert, 2014; Ruppert et al., 2015; Ruppert et al., 2012; Ruppert and Linstädter, 2014).

NB: Figure 2 of this paper was originally published as Figure SPM.7 from IPCC, 2013: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker,T.F., D.Qin, G.-K. Plattner, M.Tignor, S.K.Allen, J.Boschung, A.Nauels, Y.Xia, V.Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA.

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The Alberta Rangeland Ecological Tool Kit: Knowledge Tools for Sustainable Rangeland Resource Management

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Introduction to Alberta Rangelands

Alberta rangelands are native plant communities where the principle form of management is manipulated grazing including grasslands, shrublands and grazed forests, covering a total of 17.1 million acres (6.9 million ha) of which about 65% are under public ownership. Alberta rangelands have supported livestock production for over 125 years and are home to families and a ranching industry that are proven stewards of the environment and an icon of western Canada. Alberta rangeland provide about 15% of the forage supply for the provinces livestock industry which is valued at $3.1 billion in farm gate cash receipts (Stats Can 2011). In the last century, vital lessons were learned about rangeland conservation that served to shape public land policies and sustainable grazing practices that are applied today (Anderson 1941).

The native rangelands that intersperse the developed landscapes of Alberta are a key guarantor of regional environmental quality. Managed to express their natural vegetative cover, rangelands capture precipitation and mediate the beneficial release of water, enhancing water quality and quantity, a value recognized in the early protection of Eastern Slopes watersheds. Alberta rangelands also provide open spaces and recreational and hunting opportunities that support our unique quality of life. Alberta rangelands figure prominently in the maintenance of biological diversity (ABMI 2015). For example in the Grassland Natural Region, rangeland landscapes are home to over 75% of Alberta's species at risk.

Conservation of Alberta's remaining native landscapes is a high priority in Alberta with only 37% of the original area of native grassland remaining (GOA 2014). Development pressures from a variety of land use practices threaten the long-term integrity, health and function of rangelands (GOA 2014). Road construction, motorized recreational activity, energy development and country residential development all lead to rangeland fragmentation and an increased potential to introduce invasive plants that can alter the character and quality of rangelands. Future stewardship practices also need to integrate rangeland management practices with the management needs of species at risk and also adaptation to potential climate change impacts on rangelands.

Alberta Rangeland Ecological Knowledge Tools

In this paper, the theme of rangeland technology will focus primarily on rangeland management as an approach for integrating many types of knowledge and ecological knowledge tools to maintain health and function of rangelands and in so doing, sustain the values and benefits that rangelands provide.

The province of Alberta has been an international leader in the development of rangeland ecology knowledge and tools. The tool kit includes the following components (other secondary tools are described in subsequent sections):

Rangeland Reference Areas
Rangeland reference areas (Willoughby 1993) are study sites set aside, managed and protected to illustrates and monitor ecological site types with their associated plant communities of significance in the landscape. Alberta's network of 185 sites have accumulated progressively over 65 years, with the earliest sites being established in the Rocky Mountain Forest reserve in the 1950's and a number of prairie sites as early as 1927. These sites assist in determining the characteristics of plant community succession in the presence and absence of disturbance for key ecological sites and provide outdoor classrooms and demonstration sites for range managers, ranchers, students and the public. Reference sites have had considerable value to the research community by providing a historical record of plant community dynamics and forage productivity.

ECOSYS
ECOSYS is an advanced data base and knowledge management tool sponsored by Alberta Environment and Parks and is designed to store and manipulate site, soil and vegetation data for the purpose of plant community classification. ECOSYS provides two primary functions, first acting as a repository for vegetation inventory plot data, currently housing about 29,000 plots and secondly a platform for the development and management of ecological site descriptions (ESDs). Plant community guides are developed and housed in ECOSYS within Alberta's ecological classification hierarchy (Downing and Pettapiece 2006).

Vegetation Inventory and Plant Community Classification
Ecological classification systems are an important tool for resource managers and they help us to organize what we know about ecosystems, provide a common language for resource management and planning, facilitate ecologically-based decision making and understand and refine resource potentials and carrying capacities over time (Willoughby and Alexander 2006). Range plant communities are defined in an ecological classification system by grouping vegetation data, from research plots and range vegetation surveys "into similar functional units that respond to disturbance in a similar and predictable manner (Beckingham and Archibald 1996)". In the 1980s, the Government of Alberta developed a standardized rangeland vegetation inventory methodology, facilitating consistent field methods for the capture of vegetation and site data (GOA 2007). Community types are defined not only by their vegetation composition but also by the environmental conditions under which they occur. Plant community types are captured within Alberta's hierarchical ecological classification system with 6 Natural Regions and 20 Natural Subregions (Downing and Pettapiece 2006). Plant community descriptions provide the working core of the tool kit.

Land Cover Mapping
The Grassland Vegetation Inventory (GVI) represents Alberta's new vegetation inventory for the Grassland Natural Region of the province (ESRD 2007). GVI was designed to meet a multitude of business needs integral to the Alberta prairie landscape. GVI data are captured as a polygonal, line and point spatial features and stored in a relational database that provides information on a number of different landscape features. These features include 14 upland range site descriptions (loamy, limy, sandy etc.), ten wetland/riparian feature classes, four anthropogenic agricultural classes, two industrial classes and two anthropogenic urban/rural classes. Vegetation characteristics are described in general by tree, shrub, herbaceous percent cover, height, density and distribution pattern. In forest and parkland landscapes of Alberta, other resource inventories provide a vegetation theme for landscape stratification including the Alberta Vegetation Inventory (AVI) and the Primary Land Vegetation Inventory (PLVI).

Rangeland Health Assessment
Rangeland health assessments are utilized to make a rapid determination of the ecological status, health and functioning of rangelands. In 1999 an Alberta provincial task group began the process of developing a standardized approach to range health assessment for application to all types of range and pasture in the

province. The system incorporated new science and addressed the need for a single, more robust, yet practical tool for rating rangeland and tame pasture health. Building on the traditional range condition approach, the range health assessment (Adams et. al 2010) focuses on five indicators including plant community integrity, plant community structure, the presence of organic residues or mulch, site stability and the presence of restricted weed species. Ecological health and function is inferred indirectly from these indicators by comparing the functioning of ecological processes on an area of rangeland to a standard known as an ecological site description. From 2000 to 2003, the new system was refined, evaluated by grazing disposition holders, by other agencies and NGOs and gradually phased into operational use. The health assessment is subject to regular review and updating, the most recent in 2016. A field workbook provides detailed guidance in the application of assessment methodology. Field worksheets provide an abridged overview of the method for staff training and extension activities with grazing disposition holders and the public. As the new protocol gained acceptance among staff, grazing disposition holders and the public, external interest in the system emerged from other provinces in Western Canada. The workbook has also been used in China and Inner Mongolia, having been translated into Mandarin.

Range Resource Management

The Government of Alberta has a long history of working proactively with farmers and ranchers to promote sustainable range livestock grazing on Alberta rangelands. Alberta Environment and Parks is the principle manager of public rangelands in the province with 6.8 million acres managed by approximately 7,400 disposition-holders.

Grazing lease stewardship goals are guided by the Grazing Lease Code of Practice (GOA 2007) which defines specific range management principles and practices that may be applied by grazing disposition holders to achieve sustainable range resource management, to maintain health and function of rangeland ecosystems and maintain important ecological services including biodiversity.

Rangeland health assessment (including riparian health assessment (Fitch et. al 2009) is an audit activity applied on grazing dispositions to measure stewardship outcomes and to define management objectives when remedial actions are required. Rangeland health assessment data is used in a number of ways to support grazing disposition management. This is also a risk assessment tool applied to establish workload priorities in the grazing disposition audit process. As such, audit point allocation and intensity may be weighted to critical locations where it is important to describe range health issues. Rangeland health assessment data is also used to populate the Range Management Form (GOA 2005). This template facilitates a number of key business processes including the summary of audit results, calculation of billable grazing capacity and serves as an education and awareness tool. It allows a kind of netting down for various management considerations to understand both the ecologically sustainable stocking rate of the disposition, as well as the billable grazing capacity of the disposition. A very specialized application of the tool kit to rangeland conservation has been developed by the Alberta Rocky Mountain Forest Range Association (RMFRA) which sponsors detailed range resource inventories on member grazing allotments within the Rocky Mountain Forest Reserve, an area of the Rocky Mountain front with especially high values for watershed protection, wildlife habitat and recreation. The process combines the tools of mapping, range inventory and range health assessment to produce high quality resource inventory maps and reports. These products facilitate ongoing adaptive management to address emerging issues and sustain rangeland resources based with sound, science based information.

Integrating Wildlife Needs

MULTISAR is a voluntary grassroots conservation and habitat stewardship program working with ranchers in the grasslands of Alberta. MULTISAR (Multisar 2015) has integrated the tool kit into the processes associated with the development of habitat conservation strategies for managing habitat for multiple species-at-risk. The Grassland Vegetation Inventory is used by Multisar to evaluate habitat suitability through both Habitat Index of Suitability (HIS) and Resource Selection Function (RSF) modeling. Perhaps the most important application made by MULTISAR is in the consistent stratification of candidate ranches into GVI site types which are useful to efficiently structure and organize wildlife monitoring and rangeland health assessment activities. The use of GVI assures that a common landscape frame is used for both types of inventory. An important innovation that MULTISAR has made is in the application of the range health assessment protocol as an index of disturbance, correlated with presence and abundance of wildlife species. In the MULTISAR approach, range health scores are expressed in five health classes, instead of the normal three categories as published in the field workbook, and then a visual interpretation of species locations and abundance are related to the health class. In so doing, the value laden health terminology is set aside and the health scores are viewed more as index of grazing disturbance, which can be viewed to achieve desired landscape goals reflecting a range of natural variation appropriate to both sustainable grazing and multi-species management.

Reclamation and Restoration of Rangelands Disturbed by Industry

The Alberta's energy industry has been disturbing native rangelands in Alberta since the early 1900's. In 1963 Alberta became the first province in Canada to enact legislation specifically focused on land reclamation. For the next roughly 40 years, the predominant goal of reclamation for energy developments was to re-contour the landscape and stabilize the soil by seeding agronomic species or native cultivars. In the past several decades there has been a growing awareness of the disturbance impacts of various land use activities like oil and gas development on biodiversity and the health and function of Alberta's remaining native prairie rangelands and the need to develop reclamation practices that restore native plant communities. The path to restoration was long and continues.

The tool kit has been adopted by the energy sector, especially the oil and gas industry, and when applied in combination, results in reduced surface disturbance and improved reclamation and restoration outcomes within the Grassland Natural Region of Alberta (Neville et. al 2014). For example, a reclamation risk assessment guide helps companies to evaluate the relative risk associated with energy development projects on different ecological sites. GVI and the plant community guides assist in pre-site assessments and development planning so that cumulative development impacts can be reduced. Special recovery strategy documents provide detailed guidance in the application of rangeland ecological tools to the whole process with the potential for vastly improved restoration outcomes.

Future Applications and Further Development

Ecological Services

Rangelands are recognized more and more as supplying a wealth of ecological services, beyond provisioning. The capacity of rangelands to provide these services requires the application of ecologically based principles and practices of range management by rangeland stewards (Havsted et. al 2007). Resource managers will need tools such as those composing the tool kit, to identify rangelands at risk and in need of improved management to restore health and function. An improved understanding of the ecological services provided by healthy rangelands can help to better define the economic benefits of stewardship as well as incentives to assure long term sustainability. As research continues to highlight the linkage between rangeland health and the capacity of rangelands to supply ecological services, the range health components of the tool kit will be particularly useful in validating stewardship practices on the ground.

Climate Change Adaptation

Projected climatic changes vary temporally and spatially and will be different across Alberta's ecoregions (Schneider, 2013). Projected changes potentially affecting Alberta include increased air temperature, increased growing degree days, increased precipitation for all periods except summer which may decrease, decreased snow accumulation and earlier spring snow melt. Summer soil moisture is expected to decline, resulting from earlier snowmelt and increased summer evapotranspiration. Overall, dominant watershed character is expected to change from being snow-dominant to mixed rain and show. Resource managers agree that promoting and managing for healthy rangelands is perhaps the best measure in adapting to climate change. Vigorous and intact plant communities with litter reserves and few invasive species will best suited to adapt to changing climatic conditions. The tool kit, especially the core range health indicators will be of great value in assessing risk levels and adjusting management practices as climate change unfolds.

Summary

The Alberta Rangeland Ecological Tool Kit has been developed over the past two decades, primarily to serve the business needs of public rangeland resource management. In the past decade, practitioners in many other sectors have adopted the tool kit to their own particular resource management requirements. A number of future opportunities are emerging including improved management of rangelands to provide ecological services and to adapt rangeland practices to a changing climate. One particular priority will be to promote awareness and accessibility to the tool kit by new generations of Alberta ranchers.

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Impact of Communication Technologies on Pastoralist Societies

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Introduction

The rangelands cover approximately 20% of the World's land surface and provide 16% of annual food production as meat and milk for local and distant markets (Holechek, 2013). Food production from rangelands represents an important source of nutrition as global human population is projected to exceed 9 billion by 2050 (United Nations, 2015). There is pressure to increase production from the pastoralism but this has to be done sustainably to ensure the productive capacity is not eroded in the longer term for short term gains. Information technology represents a very real opportunity to improve livelihoods, increase food production and secure environmental outcomes in the pastoral lands.

About 70% of the World's pastoral lands are found in developing and emerging economies where they support indigenous human populations existing in a close synergy with their livestock (Reid et al., 2014). Such societies are driven by cultural mores that often lead to sub-optimal livestock production, over grazing and poor resilience to factors such as climate change and societal upheaval. In developed countries, pastoral lands are under threat from depopulation, loss or lack of infrastructure to support developed production systems and competition for alternative use of the rangelands, such as carbon storage, mining, ecosystem services and tourism (Roxburgh and Pratley, 2015). Against this background then, how can information technologies transform the pastoral lands from marginal production systems to those that are resilient to challenges, sustainable in the long term and deliver optimum levels of livestock production?

Opportunities for the Pastoral Lands from Information Communication Technology (ICT)

Technology has been employed to study and manage rangelands for over a century and over that time the tools and techniques used by researchers have greatly improved (Rango et al., 2011). Recently ICTs have become more widely used by pastoralists to enhance management for productivity and natural resource management (NRM) outcomes. The earliest use of ICT was for imaging of rangelands (Rango et al., 2011). Today remote sensing is a relatively mature technology (Handcock et al., 2015). Temporal and spatial granularity has improved to the point that detailed information regarding biomass, species composition, bare ground and erosion can be used to aid in the decision making processes of individual pastoralists (NRMHUB, 2015). Over the past decade or so a range of novel ICT advances have been developed that allow the researcher and pastoralist a much wider suite of tools to aid in the understanding and management of livestock grazing the rangelands. This review will focus on these technologies, the significant barriers to adoption and explore how ICT may transform the pastoral lands and the people that rely upon them.

Monitoring of groups of livestock in pastoral lands

In extensive grazing systems, livestock can exercise a high degree of autonomy in where they choose to graze, rest and access water. Knowledge of how livestock utilize a grazing area can be used to optimize fencing design, stocking rate, placement of water points, and mustering. Passive radio frequency identification (RFID) tags are mandatory in some countries and have limited capability in monitoring animal whereabouts (Rutter, 2014). However, active devices mounted on individuals within the group can provide much richer data regarding animal position and movement within the landscape (Rutter, 2014). Position can be determined by ground-based triangulation or by global positioning satellite system (GPS; Swain et al., 2011). The addition of other sensors on the device, such as activity sensors (Guo et al., 2009) also allow for the allocation of discrete behaviours of livestock in the field. Nevertheless, limitations of power supply to drive high fix-rate GPS, cumbersomeness of devices to attach units to livestock and robustness of the electronics are all impediments to more broad-scale adoption of these technologies by pastoralists. Recent advances with solar-powered units small enough to fit in an ear tag demonstrate that many of these impediments will be resolved in the next few years (Greenwood et al., 2014). Field-based sensors can also monitor gaseous emissions such as methane from extensively grazed livestock and thus contribute to understanding the impact of rangeland livestock on climate change (Tomkins and Charmley, 2015).

Monitoring of the individual animal

Information on the herd or flock is pertinent in relation to management of the environment for productivity or other values such as biodiversity. However, when ruminants are managed in large groups there is benefit to being able to optimize management of the individual (precision livestock management). Behavioural monitoring of the individual is possible, but the practical use of such data is questionable at this time. However, data on body weight, weight change, health and reproductive status can be used as a management aid (Bishop-Hurley et al., this conference). Remote in-field walk-over-weigh (WoW) systems are now commercially available in Australia (e.g. Precision Pastoral.com.au). Once the concept of a walk though unit in the environment is established, and the data is transferred to a remote user interface, then other applications quickly become possible such as auto-drafting and scanning for body condition (CSIRO, 2015) or body temperature (Gonzalez et al., 2013) In rumen sensors can measure pH, temperature, volatile fatty acids, ammonia, methane and hydrogen and can be integrated into remote telemetry systems (Bishop-Hurley et al., 2016).

Integrating sensors and systems for management.

While the above demonstrates that the range of sensors is extensive and ever growing, it is the integration of sensors to provide useful data that will determine the utility of much of this IT for pastoral industries. Collection of data is one thing, telemetry of data, especially when there are large amounts of data to be transferred, represents a challenge. Once data can be aggregated it has to be converted into useful information. The confluence of pastoral data collection with the internet of things and our ability to integrate big datasets is beginning to happen. An example of this is virtual fencing (Anderson, 2007) which is now being developed commercially. Within the next few years, networks from farm-based to country-wide in scope will be developed that could represent a paradigm shift for how rangelands are managed and monitored. The concept of a digitally connected pastoral property with an integrated sensor network has been demonstrated (Bishop-Hurley et al., this conference). At a national scale, two recent ventures; the "NRM Spatial Hub" (www.nrmhub.com.au) and the National Farmers Federation "Digital Agriculture Service" (www.nffdigital.com.au) both aim to provide countrywide support to assist in individual property management through the smart use and integration of data.

While these examples represent the vanguard of ICT for pastoralist societies, the rate of adoption is increasing as impediments, particularly in the developing world, are overcome.

Impediments to adoption of ICT in the pastoral lands

Technology everywhere?

Information and communication technology now encroaches on almost every aspect of life in developed countries. Universal use of home computers, for example, has given widespread access to information and products that have transformed the way we live. Today, information technology is rapidly transforming lifestyles in many developing countries too. The widespread availability of networks for smart phones is connecting remote communities and opening up new opportunities in finance, marketing, health and lifestyle on a scale that was hitherto unimaginable (e.g. Safaricom in Kenya; www.safaricom.co.ke). However, the impact of ICT is only now beginning to impact on the rangelands and the pastoralists who sustain a living from those rangelands.

Networks and bandwidth

While the opportunities of ICT exist for pastoralists, realizing those opportunities remains a challenge. Even in developed countries, connectivity across extensive areas is an impediment to the roll out of many data hungry applications (Curtin, 2001). For example, Figure 1 demonstrates the almost complete lack of overlap between the Australian rangelands and internet responsiveness to a national survey of internet usage (BIRRR, 2015; Figure 1). In many sparsely populated pastoral regions, download speeds can be as low as 0.7 Mbps (BIRRR, 2015). Expensive and unattainable access to either mobile or internet connectivity adds to the digital divide (Curtin, 2001).

(A) (B)

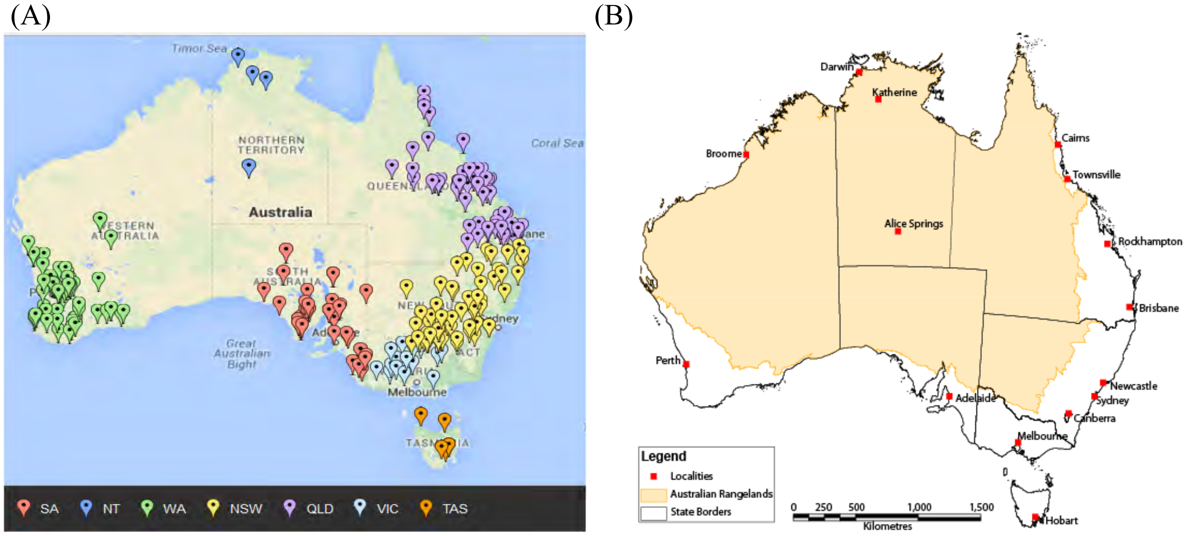


Figure 1. Responses mapped from the Better Internet for Rural Regional and Remote Australia (BIRRR) Regional Internet Access Survey showing access to internet in Australia (A), and location of Australian Rangelands (www.environment.gov.au/land/rangelands) (B).

So, while ICTs are poised to effect a paradigm shift for the pastoral industries, there remain many barriers to adoption; technical, physical and environmental. However, bridging the human-machine interface is by far the greatest impediment to ICT adoption and transformation of the pastoral industries.

The Human Computer Interface

Both developed and developing countries suffer challenges of bridging the human computer interface. Human challenges include several factors, for example socio-economic, agro-economic, institutional, informational factors, and producer perception, behavioural factors, and technological factors.

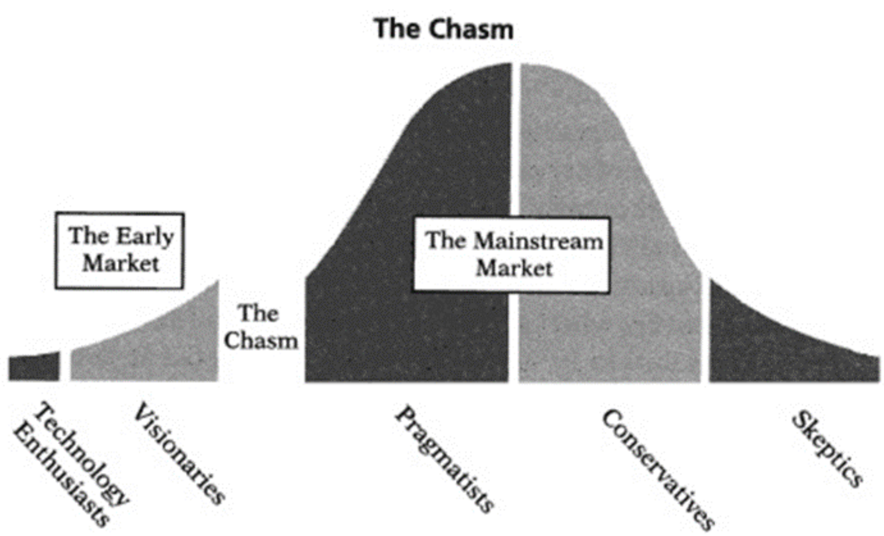
Socio-economic factors such as access to global markets and instantaneous information and service delivery require a high level of engagement with technology which is influenced by producers' capacity and ability (Tey and Brindal, 2012). Agro-ecological factors consider how the land is being used. In developing countries diversification and intensification of land use requires an ability to change (Reid et al., 2014) and an opportunity to adopt ICT. The ability to adapt to change, both reduces vulnerability and increases security. Institutional factors may influence land use. Privatisation, conservation and reforestation, can negatively affect technology adoption (Reid et al., 2014; Tey and Brindal, 2012). Information dissemination through extension services or product consultants is often the purview of men, and often fails to embrace the benefits of social media. However, in both developing and developed countries, women are recognised as harder working, more trustworthy and better decision makers than men and are more ready to adopt new technology and communication channels (Hay and Pearce, 2014).

Producer perception and behaviour will also drive adoption. If the farmer perceives the technology to be both useful and easy to use then adoption will readily occur (Davis, 1989). Behaviour is influenced by time and capital, and willingness and effort. When this influence is positive, adoption of technology will ensue. By contrast if influences are negative, then the opposite occurs (Tey and Brindal, 2012). Finally, the implications for technological factors include the types of technology available and the operator required to use them for example, the personal computer. Computers are used to analyse the data that is collected by the rural digital technology, therefore if the producer has a negative relationship with computer technology, he or she is unlikely to adopt the technology (Tey and Brindal, 2012).

The conservative grazier and the right technology

Adoption of any new technology follows a bell curve (Figure 2). The early adopters, or visionaries, are risk takers, not a trait normally associated with graziers (Marshall et al., 2014). There is a distinct lag before mainstream uptake and this is very characteristic of the uptake of technology in pastoral lands. Thus, adoption has been slow in the pastoral industries, nevertheless the advances and availability of low cost technology is slowly changing the status quo. An emerging issue with ICT lies around its novelty. Pastoralists have very little prior experience with ICT and it is difficult to evaluate exactly what will fit their needs. ICT developers are often focussed on selling their product, in doing so they focus on the bells and whistles version which is too complicated and has redundant functionality. The developers' misguided focus becomes a barrier to adoption (Lamb et al., 2008). However, recently it was observed

Figure 2. The adoption curve (After Moore, 1001).



that more pastoralist men are taking an interest in using technology. The introduction of the smart phone has made it easier for men to learn how to use and rely on technology. Having a hand held computer that fits in your pocket and can be used in the paddock means that the pastoralist can look things up when they need to (e.g., weather, water sensors, WoW data, tractor parts, cattle prices). Having a small hand held device also means that they can learn in private without fear of being ridiculed. However, Marshall et al. (2014) found that only 16% of pastoralists in a developed country have the ability to change and adopt to new technology. Producers that have tried new technologies and have had a bad experience may be reticent to try again. Widespread use of ICT may take a generation.

Pastoralists generally operate low input systems, new to market technologies tend to be expensive and are therefore not easily justified. Access to technical support is limited or non-existent due to the tyranny of distance. Producers are often even more wary of transformation technologies which to realise their full potential require a significant change in the business and therefore management input (Marshall et al. 2014). The Technology has to work properly and all the time, it has to be reliable and easy and cheap to fix. Extremes of heat and cold, ultraviolet light intensity, invasion by insects and physical attack by birds also render many ICT devices quickly inoperable. Durability and reliability have to be assured if the technology is to be adopted.

Drivers for adoption of ICT in the pastoral lands

In spite of the many challenges that face adoption of ICT in pastoral lands, change is happening (Schellberg et al., 2008). In developed countries, the scarcity of labour, through chain monitoring and proof of provenance lead to reduced production costs and increased value and marketability of product. In industries where margins are tight, the ICT revolution is one of the few levers open to producers to improve profitability. As the impediments are slowly resolved, resistance to change is evaporating and those who do not embrace ICT will be left behind.

While it is acknowledged that a generational change, perhaps coupled with leadership from women will take time, improvements in reliability and availability of technology progresses at a pace. Similarly, internet coverage, speed and bandwidth are improving throughout the World. Thus many of the impediments are rapidly disappearing. Perhaps what is lagging are the appropriate tools to allow pastoralists to fully benefit from the benefits of the digital age.

With the advent of the appropriate and functional technology, new, unplanned opportunities appear. Reduced reliance on livestock through the development of other revenue streams builds resilience into systems and peoples, for example. Recognizing the importance of co-benefits in terms of environmental sustainability (Lipper et al., 2010) realizes not only improved productivity but the potential for C sequestration, ecological returns and tourism. In the developing world, the status of ICT is quite different. While networks are demonstrating the value of communications, and women are at the vanguard of change, the drivers are different and subtle. Typically it is access to markets and credit that can transform lifestyle and this ultimately leads to changes in the way pastoral lands are managed (Frelat et al., 2015). Examples include the use for feed supplements to manage feed gaps, reduced stocking rates and concomitant improved livestock fertility.

Conclusions

Information technology offers the potential to convert nomadic herders to farmers in the developing world and graziers to producers in the developed world. While there are impediments to adoption of ICT, the rate of adoption in other sectors suggests that eventually pastoralist societies will embrace digital solutions. The rangelands represent one of the least modified biomes on the planet, yet overgrazing, desertification and climate change will hinder their long-term viability and contribution to global food supply. While ICT is not a panacea it does represent one tangible game changer for the pastoral lands of the globe. Technology will evolve in many ways from the basic smart phone to a fully integrated value chain network. Based on experiences in other domains, ICT will transform the pastoral lands but in ways we can only imagine.

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Voices of the IRC - Synthesis Poem for Sessions 4, 5 and 6

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Introduction

These poems were written drawing primarily from the words and language of the scientific papers in the proceedings with some additions and modifications. I was trying both to distill the scientific findings and to capture underlying feeling, beauty or humor embedded in the language or content of the paper. I intended to do all the oral presentations, but didn't quite succeed. I included a few posters that caught my attention. There are about 42 poems altogether. Of necessity, they were hastily done and as a result, do not live up to their potential as poems. I enjoyed doing this and recommend it as a method for summarizing papers. It helps get to the heart of the matter.

Prelude—Paleo-ecology

Earth thrusts and floods
Sands shift, ice over
Carbon we dig today
Squeezed into being
Held in folds
Of rock and time

The planet's skin
Greens over
Cryptograms and saxifrage
On barren islands of the north
Lichen, moss and shrubs
Prairies fine with grass and buffalo
Steppes alive with birds
Savannah, where wildebeest teem
All this a paleo-ecological
dream

We came out of Africa
Followed the caribou
Tamed the yak
Grew our herds of sheep and beef
Mounted our horses, boarded our boats
And peopled the world

We watched and learned
Experimented, observed
Lived, worked, loved, played
We shared, we fought
Eden it was not
And yet
We knew who we were
And how to be
Together
With our beasts, the land
And one another

Multiple Use of Rangelands

The carbon buried deep below
We need it now
To make things go
Tear back the skin
Scrape off the grass
Reap the treasure
Oil, coal and gas

From Boroo Gold
To the Bakken Field
Wounded earth and
Poisoned waters
A legacy for
Our sons and daughters?
Jobs, profit, royalties
Impacts on communities

Science helped to hone the blade
Can science heal the mess we made?

Bring back the fires
Kill the weeds
Harvest and replant native seeds
Teach our people
Help them learn
What we grow is
What we earn.

Science loves simplicity
Elegance, replication, and objectivity
Yet simple solutions
Seldom succeed
Diversity and complexity
Are what we need.

High Altitudes and Latitudes

Life is hard
On the roof of the world
For plants, animals, people

In Tibet,
Yaks: without them life would be impossible
Rangeland deterioration
Rooted in ideologies, policies and paradigms
Of modernization
Development the cost of
Traditional knowledge, management
Culture, identity
Yaks are more than income
More than food
Yaks are who we are
We made this place with fire
And kept it with our animals
We move and keep moving
Adaptive and flexible

In the Swiss Alps:
Summer farming
In the high meadows
Ancient practice
Embedded
In custom and place
Farmers do it for
Cheap grass
But also for the pleasure
Of grazing summer pastures
Labor is hard to find
Now younger people
Women, city folk
And foreigners
Take to the mountains
For meager pay
Learn the work,
Tend the stock
And make the cheese
Like my favorite childhood story,
Heidi.

Tibet, again.
Parks and people
Can be compatible
If managed cooperatively
Pastoralist communities,
Empowered,
Feel identity with place
Know who they are
And how to be
In this high,
Cold country.

Climate Change in Rangelands

Rangelands 50% of earth's land
Fodder for poetry
ANPP
A core ecological currency
For ANPP
Rainfall is the key
Grazing effects vary
With evolutionary
History
We know well
How these work
Independently
But not so much
Simultaneously

The world will warm
Less rain will fall
In many rangelands, anyway
Extreme events
Uncertainty
Potential famine
And calamity

So…

In the heat of the future
The drought of the day
The dzud of the winter
What can we say?
How can we adapt
Or mitigate?

Indigenous herders use what they know
Move with the grass, stay on the go

Flexible stocking if it doesn't rain
Adaptive planned grazing, out on the Plains

Climate Clever Beef say the Aussies down under
Reduce stocking and wait for the thunder

To capture the carbon, let the shrubs grow
Use multiple measures, New Zealanders know

Find the fodder with the lowest methane emissions
Treat urine patches to reduce nitrous dioxide emissions

Resilience-based management is the word on the steppe
Co-produced knowledge will get us there yet

How to empower the people to act
Pay them for services, make a firm pact?

Build on the knowledge they already hold
Workshops, Theater, Poetry, be bold!

How can we understand better their choices?
Be quiet, and listen to pastoralist voices.

Multiple Use of Rangelands - A

Mining could be a valuable component
A veritable gold rush
Coal, copper, diamonds
Sand, clay, salt
Oyu Tolgoi, turquoise hill
30% of Mongolia's GDP by 2021
30,000 informal artisanal miners
Air pollution
Water pollution
Mercury pollution
Cyanide pollution
Arsenic pollution
Rural people see
Mining as destructive of nature
And Grazing
With little economic benefit
Mining is not compatible
With Mongolian culture
With cherishing
The environment

Multiple Use of Rangelands - B

North American rangelands
Energy independence
Diversify energy sources
Untapped energy sources
Renewable and non renewable sources
Demand for resources
Alternative energy resources
Biophysical processes
Socioeconomic processes
Complex interactions
Positive and negative feedbacks
Goods and services
Laws and culture
Education and attitudes
External outcomes
Include
Soil erosion
Water pollution
Greenhouse gas emissions
Biodiversity loss
Etcetera
Etcetera
Etcetera
Still numerous knowledge gaps
Next step
Multidisciplinary research
Standard indicators
Develop policies
Minimize and mitigate
Impacts
Goods and services
Critically important

Energy Development & Reclamation of Industrial Disturbances

Poem 1

Argentina
Biofuels
Energy crops
Aroused new interest
Transformational processes
Perennial grasses
High accumulation
Translocation
One annual crop
And one perennial
Feedstock and
Biofuel
Food and energy
And environment
Trilemma
Perennial grasses
For food and fuel
Could be a solution

Poem 2

In mining reclamation
Regardless of seeding rate or rainfall
Seeded grasses similarly abundant
Long after seeding.
Conversely,
Starting conditions regulated
Native shrubs.
Practical knowledge can emerge
From studying restoration
In practice

Poem 3

What is the relationship
Between soil crusts and seed banks
In the Great Plains?
Plant communities shifted more than seedbanks
In response to pipelines
Soil biological crusts were highly sensitive
To pipeline presence.
Watch out for invasive legume Melilotus!

Poem 4

In the Bakken
So much gas
So little space
Fugitive dust, disruption and ineffective restoration
Jargon in contracts and leases
Stress on social networks and local services
Better policies, planning and public relations
Could improve life and reduce conflict
In the Bakken

Wildlife Conflicts
Range supply review
A way to inventory, map and visualize
And measure cumulative impacts

Fire Management & Restoration in Rangelands

Poem 5

Fire is a natural disturbance
Most fires occur in C4 grasslands
Most in the Southern Hemisphere
Pastoralists have traditional knowledge
Of vegetation management
Using fire
Burning causes warming
Global warming
Black carbon
Melts ice
Smoke cools
Charred plants reduce albedo
Warm soils
Does managed fire make it worse?
The warming?
As a rule
Fire alone cannot control
Invasive species
Conservation
Reduces livestock
Leaving only
Fire
Conservation landscapes
Working landscapes
Mosaic
Grazing and fire
Are synergistic
Diversity
Heterogeneity
Shifting mosaic
Grazing lawns
Scholarly reviews, management reviews
Challenge long held views
Include controls
And Before and after
Measures
To avoid confounding weather
Traditional
Spring ritual
Pasture Burning
Climate change increases fire risk
Prescribed burning decreases risk of fire
Traditional burning is widespread
Lacking scientific knowledge

Poem 6

How do fire seasonality and return interval
Affect rangeland productivity and plant composition?
Spring, summer and fall burns
1, 3 and 6 year return intervals
Season and fire frequency interact
Fire had little effect on productivity
But shifted species composition
Fall and summer fires at short intervals
Favor rangeland integrity.

Poem 7

Megafires are a bigger problem
Than drought
Finding durable solutions
Requires collaboration
Among diverse stakeholders.

Poem 8

Burning is risky
But extreme heat is needed
To kill shrubs in the Southern Great Plains
Which is greater:
The risk of escaped fire?
Or the risk of doing nothing
And watching the trees encroach
On your grass?
Many factors affect
Landowners' attitudes towards fire

Poem 9

Targeted grazing can be used to
Manage fuels and alter
Fire behavior
By reducing fuel loads and
Creating fuel load heterogeneity
Patchy burns leave islands
Of unburned sagebrush
A seed source for recolonization
Across the steppe
Effectiveness of targeted grazing
Depends on fire weather conditions
And the structure of

The plant community.

Poem 10

Acacia has invaded Uganda
Reducing forage and livestock
Productivity
Traditionally, pastoralists managed brush with fire
But burning is now banned
And shrubs increased

Cropland Abandonment, Revegetation with Perennial Forages & Re-Used as Rangeland

Poem 11

Mexico
Plantations of native shrubs
An alternative for restoration
Of deteriorated rangelands
Colors from the visible range
Of the electromagnetic spectrum
Have differentiated effects
On photosynthetic activity
Can different radiation environments
Shorten shrub production
For restoration?
Effects were significant
For shoot length
But not for roots
Plants like red light best

Poem 12

Kochia competes well with weeds
Suppresses fires and
Increases diet quality
But how to establish it
In disturbed sites?
Plant in April not March
Monitor over time
To see how it gets along
With natives.

Poem 13

My mother told me
"Cut your food small
so you don't choke."
In Bangladesh
Cross-bred dairy cows
Eat more and gain more
When their para grass
Is chopped.
Mom was right.

Poem 14

Tamilnadu, India
Wild plants are
Sustenance for dryland dwellers
Nomadic shepherds
Firewood collectors
Skilled craftsmen
Each use plants
For different purposes
Fodder is the main use of many plants
Wild fruits, to cook with
Cassia, Strychnosis and others for medicine
Agaricus, wild mushroom, for food
And Eracrostis cynosuroides,
A sacred grass
(And many more)
We need to know
What these plants are
And how to use and
Tend them well
So people and plants
Both survive and thrive.

Invasive Species Impacts & Management in Rangelands

Poem 15

When tame goes wild
Disperses and colonizes
Aggressive invader
Synthetic survey
Delicate balance
Between
Ecological risk
And economic value
Bromus inermis
Is least dominant in the most diverse sites
So, richness lends resistance
But suppressive effects of Brome are greatest
In high diversity sites
What is the mechanism that explains this
pattern?

Poem 16

Absinth and tansy
Hard to eradicate
Toxic to people
And livestock
Spray? Wipe? Or send out the goats
To eat?
Spraying kills good plants, too
Rotowiper sometimes works
Goats gobble up tansy

But it grows right back
Need to follow up with herbicide
Or graze for multiple years.

Poem 17

Need to kill that
Tamarix
Which herbicide
Is best?
IMazapyr
Imazapic
Triclopyr
Experiment on the Cimarron National Grasslands
Happyditch soils
Imazapyr kills
Non-target plants
IMazapic does much
Less damage
Triclopyr
Was a distant 3rd
In effectiveness.

Poem 18

Yes! Finally
A paper about weeds and people
Australian researchers
Consult producers about
Indian couch, an exotic grass
To identify a research and development agenda
A proposal is underway.

Poem 19

Kenya
Ipomoea
Creeping annual herb
Except bees and
Hairy black caterpillars,
Nothing eats it.
Pastoralist field schools
Schools without walls
Build on traditional knowledge
Innovate and empower
Learning by doing
Instead of telling what to do
Awareness raising: Posters
Role plays, poems!
TV talk shows, radio, YouTube and SMS
Fencing, uprooting and
Range rehabilitation can help
Eradicate Ipomeaia

Poem 20

An institutional
Solution to invasive
Exotic predators
Wild dogs.
Collaborative Area Management
Adjacent landowners
Fence their perimeter
To keep out dogs
Manage total grazing pressure
Aussie government pays half
Lambing rates went from 7% to 70%
A $504,000 Return on Investment.
Wow.

Wildlife Conflicts & Commercial Wildlife Utilization Opportunities

Poem 21

In Alberta
Feral horses, elk and cattle
Share the range
We need to know
How much forage grows
And keep stocking rates
In line.

Poem 22

Elk populations are recovering
In the Cariboo-Shilcotin country
Getting into stack yards
Causing general mayhem
Stakeholders may disagree
About what to do
There are no solutions
Only implications.

Poem 23

In Patagonia
When sheep left
Guanaco increased
And didn't overgraze

High Altitudes and Latitudes

Poem 24

Oblique angle of insolation
Cold temperature
Short growing season
Peat turns to
Permafrost
Covered in
Thick lichen and dwarf shrubs
Northerly and westerly Canadian islands

Are the coldest in the high arctic
Barren, black cryptograms, lichen,moss and sparse grass
Further south dwarf shrubs emerge
Then low arctic tundra
And finally subarctic woodlands
Pine, fir and birch
Bighorn sheep, musk oxen, reindeer,
And don't forget the geese
Reindeer eat lichen
Migrate
Populations fluctuate
Eluding management
They provide food
Clothing, identity
To arctic native peoples
For hundreds of years
Traditional agreements
Between family groups
Allowed flexible boundaries
Sharing resources
According to needs
And range conditions
We don't know what the future will bring
Baselines are needed
Government should heed
Traditional management.

Poem 25

Yaks:
Without them life would be impossible
Across high Asia
The rangelands are deteriorating
From ideologies, policies, modernization paradigms
Development at the cost
Of traditional knowledge and management
Yak are so much more
Than economic assets
Cultural ecosystem services
People and land
On the plateau
Grasslands created by burning
And maintained by grazing
Transformed by and for pastoralists
To create a sustainable food system
Adaptive, flexible
On the move
Mobility-essential to conservation
Water protection, carbon sequestration
Parks and people
Can be compatible
If managed cooperatively
If not injustice reigns
Pastoralist communities
Empowered feel identity with
Place, know who they are,
And how to be
In this high, cold country

Poem 26

Summer pastures in the Alps
Heidi's land
Now being abandoned
The shrubs creep in
Farmers graze the highlands
For cheap grass and good animal health
And the pleasure they take
In working the summer farms
The tradition.
As climate changes
The high mountain pastures
May buffer change below
Rooted deep in tradition
Summer farming in the Alps
Continues to evolve.

Poem 27

In Ladakh
High elevation pastures
Challenging terrain
Harsh climate
Dwindling resources
R&D needed to assure
Sustainable fodder supplies
Without further degrading the landscape
Researchers should work
With local organizations.

Poem 28

Qinghai
On the roof of the world
Plant litter decreases
Plant height
And aboveground biomass
On dark felty soils.

Poem 29

Peru
Above 4000 meters
On Communal Cooperative lands
Ecological sites and paddocks overlayed
For rangeland planning
Improvement strategies selected
Based on ecosites and potential for improvement
Even better would be adding economic
And social criteria
Must think for the long-term
Change in Andean rangelands is slow.

Poem 30

Altay Mts, Mongolia
Tsunhal Nur
Participatory mapping with herders
Of three ethnic groups
The lakeside is most productive
And most vulnerable to overuse
Herders suggested strategies:
Mobility and make it rain.
Prayer came in last.

Poem 31

In Cameroon
Transhumance from Savannas to wetlands
Has ecological, economic and social impacts
Coordination is needed
To avoid degradation
And conflict.

Climate Change

Poem 32

Rangelands 50% of earth's land
Fodder for poetry
ANPP
A core ecological currency
For ANPP
Rainfall is the key
Grazing effects vary
With evolutionary
History
We know well
How these work
Independently
But not so much
Simultaneously

The world will warm
Less rain will fall
In many rangelands, anyway
Extreme events
Uncertainty
Potential famine
And calamity

What can science do?
Look beyond our toes
Coordinated, distributed experiments
Data fusion and meta-analyses

Poem 33

Nine thousand years
Is a long time
Longer than
Ranching has been
On the plains
(But not longer than human history here)
Comparing recent climate and
Ecological conditions
To the range of conditions over
9,000 years
What can it tell us about resilience
To human-caused climate change?

In recent years productivity increased
More than increased moisture predicts
Due to species changes
More wheatgrass and needle and thread
Less blue gramma

In the Holocene
Lake sediments say
Five drought cycles
Each lasting more than 100 years
Grassland pollen down to 5%
Compared to today's over 20%
The Dust bowl had nothing
On those dry times

Tree rings say the last 500 years had
36 years drier than 1936
One drought lasted 13 years
Another 31

What does this mean?
The impact of anthropogenic
Climate change
May not be loss of productivity
But instead increased variability.
In the northern Great Plains.
We'd better get ready.

Plant Adaptations to Climate Change

Poem 34

In Sudan
Browse is a critical part of animal diets
In the semi-arid, arid and semi-desert zones.
They may be even more important
As climate changes.

Poem 35

Saskatchewan hay yields show long-term decline
Is there less water in the soil?
As warming occurs over time
The same amount of rain
Grows less hay

Physiology of photosynthesis explains this
Other crops adapted but not hay
Producers haven't switched to more adapted
Alfalfa
Hay shortages loom.

Poem 36

What grasses will grow best in salty Pampas
Three varieties of Chlorisgayana were tested
Finecut has the greatest density and cover
Santana the most seeds.

Poem 37

Apocynum venetum is a semi-shrub
From Eurasian desert-steppe.
What mechanisms allow it to thrive
In drought?
It grows in K deficient soils and is able to survive
In drought and saline environments
Making it valuable for improvement
Of barren and saline rangelands
In arid and semi-arid areas

Poem 38

Climate clever beef

Poem 39

New Zealand
Maori pastoral farms
Found trade-offs between profitability
And reduced GHG emissions
Culture must be accounted for
And tempers profit-maximization
Maori prioritize protecting
The environment.

Poem 40

The Puna of Peru
Supports 80% of Peru's cattle and sheep
And 100% of alpacas and llamas
Climate change and
Overgrazing
Increase herder vulnerability
They need adaptive management strategies.
And an early warning system

Poem 41

Holistic Planned Grazing Meta-analysis

Poem 42

Ghana
Climate change could trigger resource competition
And violent conflicts
In pastoral communities
Strategies include:
Mobility, adoption of drought tolerant livestock, production and purchase of hay, use of private rangelands.

Namibia and South Africa
Use different strategies across different temporal and spatial scales
Haven't adopted NEW strategies in response to climate change.

State of Global & Canadian Rangeland and Pasture Resources

1.1 Ecosite descriptions and ecoregion classification

Developing Ecological Site Descriptions on Mongolian Rangelands to Enhance Monitoring Condition and Trend

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Key words: GLEWS, PHYGROW, ecological site descriptions, Gobi.

Introduction

A study area was established in the South Gobi Region of Mongolia to demonstrate a variety of monitoring techniques. Our monitoring focused on 25 permanent rangeland sites that had been previously established during the Gobi Forage Project to develop a Mongolian Global Livestock Early Warning System (GLEWS) and 13 additional sites selected near the Oyu Tolgoi mine complex. Although our study area had limited area, it did include portions of five steppe and desert ecozones. At each monitoring site, we used frequency transects to compare changes in vegetation condition with earlier measurements, described topographic-edaphic characteristics, described potential Ecological Sites and assessed current Rangeland Health.

Materials and Methods

A hierarchy of information was used to distinguish and describe ecological sites visited during the August 2011 survey in the Gobi Desert for the Monitoring Change on Mongolian Rangelands Project (Sheehy et. al. 2012). A beginning reference was the UNEP Vegetation Type Maps compiled by the 1996 Russian-Mongolian Complex Ecological Survey, which mapped distinct vegetation communities by major zones of steppe and desert. Steppe subzones included steppe, dry steppe and semi-desert steppe. Subzones in desert included north desert (semi-desert), middle desert (steppificated desert) and south desert (true desert). Another valuable resource of ecological information to develop site concepts was Petr Dmitrievich Gunin's "Vegetation Dynamics of Mongolia", 1999.

Between August 15 and 31, 2011, vegetation and soil attributes were measured at the 38 monitoring sites. Frequency, forage yield, and landscape attributes were used to describe above ground characteristics of the monitoring sites. We described ground surface and belowground site attributes by evaluating characteristics of the soil profile. Frequency analysis and vegetation yield analysis allowed us to compare current vegetation status with vegetation status at the time of initial measurement. Vegetation yield itself had a direct link to the forage databases in the Forage Growth (PHYGROW) Model.

Results and Discussion

Preliminary ecological site descriptions

The 25 PHYGROW points and 13 Oyu Tolgoi points in Dornogov, Dungobv and Omnigov Aimags, were used as reference sites to develop 19 ecological site descriptions (ESD). Site names describe primary soils characteristics and a four class precipitation zone (PZ) that follows a latitudinal and elevation gradient. Precipitation was measured on a 40 year annual average. The 10-20 centimeter zone extends from grass steppe south to dry steppe and generally lies above 1200 m elevation. The 10-15 centimeter zone mirrors the 10-20 zone but lies below 1200 meters and extends south to the dry steppe and semi-desert steppe zones. The 7-13 centimeter zone extends south from steppificated desert into true desert and the 6-12 centimeter zone represents the driest desert zone (Table 1).

Table 1. Proposed ecological site descriptions, precipitation zones (PZ), and reference sites from the 2011 monitoring change on Mongolian rangelands study.

ESD	PZ (cm)	PHYGROW points/Reference Site
1 Gravelly Loam	10-15	DG-0035, DO-0001
2 Shallow Clay Loam	10-15	DO-002, DO-0023
3 Clay Loam	10-20	DG-36, DG-38
4 Loamy Skeletal	10-15	DO-03, DO-28, DG-07
5 Loamy Sand	10-15	DO-29
6 Clay Loam	10-15	DG-34
7 Sandy Loam	10-15	DG-01, DG-06
8 Loamy	7-13	OT-1R, OT-2R, OT-3-R, OT-4R
9 Clay Loam	7-13	DO-16, OT-5R, OT-10W, OT-12W
10 Loamy Skeletal	7-13	OT-6M
11 Loamy Sand	7-13	UG-39, UG-40, UG-44, UG-45
12 Fine Sandy Loam	7-13	UG-38, OT-11W
13 Shrubby Sandy Loam	6-12	UG-47
14 Desert Loam	6-12	UG-46
15 Droughty Loam	7-13	DO-15, OT-13W
16 Sodic Loam	7-13	DO-04A, DO-04B
17 Wet Meadow	7-13	D0-04C
18 Silt Loam	7-13	OT-8R, OT-9W
19 Loamy Silt	7-13	OT-7M

PHYGROW points aimag codes: DO = Dornogov, DG = Dundgobi, UG = Omnigobi, OT = Oyu Tolgoi Mine Development, R=roadside, M=mountain, W=aquifer

Preliminary Rangeland Health Assessment

Rangeland health was determined at 39 permanent monitoring sites by quantitative and/or qualitative assessment of physical and biological site attributes (Table 2). At each site, ground cover attributes, soil surface factors, and observed apparent trend were evaluated to determine ecological status.

Table 2. Ecological zones, ecological site descriptions (ESD), PHYGROW site and ecological status.

Ecological Zone	ESD#	PHYGROW site	Ecological Status
Dry Steppe	4	DO-03, DO-28, DG-07	Mid (Fair – Good)
Semi-Desert Steppe	1-5	DO-01, DG-35, DO-02, DG-01	Mid (Fair)
		DO-23, DG-38, DG-06, DO-29	Mid (Fair – Good)
		DO-36	Late (Good)
North Desert Steppe	6	DG-34	Mid (Fair – Good)
Semi-Desert Steppe	8	OT-1R	Early (Poor – Fair)
		OT-2R	Early (Poor)
		OT-3R	Mid (Poor – Fair)
		OT-4R	Mid (Fair)
Desert Steppe	9-11	DO-16, UG-44	Mid (Fair – Good)
		OT-5R, OT-12W, UG-45, UG-39, UG-40	Mid (Fair)
		OT-10W, OT-6M	Early (Poor)
Middle Desert Steppe	12	UG-38	Early (Poor)
		OT-11W	Mid (Fair)
		OT-7M	Mid (Fair – Good)
Desert	13-15, 18	OT-9W, OT-8R, UG-47, OT-13W,	Mid (Fair)
		UG-46, DO-15	Early (Poor)
Dunes (Mound)	16	DO-04A	Mid (Fair)
		DO-04B	Early (Poor)
Meadow (Oasis)	17	DO-04C	Late (Good)

Conclusions and Implications

The rangeland health assessment within a reference ecological site provides a qualitative assessment for determining condition. Combining this method with the quantitative measurements required at each of PHYGROW point, would provide a robust rangeland monitoring protocol for Mongolia, and across worldwide rangelands. We recommend establishment of a national rangeland monitoring program that utilizes Rangeland Health Assessments over multi-year time frames to determine condition of ecological sites, uses conventional rangeland monitoring techniques to annually assess impacts of large herbivore grazing on defined rangeland units. We also recommend incorporation of the Forage Growth (PHYGROW) Model in a national rangeland monitoring program.

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Testing the State and Transition Model for the Stipa krylovii — Cleistogenes squarrosa — Forb Community in Mongolian Steppe

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Key words: States, phases, cover.

Introduction

State and Transition Models (STMs) describe potential alternative states linked by transitions defining opportunities for restoration to healthy states and risks of further degradation (Briske et al. 2005). Application of STMs in management can help prevent ecosystems from crossing undesirable ecological thresholds of land degradation as well as suggest appropriate interventions for maintaining the health or restoration of degraded lands (Bestelmeyer et al. 2011). The Green Gold rangeland management project, SDC Mongolia has supported development of STMs and ecological site descriptions (ESD) for Mongolian rangelands as tools for collaborative adaptive management. Mongolian rangelands were classified into 25 ecological site groups (ESGs) with corresponding STMs (http://jornada.nmsu.edu/files/STM_Mongolian-catalogue-revised_2015.pdf). The objective of this study was to test and validate the *Stipa krylovii-Cleistogenes squarrosa*-forb STM in Mongolian steppe which covers about 30 % of total territory.

Materials and Methods

One of the most common STMs in Mongolian steppe, out of pre-existing 25 STMs, *Stipa krylovii-Cleistogenes squarrosa*-forb (Figure 1) is assumed for this study.

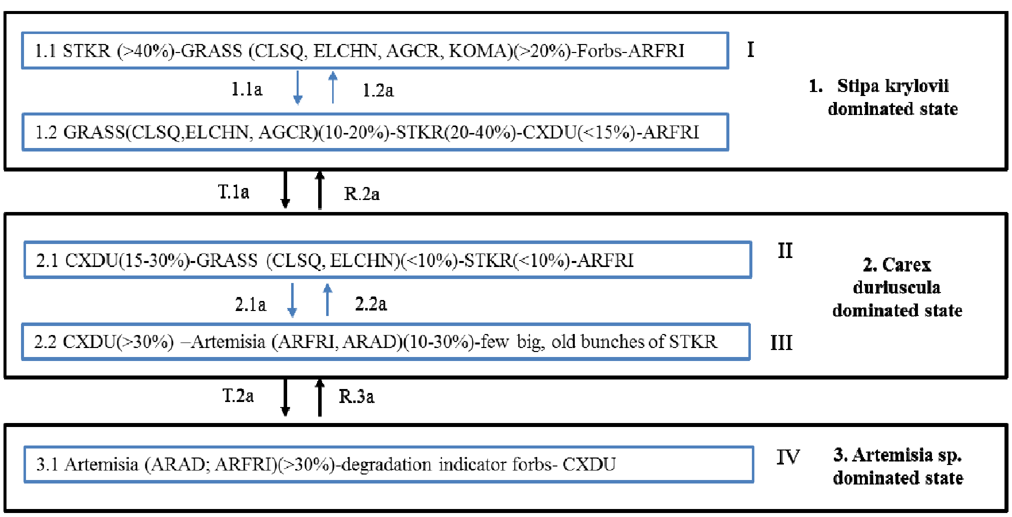

Figure 1. Existing STM for the *Stipa krylovii-Cleistogenes squarrosa*-forb community in the Mongolian steppe. Species name abbreviations in boxes: STKR-Stipa krylovii; CLSQ-Cleistogenes squarrosa, ELCHN-Elymus chinensis; AGCR-Agropyron cristatum, KOMA-Koeleria macrantha, ARFRI-Artemisia frigida, CXDU-Carex duriuscula, ARAD-Artemisia adamsii. I-IV are recovery classes describing increasing constraints to recovery. T1a, T2a are transitions: heavy grazing and climate change, R2a and R3a are restoration pathways: rotational grazing and resting.

Based on this proposed STM developed using another dataset and expert knowledge, a total of 215 sites from the National Agency of the Meteorology and Environmental Monitoring program were assigned to three states and five community phases, of which 108 were assigned to State 1, 81 to State 2 and 26 to State 3 due to dominant species composition.

To test for state differentiation as proposed in the initial STM, descriptive statistics and ANOVA were used to compare total foliar cover and the cover of key species between different states. Cover of key species groups were used as explanatory variables in the Principal Component Analysis (PCA) in CANOCA software v.5.

Results and Discussion

The first two axes explained 53.1% of total variation in composition. Ordination clearly distinguished among different states of the STM. Using plot data assigned to the three states, total foliar cover and *Stipa krylovii* cover decreased, whereas cover of *Carex duriuscula* and *Artemisia adamsii* increased, from states 1-3 (Fig. 2). These results support the notion of the *Stipa krylovii-Cleistogenes squarrosa*-forb STM. Moreover PCA can be a useful tool to test concepts for STM states using the cover of key species or functional groups.

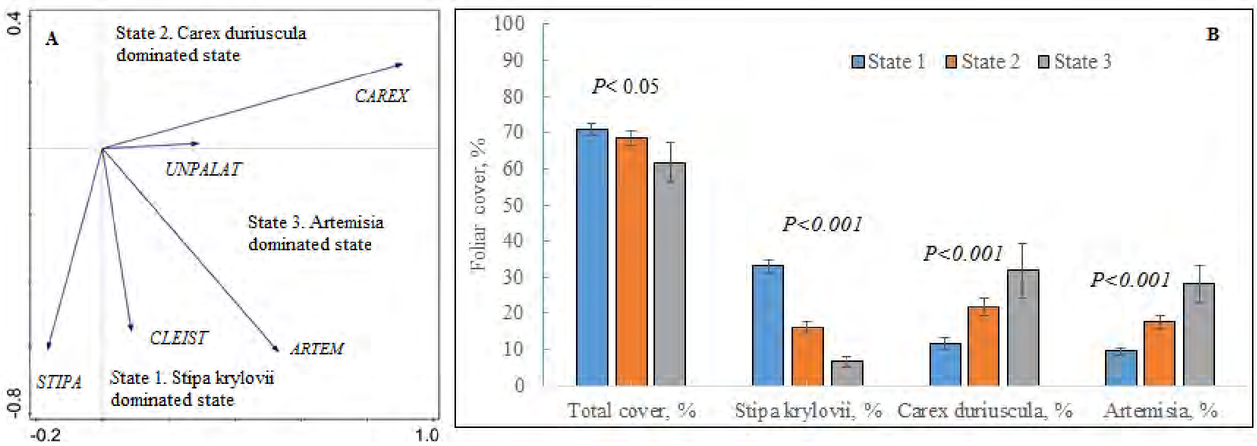

Figure 2. A. Cover data of plant species at the study sites ordinated by PCA. The cover of key plant species used as explanatory variables are shown as vectors. Abbreviations: UNPALAT- unpalatable, ARTEM-Artemisia, CLEIST-Cleistogenes. B. The comparison of total and key species foliar cover (mean±SE) of three different states.

Conclusions and Implications

Our PCA analysis supported the differentiation of states in the proposed STM for the *Stipa krylovii-Cleistogenes squarrosa*-forbs community. With the ability to evaluate the current and reference states of rangelands and predict future alternatives, this STM has the potential to serve as an essential tool for monitoring rangeland health and facilitating management planning (Herrick et al. 2006).

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Soil Types and Vegetation on a Grassland Ecosystem in Uruguay

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Key words: Natural grassland, soils, biodiversity, richness, evenness.

Introduction

Natural grasslands comprise 64% of the Uruguay landscape, and the knowledge on its floristic diversity and influential factors is scarce. Such landscape is formed by vegetal cover which combines a great number of species that vary in frequency, physiologic and ecologic habits according to the soil where they develop (Millot et al., 1987). Moreover, the competition of the species is modified by the application of fertilizers, which alters the structures of the fields and therefore their productivity and seasonality. The aim of this paper is to study the associations between soil type and fertilization on the structure of the vegetation of a natural field.

Materials and Methods

The study was carried out on a natural grazing grassland in Facultad de Agronomía Uruguay, (32°23'57,37"S; 58°02'41,72"O) during November 2014. The study took 8 hectares with an experimental complete block design with four replicates and four treatments: (N) natural grassland, (I) natural grassland improved with oversowing *Trifolium pratense* and *Lotus tenuis*, and fertilized with 40 $kg.ha^{-1}.year$ of P2O5, and natural grassland at two levels of nitrogen fertilization (120 and 60 $kg.ha^{-1}year^{-1}$ of N) and 40 $kg.ha^{-1}.year^{-1}$ of P_2O_5 (6;1). The dominant soils in the area are: Lithic Hapludoll (LH), Typic Natraquoll (TN), Argiaquic Argialboll (AA), Pachic Argiudoll (PA). The vegetation associated to each type of soil was assessed in $1m^2$. The coverage of each species was registered, which resulted in 144 samples in total. The species of the Poaceae family were grouped according to functional types, defined as the combinations: life cycle, productive cycle and vegetal type. The data was analyzed with main-component technics.

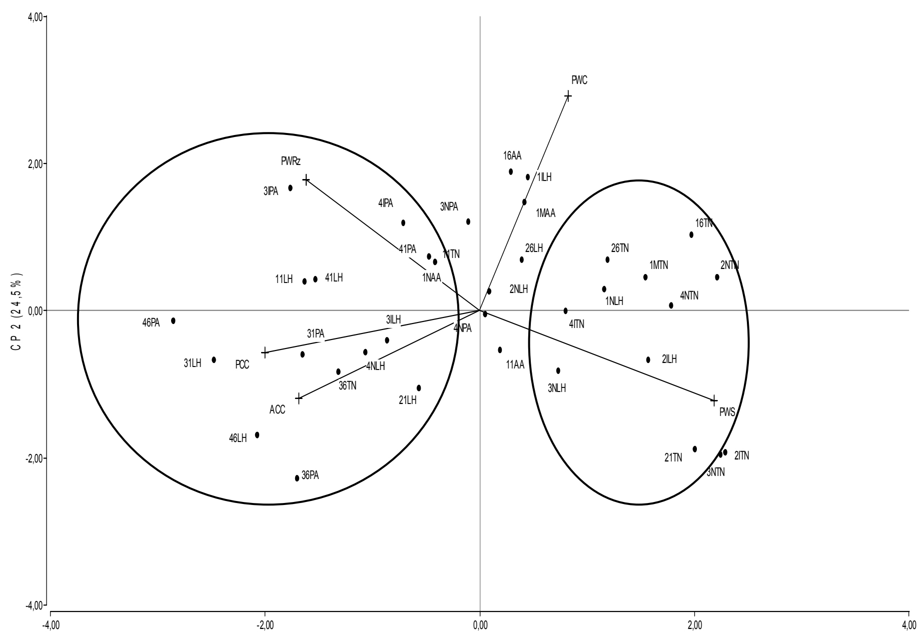

Figure 1. Diagram of ordination by principal coordinates, based on cycle of life (A-annual, P- perennial); productive cycle (C- cold grasses, W- warm grasses), vegetal type (C-cespitose, Rz- rhizome, S-stolonifera).

Results and Discussion

Figure 1 features 1 and 2 axes that explain 41.7% and 24.5% of the variation among the sites, respectively. Principal component 1 correlates positively with Perennial Warm-season Stolonifera grasses (PWS) and negatively with Annual-Cold-season-Cespitose grasees (ACC), Perennial-Cold-season-Cespitose grasses (PCC) and Perennial-Warm-season-Rhizome grasses (PWRz). Two main groups are distinguished and no clear effect to the treatments is observed. One of them is associated to PWS, which mainly corresponds to TN soils, where the dominant species are *Bouteloua megapotamica* and *Paspalum notatum*. The other group is associated to winter grasses both annual (*Briza minor*, *Lolium multiflorum, Poa annua, Vulpia autralis*) and perennial (*Bromus auleticus, Piptochaetium spp, Stipa setigera*) grouped mainly in LH and PA areas. The remaining areas did not show a clear pattern of association with functional groups of grasses.

Conclusions and Implications

The association among dominant functional groups and areas corresponds to the differences in the adaptation of flora to physical and chemical restrictions in the soils. A greater proportion of species that indicate fertility was observed in deeper soils (*L. multiflorum, P. ditalatum*) and low-fertility indicating species were observed in TNs, which matches the results.

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Validating Riparian State-and-Transition Models

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Key words: Ecological site, state-and-transition model, riparian

Introduction

A project was conducted in North Dakota to develop riparian complex ecological site descriptions (RCESDs) and state-and-transition models (STMs). The geomorphic features of a riparian ecosystem and the vegetation communities together form the riparian complex (Winward 2000). A riparian complex is defined by valley type, gradient, substrates, fluvial surfaces, and vegetation patterns. For ESDs to adequately describe riparian systems, geomorphology and riparian complex need to be incorporated (Winward 2000; Stringham and Repp 2010).

STMs outline the multiple successional pathways for an ecological site; describing potential states, transitions, and thresholds (Westby et al. 1989), explaining ecological processes. To adequately describe ecological processes and predict responses to disturbance riparian STMs need to include channel classification, channel evolution models, description of fluvial landforms, plant community components, and soil-water-vegetation dynamics (Stringham and Repp 2010). Channel evolution models describe the potential changes in channel morphology in response to disturbances that change flow, sediment load and bank stability (Rosgen 1994). Channel responds to disturbance by making a series of adjustments, changing the stream type. Within a riparian STM the various stream types that comprise the channel evolution model are the building blocks (Stringham and Repp 2010). Stream channels are grouped in states based on channel morphology and stability. A STM for a riparian ecosystem is comprised of three states: 1) stable potential channels, 2) unstable channels, and 3) confined stable channels.

STMs provide guidance to land managers, explaining how a particular stream is expected to respond to various disturbance and management strategies (Stringham and Repp 2010). The objective of this study was to validate current riparian STM by determining whether the Rosgen's classification of natural rivers and the channel evolution model is capable of predicting the potential states and thresholds within a riparian complex.

Materials and Methods

Forty-one stream reaches were inventoried along eight streams across North Dakota. Reaches were inventoried utilizing Rosgen's classification. Cross-section and longitudinal profile data was collected using a laser lever and survey rod to record elevations. The cross-section profile was used to calculate the entrenchment ratio (ER), width to depth ratio (WDR), bank height ratio (BHR) and channel sinuosity. The longitudinal profile was used to determine the meander width ratio (MWR), sinuosity and channel slope. The dominant channel material (D50) was determined using the Wolman Pebble Count.

A cluster analysis was conducted of the measurements to group similar streams. Cluster analysis was performed in PC-Ord with the flexible beta method using a beta value of -0.25 and correlation as the distance measure. An indicator analysis was conducted to assess variables ability to predict stream type and state. Nonmetric Multidimensional Scaling (NMS) ordination as used to examine differences between stream classification parameters measured among reaches sampled.

Results and Discussion

Classification of the forty-one cross-sections sampled resulted in ten cross-sections being classified as E streams, 15 C streams, 11 B streams and five F streams. The E and C streams are the potential natural channel for many prairie streams and are found in states one and three of STMs. In the prairie B, streams are transitional and occur when an unstable F stream begins the transition to a stable C or E channel. E channels are slightly entrenched (ER > 2.2), narrow and deep (WDR <12), and typically have a sinuosity greater than 1.5. C channels are slightly entrenched (ER > 2.2), have a WDR greater than 12, and sinuosity greater than 1.2. B channels are moderately entrenched (ER 1.4 - 2.2) with WDR and sinuosity similar to those of a C channel. F channels are entrenched (ER <1.4) and do not have an active floodplain. These streams are wide and shallow (WDR > 12) and relatively straight compared to the potential natural channels.

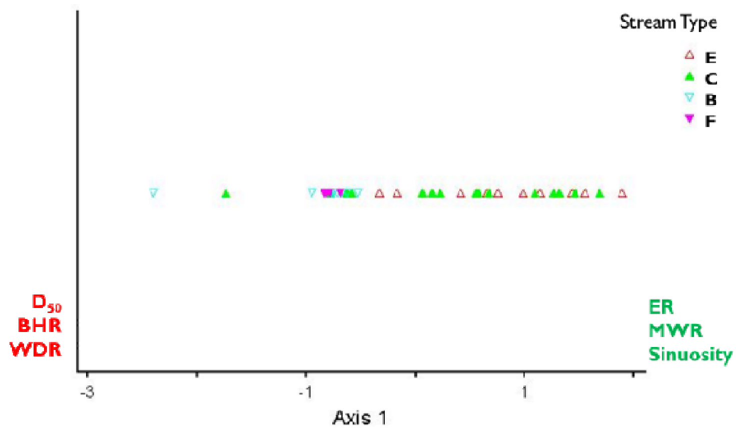

Figure 3. Non-metric multidimensional scaling ordination of the stream reaches. Points in ordination space represent individual sites

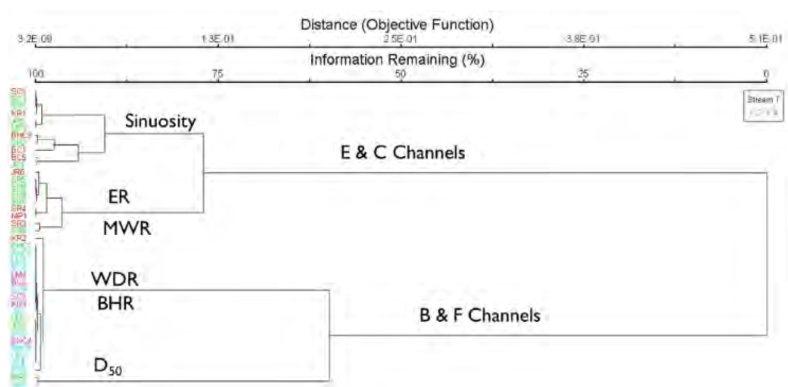

Figure 4. Results of cluster analysis of stream reaches depicting variables having the strongest influence on each grouping according to indicator analysis.

The results of the cluster analysis indicated that four clusters resulted in the strongest groupings (Figure 1). The results of the indicator analysis found the strongest factors influencing the groupings was BHR, ER and MWR (P≤0.05). It is not surprising BHR is significantly linked to state determination, as it provides the basis for the channel evolution models. MWR and ER are measures of confinement, measuring the stream's ability to move laterally within the floodplain and its ability to access the floodplain, respectively. According to Rosgen's classification, ER has the greatest influence on channel morphology. WDR and sinuosity also had a significant influence on the groupings ($P \leq 0.05$). Within a STM change in BHR, ER and MWR indicates that a transition between states is taking place; whereas, changes in WDR and sinuosity are indicative of phase changes occurring within a state. These findings are further supported by the NMS ordination of the stream measurements which produced a one dimensional final solution with a stress of 15.52589, a fair ordination that provides a usable picture (Figure 2). Axis one was positively correlated with measures of confinement (ER, MWR and Sinuosity) with ER exerting the strongest influence. Axis one was negatively driven by WDR, BHR and D50.

Conclusions and Implications

These findings support the current methods used to develop RCESDs and STMs. Rosgen's classification and channel evolution models are valid tools for the development of riparian STMs. Current STMs capture the variability in channel morphology across a site and predict when a stream is at risk of transitioning. RCESDs and STMs are valuable tools to guide management decisions for riparian ecosystems.

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Present Status and Sustainable Management of Grasslands in Indian Himalayas

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Key words: Bugyals, Indian Himalayas, succession, deferred grazing, Silvi-pasture

Introduction

The Indian Himalayan region (IHR) lies between 27^0 to 36^0 N latitude and 74^0 to 97^0 E longitudes and stretches over 2500 km in length between 80 and 300 km wide and rising from low-lying plains to over 8000 m above mean sea level (asl). The IHR has a total geographical area of about 530795 km^2 representing 16.16% of the total area and 3.73% of the total population of India. The Himalaya region can be divided into three sections: a. *Inner or The Great Himalaya* comprising of the northern most ranges with an average height of 6000m, b. *Middle or Lesser Himalaya*, an intricate system of mountains and valleys with an average height between 3500 to 5000m, and these ranges have extensive alpine and temperate grasslands where the easily accessible lands are extremely exploited, and c. *Outer Himalaya* or the *Foothills or* the *Shivaliks* which are entirely made of alluvial deposits**.** The people of the IHR are heavily dependent on agriculture, forestry and livestock for their livelihood. The fodder and fuel collection and agricultural activities except ploughing are performed by women. Deforestation, soil erosion, silting of water bodies, drying-up springs, replacement and disappearance of plant species are the major problems of IHR. Under above scenario, the fetching of fodder from forest and rangelands has become more energy intensive and so increasing drudgery of women folk. The grassland in the IHR occupies nearly 35% of the geographical area and includes the warm temperate grasslands, sub-alpine and cool temperate grassy slopes, alpine meadows of the greater Himalaya and the steppe formations of cold arid regions or alpine dry scrub. These grasslands differ in origin, structure and composition but support a large number of wild herbivores, domestic livestock and several agro-pastoral cultures. *Sedentary, semi migratory* and *migratory* systems of grazing are common in India. At present, the grasslands have degraded even though they are vital for rearing domestic livestock mainly due to the high livestock pressure and unscientific grazing.

The Himalayan grasslands can be classified into Eastern, Central and North-West Himalayan regions. The eastern IHR is comprised on 9 states Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizorum, Nagaland, Sikkim, Tripura and hilly region of West Bengal covering 212000km^2 hilly region. Thick rainforests cover 63% and shifting cultivation 35% of total eastern Himalaya land area. The region suffers from a shortage (>50%) of green fodder that leads to free animal grazing in the forest resulting in heavy degradation. The native fodder trees like *Acer, Aescuwus, Albizzia, Anogeissus, Ailanthus, Bauhinia, Betula, Cedrala, Dalbergia, Erythrino, Ficus, Grewia, Puercus* and *Ulmus* are also the source of green fodder. The forest grasses are nutritionally poor (2.18% crude protein), however the grasses of high altitude are highly nutritious with mean crude protein of 17%. Central IHR is comprised of the Uttarakhand state that covers 5.15 million ha and the 80% hill population is dependent on agriculture and livestock. Forage shortage levels for green, dry fodder and feed are 35, 24 and 60%, respectively. Fodder cultivation is almost negligible in sub alpine and alpine region, therefore free and unscientific grazing is a common practice. The total fodder availability in central Himalaya is only 8.3 million tons against the requirement of 22.4 million tons. This shortage forces local pastoralist to migrate horizontally and vertically throughout the region with their herd. North-west IHR includes Jammu & Kashmir (J&K) and Himachal Pradesh. The total area of J&K is 138124 km^2, of which 4164 km^2 is under pasture/grazing land while Himachal Pradesh‘s total area is 145000 km^2, of which 55600 km^2 is under pasture/grazing land. Above the middle Himalayas, lie the cold arid deserts of Lahul, Spiti and Ladakh. In this region, complex transhumant grazing is a very common means of supplying domestic livestock with enough fodder to survive and to be productive. The pastoralists migrate with herds in the alpine region in summer and return in the winter. Fodder crops are grown in very small scale or not at all in the temperate zone. Forest area, community sub alpine and alpine pastures are the major source of fodder. These pastures are known as 'Marg (s), Bahak (s) or Dhoke in J&K, Thach or Bugyals in HP and Uttarakhand. Hay and green leaves of fodder tress like *Celix, Celtis* and *Robinia* etc. and also crop residue like paddy straw are the major source of fodder in winter season. Cold-Arid Deserts lie above the middle Himalayas in the greater Himalayan system, are covered most of the time (November to April) by snow and are unique biological entities and area like Lahul-Spiti and Laddakh only have 5% of the area under vegetation. The fodder production is meagre even though animal husbandry is a major livelihood means up to 5200m height. *Medicago sativa* and *M. falcata* are extensively grown during summer and hay is prepared for winter season. Also range grasses are used for grazing and for hay.

The Succession trends have also been observed in nature and composition particularly on the steeper south facing slopes in the temperate and sub-alpine regions of the Indian Himalayas. According to Dabadghao and Shankarnarayan (1973), *Themeda anathera* represents the higher seral stage in the *Themeda-Arundinella*type of cover. As grazing pressure increases, the *Themeda* community is replaced by *Arundinella nepalensis* and *A. bengalensis*. On heavily grazed areas, *Cynodon dactylon* replaces all other communities. Towards higher altitudes, the *Poaannua*, *Koeleria-Chrysopogon gryllus* and *Agrostis munroana* communities occupy the frequently grazed sites (Singh and Saxena 1980).The alpine meadows exhibit a complex mosaic of plant succession. The species which occur on frequently grazed sites include *Danthonia cachemyriana*, *Calamogrostis* spp., *Stipa* spp. and *Agrostis munroana*. Under meadow succession, the moss-lichen (pioneer) community in a glaciated valley on the terminal and south-facing lateral moraines give rise to several annual herbaceous formations. The *Cyananthus-Kobresia-Anaphalis* association and *Danthonia cachemyriana* patches form the climatic plant community on such slopes.

Sustainable Management

In general for the total geographical area in the Indian Himalayas, over 10% of the area is under crop production whereas the forest and rangelands comprises 50-70%. These rangelands and forest are not only the backbone of the hill farm economy but also fundamental to rearing animals. The region is also a rich source of herbs and medicines. So far, the natural resources of the region have been exploited haphazardly for centuries. The reckless tree felling, overgrazing, burning/fire and an absence of rehabilitation programs have led to denuded hill slopes and rangelands. Modernization infrastructure and hydro-electric dams have intensified the problems in whole Indian Himalayas. The sustainable development of rangelands in the region may reduce the problems of landslides, soil and water erosion, erosion of biodiversity and very important migration from hills and finally may lead to conservation of forest and rangelands, biodiversity and sustainable livelihood of the region.

The research work on rangeland improvement is in progress at Indian Grassland and Fodder Research Institute, its regional centres at Srinagar (J&K) and Almora (Uttarakhand) and state agricultural universities. Number of research findings have been made and implemented for its sustainable development. However sincere and intensified research findings need to be implemented and further regional research needs to be encouraged for better development of rangelands and forest of the region. Introduction of new high yielding strains/varieties of grasses and crops, soil and water conservation, reseeding and gap filling, fencing, weeding and bush clearing, destocking, balanced fertilization, rotational/deferred grazing, proper cutting/harvesting management, agro-forestry/silvi-pasture system etc. are the methods and practices that may restore our rangelands and forest and improve the livelihood of the region.

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Application of the Rangeland Hydrology and Erosion Model to Ecological Site Descriptions and Management

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Key words: Adaptive management, ecohydrology, infiltration, runoff, soil loss

Introduction

Classification and management of United States (US) rangelands are primarily based on the Ecological Site (ES) concept. ESs are a conceptual partition of the landscape based on climate, landscape position, topography, and the ability of the landscape to produce vegetation and respond to management. Community dynamics for an ES in response to disturbances and management are conceptualized in an Ecological Site Description (ESD) via a state-and-transition model (STM). An STM depicts one or more discrete vegetation-soil stable states (ecological states), transitions between stable states, and associated key ecological processes. The utility of ESDs and STMs in guiding management hinges on their ability to accurately describe and predict community dynamics and the associated consequences. For many rangeland ecosystems, plant community dynamics are directly influenced by key ecohydrologic feedbacks (Williams et al. 2015). For example, vegetation and ground cover facilitate infiltration and soil stability, and soil water recharge and nutrients further enhance vegetation productivity. In contrast, bare ground promotes runoff and erosion that further reduce soil water availability, remove critical soil nutrients, and limit vegetation productivity. Vegetation dynamics for rangeland communities are commonly well understood, but quantitative data associated with stabilizing ecohydrologic feedbacks and thresholds (e.g., bare ground and increased runoff/erosion), are often limited in ESDs and STMs. This paper demonstrates utility of the Rangeland Hydrology and Erosion Model (RHEM) for predicting hydrologic and erosion responses to plant community dynamics and for enhancement of ESDs in guiding management decisions.

Materials and Methods

This study applied the RHEM tool (Version 2.3) to a select ES commonly occurring in the US. The ES is dominated by dense cover of sagebrush-steppe (*Artemisia tridentata* subsp. *vaseyana*) vegetation under reference conditions (Fig. 1A), but may transition to a woodland following encroachment by juniper (*Juniperus occidentalis*) trees. Following juniper encroachment, competition for limited soil water produces a landscape with isolated juniper and shrubs and extensive bare ground (Fig. 1B). Sagebrush-steppe is also subject to invasion by a fire-prone grass, cheatgrass (*Bromus tectorum*). Frequent fire following cheatgrass invasions facilitates a cheatgrass monoculture (Fig. 1C). The magnitude to which community transitions from a sagebrush-steppe to a juniper woodland or a cheatgrass monoculture affects runoff and erosion varies across the diverse domain in which sagebrush-steppe vegetation occurs. We used the RHEM tool, populated with characteristic vegetation cover, soil properties, and topography for the selected ES, to assess hydrologic and erosion responses to potential management practices, including "do nothing" approaches. RHEM is a process based model that estimates hillslope-scale runoff and erosion. The model requires user input of canopy and ground cover, surface soil texture, hillslope topography (shape, length, and slope), and climate as described in Williams et al. (2015). We applied the model across selected plant communities (Fig. 1) using a single climate station, 50 m hillslope length, uniform slope, 35% slope gradient, and loam soil texture. The same model formulation was applied for burned (1% canopy cover; 11% ground cover) and tree cutting treatments (10 yr post-cut; 27% canopy cover; 65% ground cover), but with requisite cover amendments.

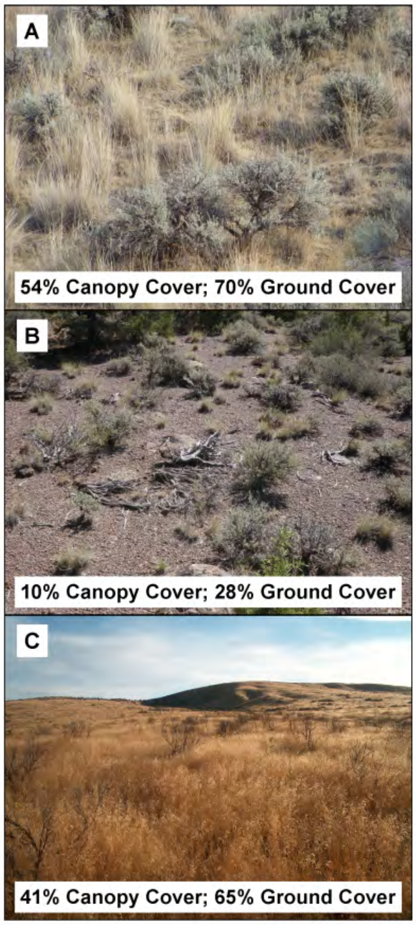

Figure 1. Vegetation structure in sagebrush-steppe (A), juniper woodland (B), e associated cover

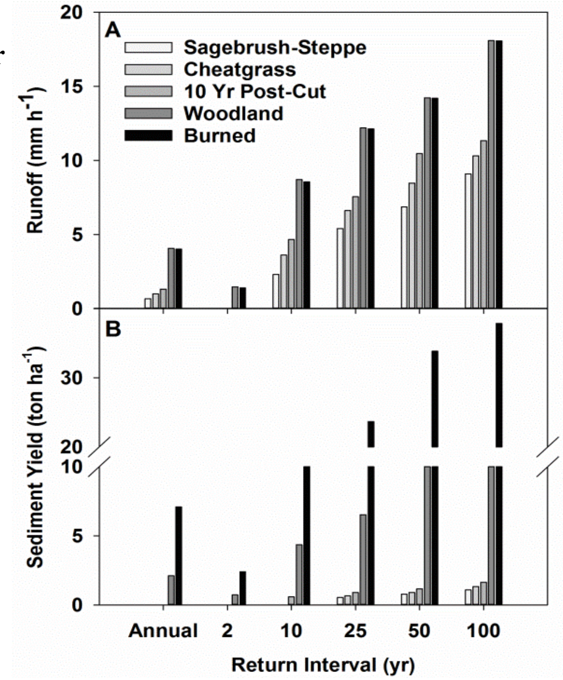

Figure 2. RHEM predicted runoff (A) and erosion (B) by return interval.

Results and Discussion

RHEM predicted runoff and sediment yield reveal the influence of vegetation and ground cover on hydrologic and erosion processes (Fig. 2). RHEM predicted runoff was generally low for 2-25 yr return-interval runoff events on well-vegetated sagebrush-steppe, cheatgrass, and the post-tree-removal sagebrush-steppe communities. In contrast, runoff from bare woodland and burned conditions generated moderate to high levels of runoff and erosion for the 10-100 yr events. Results suggest the woodland community and immediate post-fire conditions are susceptible to high levels of runoff and erosion, even for high likelihood events (i.e., 10 yr event). The high levels of erosion for the burned condition demonstrate the risk of amplified long-term soil loss associated with frequent re-burning (every 5 to 10 yr) of cheatgrass monocultures. Cutting appears to be a viable option to reduce runoff and erosion with favorable vegetation re-establishment. Although burning amplifies runoff and erosion from woodlands, tree removal by burning may reduce long-term soil loss with favorable sagebrush-steppe re-establishment.

Conclusions and Implications

Our results demonstrate application of RHEM in assessing runoff and erosion responses in ESDs. For ES with important ecohydrologic feedbacks, RHEM results can be combined in ESDs with plant community dynamics to quantify associated ecohydrologic ramifications and guide management. The example here is limited, but the approach can easily be expanded for complex management scenarios.

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Ecological Condition and Trend of Mongolian Rangelands

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Key words: Gobi, Mongolian rangeland, rangeland monitoring, Steppe, time series analysis

Introduction

Mongolia is situated in Central Asia with an area comprising 1.566 thousand square kilometers. The country is located between 87º41′ and 119º56′ of east longitude, and 41º35′ and 52º09′ of north latitude (Damiran, 2005). From north to south, the major ecological zones include: 1) Forest steppe in the northern border area of Mongolia, 2) Grass or Pasture steppe (Steppe) that stretches in a nearly contiguous belt across Mongolia, 3) Desert steppe that forms a precipitation and productivity ecotone between grass steppe and desert, and 4) Desert or Gobi which comprises approximately 40% of Mongolia's land area (Sheehy and Damiran, 2012). The objective of this paper was to document changes in ecological condition and trend that occurred over 11-yrs (1997 to 2008) in the four major ecological zones.

Materials and Methods

Condition and Trend monitoring sites (n=100) established in 1997 were re-evaluated in 2008 to determine changes in a number of site attributes. Ecological condition was determined for each monitoring site by comparing change in site vegetation and physical attributes between measurements. Site attributes measured included plant species, especially presence of increasers and invasives, plant presence by growth form, cover of site attributes, and palatability to livestock of plant species at the site (Sheehy and Damiran, 2012; Damiran, 2005). Based on the above parameters, ecological condition at each monitoring site was evaluated as excellent, good, fair, poor, and very poor.

Results and Discussion

Desert

In the Desert zone, ecological condition of winter and summer pastures had deteriorated, or did not improve if heavily grazed by livestock. The Shrub vegetation type on winter range had changed from good ecological to poor ecological condition while the Salt Marsh vegetation type remained in poor ecological condition. The Mountain Steppe vegetation type on transitional range had changed from good to poor ecological condition. Shrub and Desert Steppe vegetation types in transitional range had improved from fair to good ecological condition. On summer range, the Mountain Steppe vegetation type had changed from good to poor ecological condition while the Meadow vegetation type had changed from poor to very poor ecological condition.

Forest Steppe

The overall ecological condition of Forest Steppe Zone pastureland shifted from fair to poor in the 11 year interval between surveys. Winter pasture vegetation types remained in fair ecological condition or improved, while transitional pastures and summer pastures shifted from poor to very poor and fair to poor ecological condition, respectively. The Mountain steppe and Meadow vegetation types on transitional or summer range changed from fair or poor ecological condition to very poor ecological condition during the 11-yr interval between evaluations.

Desert (Dry) Steppe
On Desert Steppe rangeland, little change in rangeland ecological condition has occurred on winter range; however, transitional and summer range had lower ecological condition compared to the condition during the initial survey. All vegetation types on summer range except Larch Forest had lower condition. Mountain steppe and Riparian Meadow vegetation types in transitional range changed from fair to poor ecological condition, and Mountain Meadow and Sandland vegetation types changed from good or fair to poor ecological condition.

Steppe
Ecological condition of both winter and summer seasonal ranges in the (Grass) steppe zone had changed in the 11-yr interval between measurements. Ecological condition of both Mountain steppe and Typical steppe on winter range changed from fair to poor condition, while ecological condition of the two vegetation types in the Grass steppe vegetation type changed from good or fair condition to poor condition.

Conclusion and Implications

Rangeland ecological condition had declined in the interval between measurements and trend in the four zonal study areas was negative. (Table 1). Although weather patterns, vegetation, and topo-edaphic characteristics are different in each zone, the trend in ecological condition was similar. Since all four rangeland study areas indicated a negative trend in ecological condition, it is probable that rangelands across ecozones are degrading if similar change factors are present. We think this change is occurring because of livestock overgrazing and increased aridity during the period between measurements. Implications for Mongolian rangelands if the trend continues are: 1) continued and escalating friction among herders over rangeland use, 2) increased pressure on urban centers as dispossessed herders move out of the system, and 3) and wide-spread ecological degradation of Desert and Grass steppe ecozones.

Table 1. Trend in rangeland condition in four zonal study areas of Mongolia.

Ecozone	Year	Condition			
		Good	Fair	Poor	Very Poor
Desert (n=27)	1997	12	13	2	0
	2008	5	0	21	1
	% Change	-58.3	-100	950	+100
Forest Steppe (n=33)	1997	14	15	4	0
	2008	5	10	12	6
	% Change	-64.2	-33.3	140	+600
Desert Steppe (n=26)	1997	11	10	5	0
	2008	10	0	16	0
	% Change	-9.0	-100	180	0
Grass Steppe (n=13)	1997	3	10	0	0
	2008	0	1	12	0
	% Change	-100	-90.0	1200	0

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Substrate Synusia of Mosses in Rangeland Ecosystems of Uzbekistan

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Keywords: Moss synusia, substrate, epiphytic, epilithic, epighey.

Introduction

Bryophytes have wide ecological plasticity, which allows them to grow in the territories of all latitudes and in a variety of environments (Bardunov L.V. 1984). Many species of bryophytes are found only in certain ectomycorrhizal communities. However, the same species of bryophytes in plant communities may settle in different types of substrates. On the other hand, within the different communities there may be ecotopes similar in temperature, light, moisture, soil fertility and having a similar composition of bryophytes. All of these factors greatly complicate the study of the environmental features of the distribution of bryophytes in rangeland ecosystems (Gaze, 1947). The aim of our research is to analyze the distribution ecology of bryophytes according to their substrate types in rangelands of the Samarkand region in Uzbekistan.

Materials and Methods

Collection of field material was carried out by a combination of widely accepted research methods that included routine surveys, monitoring of permanent and semi-permanent plots, and setting environmental profiles in selected study sites (Mamatkulov&Bardunov, 1991). Each collected sample was marked with the location and description of the habitat in which it was found. This was then used in the ecological grouping of the surveyed bryoflora according to the Bardunov&Vasilev method (2005).

Processing of the field materials collected during 2008-2014 was done on the basis of ecological analysis of the bryoflora. In total, I processed 286 herbarium specimens for this study. All samples were stored in the herbarium of the Samarkand State University (Uzbekistan). A conventional comparative-morphological method was used for determination of systematic positions of the herbarium specimens (Mamatkulov et al., 1998). Analysis of the flora was based on phyto-geographical, comparative-floristical and statistical-floristical methods (Bardunov, 1974). For the taxonomy (genera and families) of Bryophyta I followed U.K Mamatkulov 1998, Bryopsida by M.S Ignatov et al., 2003.

Results and Discussion

Moss synusia of soil cover

In rangeland ecosystems of Samarkand region, there are three types of substrate for settling and spreading of moss species: soil, bark of living trees and stones. These substrates correspond to the following ecological groups of bryophytes: soil (epighey), epiphytic and epilithic. During the study period in rangeland ecosystems, 20 species of bryophytes were registered belonging to 13 genera and 10 families. Out of 10 families identified in the soil cover of the region, the following are considered as relatively species-rich families: *Pottiaceae* (by 4 species), *Trichostomaceae, Mniaceae, Bryaceae* (by 3 species), *Brachytheciaceae, Dicranaceae* (by 2 species), *Polytrichaceae, Funariaceae* (by 1 species). The most multispecies genera are *Tortula* (by 4 species) *Bryum*, *Barbula* (by 3 species), *Distichium, Dicranum* (by 2 species), *Brachythecium, Dicranella* (by1 species).

Epiphytic moss synusia

On the bark of living trees in rangelands I registered 15 species of bryophytes from 8 genera and 6 families. Out of 6 families of epiphytic bryophytes the following had the greatest diversity - *Bryaceae*, *Dicranaceae* (by 3 species), *Brachytheciaceae, Mniaceae* (by 2 species). The most species-rich genera were *Bryum, Brachythecium, Dicranum*. Epiphytes prefer to settle on deciduous trees such as ailanthus (*Ailanthus*), poplar (*Populus*), almond (*Amygdalus*), walnut (*Juglans*). This epiphytic moss forms a mat-like cover (synusia), usually consisting of 3-6 (rarely 10) species of bryophytes. In most cases, they form small groups on the protruding roots at the base of the trunk and rarely rise above 60 cm. This type of "limited" settlement can be explained by the peculiarities of the cortex: where the bark is smooth, characterized by increasing development synusia of moss.

For walnut trees (*Juglans regia* L.), *Orthotrichum speciosum* Hedw., *Neckera pennata* Hedw., *Amblystegium serpens* (Hedw.) Lindb. are particularly characteristic. On trees there are found typical epiksily (*Dicranum elongatum* Schleich et Schwaegr), and a variety of species of ground mosses. For ailanthus, the following moss species are characteristic: *Dicranum fuscescens* Tum., *D. montanum* Brid., *Amblystegium serpens* (Hedw.) Lindb., *Orthotrichum speciosum* Brid., *Plagiothecium latebricola* BSG, Bryol. On poplar I found *Amblystegium serpens* (Hedw.) Lindb., *Brachythecium campestre* (C.Muell.); on apple - *Leskea polycarpa* Hedw; on willow - *Plagiomnium cuspidatum* Hedw., *Amblystegium serpens* (Hedw.) Lindb., *Pylaisiella polyantha* (Hedv.) Grout. From the description of the species composition of epiphytic bryophytes, it is evident that identified species are not strictly confined to particular tree species found among the identified species. Although a certain affinity of a number of mosses to some tree species was noted (*Orthotrichum speciosum* Hedw., *Dicranum montanum* Brid.).

Moss synusia on rocky substrates

Epilithic bryophytes settle on rocky substrates. I recorded 34 species of bryophytes on rocky substrates in rangeland territories from 16 genera and 13 families. The following families have shown the highest species diversity: *Brachytheciaceae* (3 species), *Amblystegiaceae* (2 species), *Bryaceae, Pottiaceae* (2 species). The most multispecies genera are *Bryum* (6 species) and *Brachythecium* (4 species). High occurrence of species from *Pottiaceae* family reflects the specificity of the ecology of its representative species. Soil rich in organic matter creates good conditions for quick growth and development of bryophytes, especially in the conditions of sufficient moisture (Savich, 1970). As I discovered, the soil covered by *Bromus danthoniae* Trin. throughout summer season is completely occupied by *Tortula muralis* Hedw. in the spring of the following year. Based on my research in the rangeland vegetation of Samarkand region I have identified the following moss synusia: moss synusia of rocky-stony substrates; moss synusia of rock cracks; moss synusia of epiphytes; moss synusia of base of the trunks and surface roots of trees and shrubs; moss synusia of soil cover.

Each eco-coenological group is based on floristic and ecological-coenological principles. Each eco-coenological group (synusia) of mosses has its own characteristic species and is confined to certain ecotope. Under similar environmental conditions, similar moss synusia can occur in various associations. Based on the results obtained during the study of moss substrate groups of rangelands in Samarkand region, I conducted a comparative analysis of the considered substrate groups to identify their special features.

The position of the leading families in bryoflora of ground (soil) bryophytes is substantially different from those in other bryoflora substrate groups. Thus, the leading position among the mosses on the soil cover belongs to representatives of the families *Mniaceae, Brachytheciaceae*. In this case, above the substrate (epighey) of ground bryophytes I observed a greater number of hygrophytes compared to mesophytes. In contrast, mesophytic species are better represented in the bryoflora of epiphytes and epilithic. Epilithic bryophytes also include quite a large percentage of xerophytic species.

Conclusion

My results indicate that the species of bryoflora in rangeland vegetation of Samarkand region can be divided into three groups according to substrate in which they are found. The distribution of species of bryophytes on substrates is predominantly epilithic. Characteristics of substrate groups are complicated by the wide ecological valence of bryophytes. Many species select for settlement not only a single substrate, but several. Stenotype mosses in most cases are rare in the bryoflora of this region. However, despite the common species in substrates, the groups are significantly different from each other in term of taxonomical indicators, as well as in relation to the types of water and light factors.

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Development of the Ecological Site Classification in Mongolian Rangelands: Case Study in Forest Steppe Zone

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Key words: Ecological site group

Introduction

Mongolia is a landlocked country between Russia and China, situated in the transition zone between the east Siberian permafrost taiga and the Central Asian arid deserts. There are six different natural ecological zones defined in Mongolia: alpine, mountain taiga, forest steppe, steppe, desert steppe and desert. Within these ecological zones, soil and topographic features are the main factors used in classifying ecological sites (Bestelmeyer & Brown 2010). Ecological sites can be used as a basis for management even when vegetation is severely altered or soil is eroded excessively and the ecological potential of the site is unclear based on current vegetation conditions. The aim of this study was to develop an Ecological Site group classification (http://www.greenmongolia.mn) within an individual ecological zone featuring a similar climate (the Forest-Steppe zone). This zone covers about 15.2% of Mongolia (Fig. 1), is one of the most densely populated areas and experiences high grazing pressure. We used data on selected soil physical properties, vegetation and elevation to develop the Ecological Site classification.

Methods and Materials

The study area is located within the forest steppe zone (Fig. 1) The data used in this study were collected by the Green Gold Mongolia program in 2010 - 2014.

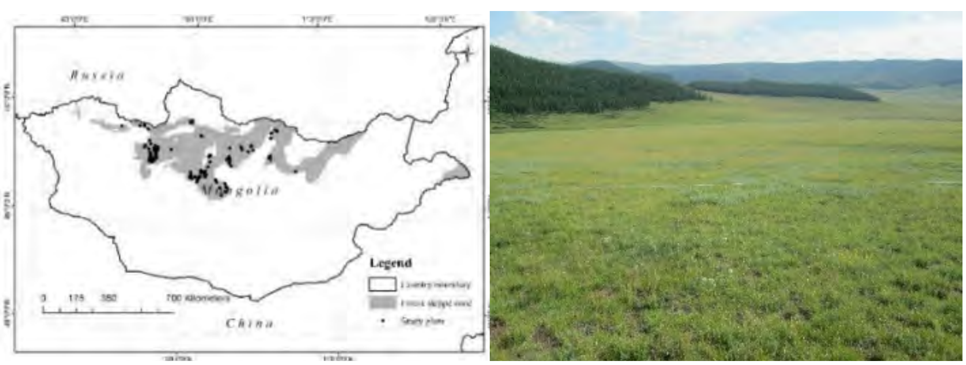

Figure 1. (Left) Map showing location of forest steppe natural ecological zone (shaded gray) and the location of study plots used in this study; (right) landscape overview image.

Ecological site data were collected using the medium intensity sampling method (Moseley et al. 2010). A total of 148 study sites were selected from different landforms using Google Earth maps. The coordinates were selected in Google Earth and located in the field using a handheld GPS with 2–4 m accuracy. Vegetation and soil surface cover were measured using the line-point intercept and gap intercept methods (Herrick et al. 2005). Soil particle size composition was determined according to Schoeneberger (2002) following the United States Department of Agriculture system. Statistical analyses were performed using SAS statistical software. Multiple cluster analyses and average linkage cluster analysis tests were used to investigate if ecological site classes could be quantitatively distinguished according to carefully measured soil and vegetation properties.

Results and Discussion

Cluster analysis of the soil properties and environmental variable data show a clear separation into three groups: gravelly soils (cluster I), loamy soils (cluster II), and sandy soils (cluster III). The loamy site had significantly ($p<0.05$) higher clay content than both the sandy and gravelly sites (Fig. 2). Gravelly sites also contained higher (40.4 ± 0.99) rock fragment content compared to other sites, with sandy sites containing the lowest amount (9.5 ± 0.72) of rock fragment (Fig. 2).

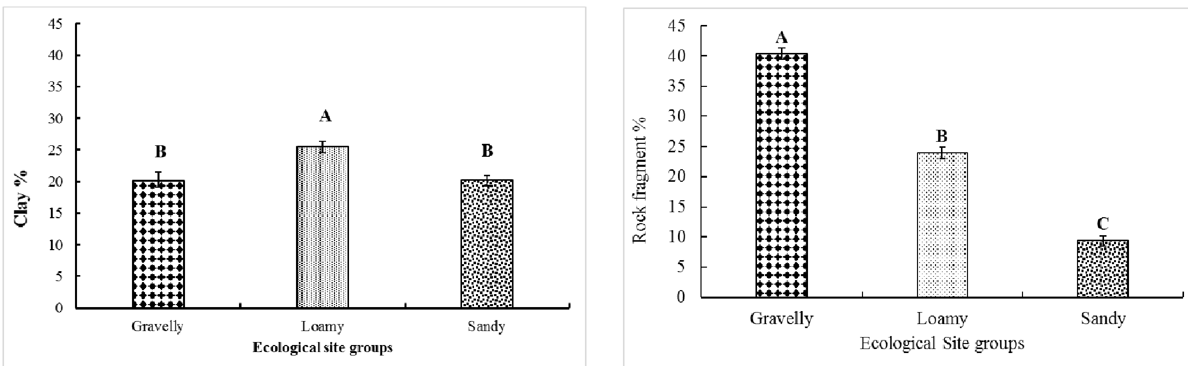

Figure 2. (Left) Clay content of soil (0–20 cm depth), (right) Soil rock fragment content (0–68 cm depth) of the three ecological site classes.
Bars show means and standard errors. Different letters indicate differences in statistical significance at the 95% confidence level ($p<0.05$).

Concordant with differences in soil morphology, vegetation communities in these three ecological site classes differed predictably in species composition and production. Gravelly ecological sites were covered by *Festuca – Forb* or *Small bunchgrass-Forb* communities, while communities in Loamy ecological sites were dominated by *Stipa baicalensis* and *Stipa Krylovii* in Sandy ecological sites (Fig3.).

Figure 3. (Left pair) vegetation community and soil profile image of gravelly site, (middle pair) loamy site and (right pair) sandy site.

Conclusions and Implications

Our statistical analyses support the utility of recognizing three distinct ecological site classes within the Forest Steppe zone in Mongolia. As a result, cluster analysis showed clear separation of the Ecological Site groups, illustrating distinct differences driven by clay and rock fragment content of the soils. Rangeland Ecological Site classification is one of the first steps in sustainable land management when it comes to grazing animals and rangeland vegetation recovery.

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Trace Minerals Profile of Forbs and Grasses at Flowering Stage in Rangelands of North Kordofan, Sudan

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Key words: trace-mineral, flowering stage, forbs, grasses

Introduction

Trace elements are essential parts of many physiological processes such as energy production, enzyme activity, hormone production, collagen formation, vitamin and tissue synthesis, oxygen transport and other physiological processes related to health, growth and reproduction. Their deficiency causes a variety of pathological consequences such as cardiac conditions in addition to immunological and hormonal functions and metabolic defects (Suttle, 2010). Reports on clinical Zn deficiency in cattle under field conditions in Sudan are relatively rare. The concentration of Cu was found to be low in sera and tissues of various Sudanese animals raised under the nomadic system. The effect of dietary supplementation during different physiological states on serum concentrations of Cu and Zn were investigated by Abo Damir et al., (1988).

Voluntary intake and mineral concentrations of base feedstuffs determine the level of mineral consumption. Adequate intake of forages by grazing animals is essential in meeting mineral requirements. The concentration of minerals in plants is dependent upon interactions among many factors including soil type, plant species, stage of maturity, dry matter yield, grazing management and climate (Farhad, 2012).The aim of this study was to investigate the effects of the type of plant on the concentration of some trace minerals during flowering stage of growth at Sheikan Locality, North Kordofan State, Sudan

Methods

Grasses and forbs were sampled at the flowering stage (rainy season) of 2010 and 2011. A total of 27 plant species (20 forbs,7 grasses) in the flowering stage were collected from the rangelands. Plants' shoots (leaves and stems) were picked so as to simulate the diet selected by sheep and ICP was used to determine minerals.

Results and Discussion

Tables 1 and 2 illustrate the concentrations of some trace elements in forbs and grasses at the flowering stage. Levels of trace elements varied among the two plant groups. Younger leaves and leaflets contain higher levels of minerals than older mature leaves, twigs and stem parts. These levels of micro minerals are adequate to meet the NRC (1985) requirements of sheep for Co (0.10-0.20 ppm), Cu (7-11 ppm), Fe (30-50 ppm) and Zn (30-33 ppm).Variations in the contents of Fe among forages could be partly explained by forage species' differences and the level of Fe in the soil. Fe level in this study ranges between 200-2000 mg/kg which agrees with Farhad, (2012) who stated that all the grazing pasture forages had higher levels of Fe than the critical content of Fe in animal tissues (30 - 50 mg/kg DM).Content of Zn (22-60 mg/kg in legumes and 23-67 mg/kg in grasses) in these forages is within recommended level for sheep. However, efficiency of Zn utilization of these forages would depend on zinc bioavailability, and its interaction with other mineral elements. Variations in the concentrations of minerals among forages in this study agreed with Hajer et al., (2014) who attributed variations in the concentrations to genotypic differences, efficiency of mineral uptake and retention and stage of foliage maturity. Younger leaves and leaflets contain higher levels of minerals than mature leaves, twigs and stem parts. In spite of selective grazing the species composition of the pasture is still important e.g. *Dactyloctenium aegyptium* has a marginal Cu concentration.

Table 1. Trace elements content of forbs (mg/kg).

Scientific name	Cu	Fe	Co	Zn	Ni
Colocynthiscitrullus	10.97	270	0.904	50.53	1.145
Seddera spp.	10.11	249	0.223	29.37	1.261
Polygala eriotera	11.46	1041	0.575	27.98	2.089
Crotalaria spp.	11.01	755	0.372	27.85	1.433
Schoenefoldiagracilis	9.58	2522	1.322	30.85	4.031
Requeniaobcordata	10.29	641	0.350	22.64	1.404
Justiciakotschyi	8.10	1080	0.807	40.41	2.155
Sesbaniasesban	10.77	231	0.387	36.26	2.183
Belpharislinarifolia	11.94	1094	0.491	35.54	1.533
Ipomoea sp.	13.63	1776	0.926	38.37	2.881
Tephrosia spp.	10.60	2452	1.251	27.38	3.705
Tribulusterrestris	10.29	1738	0.999	26.77	3.191
Corchorusoiltorius	11.48	1801	1.160	34.35	3.032
Indigoferaaspera	8.92	534	0.312	22.55	1.001
Acanthus spp.	10.23	2616	1.301	34.59	3.708
Indigofera spp.	8.21	466	0.536	25.14	1.102
Solanum dobium	18.41	1114	0.612	60.22	2.112
Dicomatomentosa	11.12	278	0.265	38.95	1.381
Farsetialongisclizua	6.70	412	0.426	23.82	0.961
Ipomoea belpharosepala	13.53	1937	1.155	37.04	3.437

Table 2. Trace elements content of grasses (mg/kg).

Scientific name	Cu	Fe	Co	Zn	Ni
Echinocloacolonum	12.70	1562	0.985	44.71	2.812
Eragrostistremula	10.24	1030	0.529	67.08	2.418
Cenchrusbiflorus	7.79	1318	0.664	32.89	2.726
Chloris virgate	8.85	579	0.682	42.26	1.816
Dactyloctenium aegyptium	6.65	2684	1.274	32.25	4.582
Cyprus spp.	10.00	4813	2.272	23.26	6.568
Aristidamutablis	9.55	1124	0.579	33.93	2.035

Conclusion

Trace mineral concentrations appear adequate for sheep. However, data of this type provide only an indication of the existence of potential mineral deficiency problems, since animal selectivity usually results in the consumption of material of somewhat higher quality than that of the total available, and conclusive diagnosis of deficiencies must be based on a positive response to supplementary supply of the mineral in question. Also levels of trace mineral in sheep's blood may be better indicator of nutrient deficiencies in the diet. Nonetheless, such data are vital in the formulation of critical supplementation experiments.

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National Resources Inventory (NRI) On-Site Grazing Land Study of Rangeland and Pasture Resources

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Key words: rangeland, resource, assessment, inventory, monitor

Introduction

Large natural resource data collection efforts are dealing with biophysical processes where there can be long time lags in cause and effect observations. It is impossible to engage in adaptive management at a National level without both spatial and temporal data collection.

The National Resources Inventory (NRI), a statistical survey conducted by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), provides nationally consistent information on the status, condition, and trends of land, soil, water, and related resources on the Nation's non-Federal lands since 1982 (USDA, 2015). Since 2003 the USDA-NRCS collects NRI on-site data on non-Federal rangelands to inventory the conditions and trends on a subset of its monitoring sites. Expansion of NRI on-site data collection to portions of Federal rangeland in the West beginning in 2011 and to non-Federal pastureland in the 48 contiguous states beginning in 2013 builds a database that will provide a more complete picture of the Nation's grazing lands.

This paper summarizes results based on data collected at over 18,000 NRI non-Federal rangeland field locations between 2004 and 2011 (USDA, 2014) and describes additional uses of NRI grazing land data. Future reports will include data from the expanded survey.

Materials and Methods

Detailed on-site data are collected by Federal employees and private contractors along two intersecting 150-foot transects and on the 0.4 ac/0.164 ha circular macro plot formed by those transects (USDA, 2016b). Quality assurance measures including annual training, performance and calibration exercises are conducted prior to data collection. Software with survey-based rules (e.g., choice lists and error checks) is installed on hand-held computers used to record field data. USDA PLANTS (2013) database is used for species codes embedded in software choice lists. Interpretation of qualitative and quantitative results are projected on to geospatial map polygons and presented as tables of conditions within political state boundaries.

Results and Discussion

The NRI Rangeland Resource Assessment was released in June 2014 (USDA, 2014). Results address current (baseline) conditions. Among the key findings, this report shows over 80% of the Nation's 409 million acres of non-Federal rangeland is in a relatively healthy condition and has no significant soil, hydrologic or biotic integrity problems based on rangeland health attributes. Non-native species are present on over half (53.8% ±1.0%) of the non-Federal rangeland. Invasive annual bromes are present on 30.1 (±1.0) percent of rangelands and cover at least 50 percent of the soil surface on 3.0 (±0.3) percent of these lands. Invasive bromes make up at least 50 percent of the relative plant canopy cover on 1.7 (±0.2) percent of these lands. While mesquite species are present on 15.2 (±0.8) percent of the nation's non-Federal rangeland, they are present on only 4.5 (±0.4) percent in areas where they have not been part of reference conditions. Estimates for other quantitative data are reported for bare ground, inter-canopy gap size, and soil aggregate stability data.

NRI rangeland on-site data are used in development of Ecological Site Descriptions (ESD) (USDA, 2016a). Relevant data include: *Classification Information* (MLRA, ESD name, Soil Component); *Physiographic Features* (Slope, Aspect, Elevation, Slope Shape); *Representative Soil Features* (Soil Stability Indicator, Basal Cover); *Plant Communities and Ecological Dynamics of Site* (Similarity Index, Apparent Trend, Productivity by species, Sum of Total Current Years Growth, Foliar Cover by spp., Litter %, Basal Cover, Vegetation Canopy Gaps, Basal Gaps, Plant Height by Species, Plant Census) *Management Information Related to Ecological Dynamics of Site*, *Disturbances,* past and present, and *Resource Concerns*) (USDA 2016).

A review of pilot pastureland data found that the most frequent resource concerns are related to plant productivity, palatability, invasive plant species, inadequate water, and soil compaction. Sage-grouse habitat metrics are being prepared for non-Federal and Federal rangelands.

Conclusions and Implications

Seventy-nine percent of the conterminous 48 states is non-Federally owned. The NRI program include confidentiality agreements to protect the integrity and confidentiality of the data gathering sites in appreciation of private property rights.

Beginning in 2012, rangeland on-site data are collected on sites visited in previous surveys. This will allow future reports to include estimates for change in rangeland resource conditions.

The data collected are used in State and Transition Models within ESDs, Rangeland Health assessments, Pasture Condition assessments. The US Geological Survey Bureau of Land Management collaborates with NRCS in collecting NRI grazing land on-site data using a common sampling design, the same protocols and the same trained data collectors for a more consistent vegetation measurement protocol across non-Federal and Federal lands. The data are used in wildlife habitat assessment; and wind and hydrology models. NRI grazing land on-site data provide a rich source of information for a wide range of uses.

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Seriphium plumosum L Encroachment Is Influenced by Landscape Factors and Variations in Grassland Community

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Key words: herbaceous layer, shrub invasion, *Seriphium plumosum* density, transect

Introduction

Shrubby plant encroachment is an increase in density, cover and biomass resulting in lower yield of herbaceous layer (van Auken, 2009), which provides a substantial proportion of forage required for livestock production. This phenomenon poses a major challenge to the land users, in particular emerging and commercial livestock farmers. The effect of woody plant encroachment on ecosystem processes is limited in extent and confined largely to pastoral land users or certain geographic regions (Eldridge et al., 2011). Consequently, there is little consensus on the effect of woody plant encroachment on nutrient cycling, particularly soil organic carbon (SOC) and total nitrogen (TN) pools.

We explored variation in *Seriphuim plumosum* density and cover from two South African grasslands communities in relation to landscape factors such as; topographic position (top, mid and bottom), soil texture (sand, silt and clay) and fertility (Org C, P, K, pH and TN). We predicted that 1) *S. plumosum* density will vary between grassland communities and among topographic positions, soil texture and fertility, and 2) *Seriphium plumosum* encroachment will be positively correlated with soil fertility (Organic C, and TN).

Material and Methods

The study was conducted in Carletonville Dolomite grassland (Gh 15) and Rand Highveld grassland (Gm 11) veldtypes, respectively (Mucina and Rutherford, 2006). *Seriphium plumosum* density and cover was determined using a 50 m^2 (25 x 2 m) belt transects at each of the 3 topographic position. *Seriphium plumosum* cover was determined by measuring the long (a) and short (b) axis of plant canopies (expressed by applying an ellipse function in order to obtain canopy area of each plant rooted within the belt transect). Soil samples were taken from five (5) random collections in each experimental plots, pooled together per transect and analyzed for texture and fertility at Agricultural Research Council – Institute for Soil, Climate and Water (ARC-ISCW), South Africa. Data was analysed as a complete randomised design with a 2 × 3 factorial analysis of variance (ANOVA) using the GLM procedures (SAS, 2009). The model included the fixed effects of grassland community, topographic position and their interaction as main effects. Comparisons were assessed by a Tukey HSD test and the differences were declared significant at $P < 0.05$.

Results and discussion

The results revealed that *S. plumosum* encroachment was influenced by grassland community x topographic position ($P < 0.0016$), grassland community ($P < 0.0016$) and topographic position ($P < 0.0236$). The bottom topographic position resulted in higher *S. plumosum* density than top and mid position in Rand Highveld grassland (Gm 11) veld type. However, there were no differences in density observed in Carletonville Dolomite grassland (Gh 15) veld type (Fig. 1).

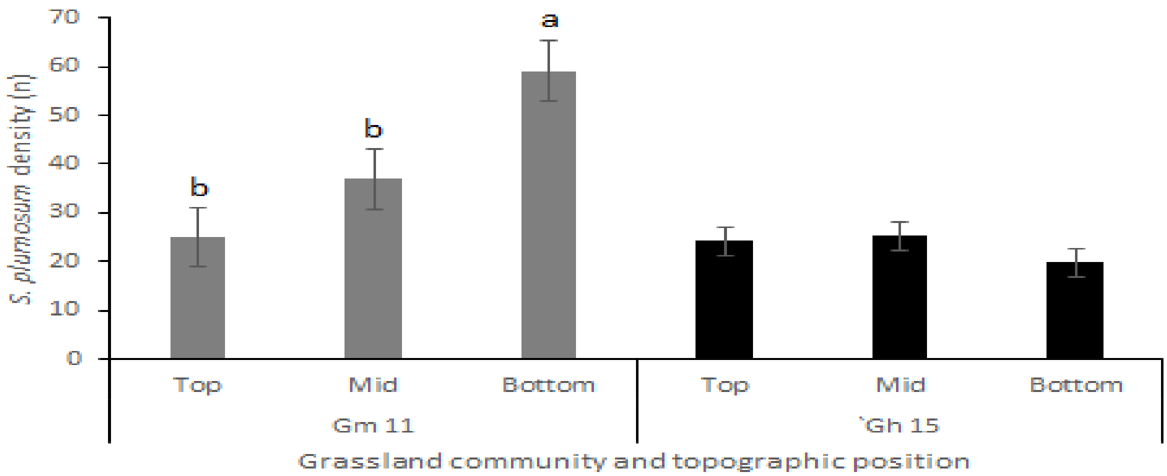

Figure 1. The effect of topographic position and grassland community (Carletonville Dolomite grassland = Gh 15 and Rand Highveld grassland = Gm 11) on *S. plumosum* density. Bars represent standard error. Same letters on the density values within each grassland community represent that P > 0.05.

Correlation analysis revealed a negative relationship between *S. plumosum* encroachment and Organic C (r = -0.27210; P = 0.0208), P (r = -0.28521; P 0.0152) and K (r = -0.29116; P = 0.0131). The results obtained in this study are supported by Snyman (2012), that grasslands are vulnerable to *S. plumosum* encroachment, following changes in environmental conditions.

Conclusions and Management Implications

The landscape factors such as topographic position, soil texture and fertility explain much of the variation observed in *S. plumosum* encroachment in South African grassland communities. The results found in this study are vital for the development of control measures of encroaching *S. plumosum* species and predicting its potential spread in grassland communities.

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1.2 HISTORICAL DEVELOPMENT OF RANGELANDS

Can Rangeland Livestock Systems Compete in a Global Market? Evidence from the Past and Present

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Key words: *Agri benchmark*, comparative performance, production, economics.

Introduction

Rangelands provide a broad array of goods and services for human existence and use (Havstad et al., 2007). In an agricultural production context, rangelands are predominantly used for the production of animal proteins, such as beef and sheep meat (Havstad et al., 2007). Rangelands based beef and sheep production systems are typified by low input/low stocking rate production systems that utilize native or naturalized grasslands under low and variable precipitation. With competition for rangeland use being increasingly driven by a range of factors (use and non-use factors), the comparative ability of rangelands to economically produce meat protein within a global market will partly determine future land use, the mix of goods and services supplied and their economic value. The focus of this study is to use global historical production and economic performance data to look at the competitiveness of producing meat protein from rangelands, when compared against grasslands and more intensive feeding based systems.

Materials and Methods

For the purpose of this study, the *agri benchmark* networks' 2014 data and models are used for the analysis. The *agri benchmark* network is a global, non-profit and non-political network of agricultural economists, advisors, producers and specialists in key sectors of agricultural value chains that have produced comparative results of farming systems over the last 13 years. The cattle and sheep network has 30 member countries (all in beef finishing, 25 in cow-calf, and 15 in sheep), covering over 90% of world beef production and 55% of world sheepmeat production.

The *agri benchmark* network uses an internationally standardised method to analyse farms, production systems, efficiency and profitability while concurrently bringing together on-farm knowledge, with analysis of international commodity markets and value chains (Deblitz, 2010). Each member provides a standardised set of physical and financial data collected directly from a range of farms typical for their country based upon a defined standard operating procedure (Deblitz and Zimmer, 2005). The strengths of this approach over normal farm survey data is that it provides realistic representations of existing farming systems, not averages of aggregated data, which supports existing farms and producers to better relate to the data of a typical farm (Kostrowicki, 1977; Nuthall, 2011); it records production system processes; and avoids the sampling bias issues associated with surveys (Kostrowicki, 1977; Nuthall, 2011). Data derived from the network is used to examine key performance indicators from a sample of rangelands based beef weaner and sheep meat production systems in comparison to a global population of 62 cow/calf and 35 sheep farms, to determine the historical and current competitiveness of rangeland systems, as well as inform future prospects.

Results and Discussions

In comparison to cow/calf beef production systems that utilise more intensive pasture based or pasture + supplementary feeding based systems (which usually coincide with relatively higher stocking rates), rangelands based systems tend to have lower costs of producing weaner beef (Fig. 1). Similarly, the Australian, Brazilian and Namibian systems also have comparatively lower total returns (in US$ terms). The exception is the US based rangelands system (US-600 in Montana), which had comparatively higher prices for weaners (a year with exceptionally high weaner prices), achieved higher weaning rates and weights, and higher production per cow in the year 2014. This leads to a diverse distribution of medium term profitability although land use intensity is similar across the sample of rangeland systems analysed.

Rangeland sheep meat production systems also tended to have lower costs of producing meat protein (Fig. 2). Land productivity is found to be comparatively lower as would be expected, similarly total live weight produced and weaning rates tend also to be at the lower end of the global results. Key economic indicators such as total returns, economic labour productivity and overall profitability are mixed and range across the whole spectrum of global comparative data.

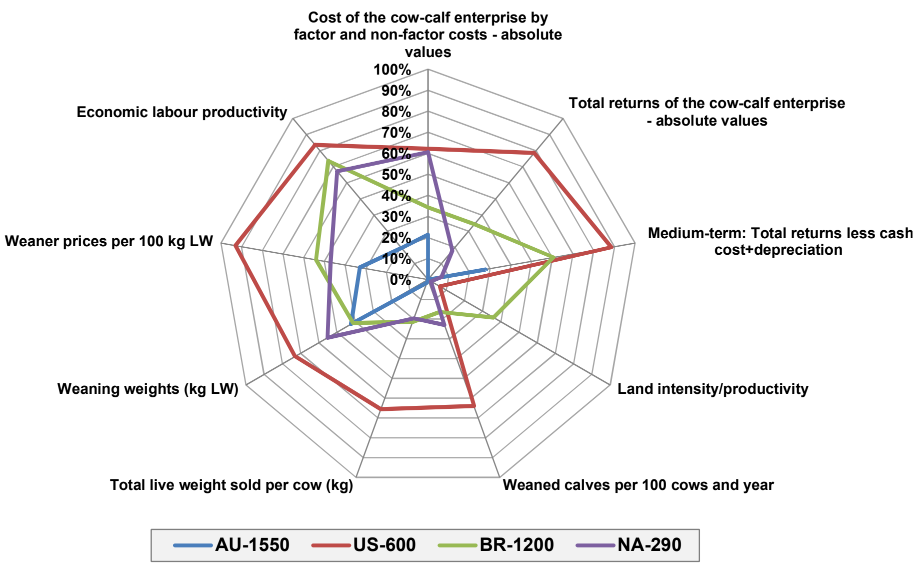

Figure 1. 2014 percentile rankings of key performance indicators for four typical rangelands beef cow/calf production systems (AU-1550, Northern Territory, Australia; US-600, Montana, USA; BR-1200, Mato Grosso, Brazil; NA-290, Gobabis, Namibia) against a global population of 62 cow/calf farms. The number in the farm code represents the number of cows being operated on a typical farm.

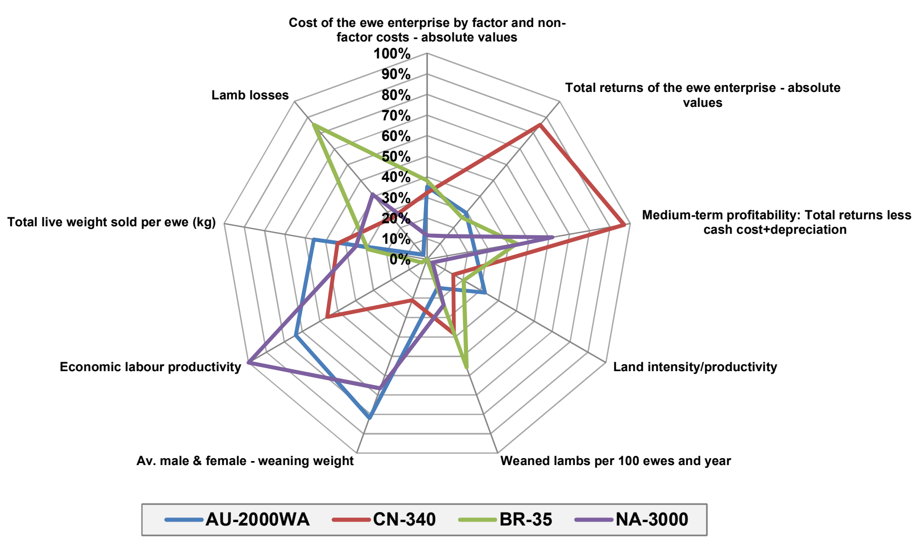

Figure 2. 2014 percentile rankings of key performance indicators for four typical rangelands sheep meat production systems (AU-2000WA, Western Australia; CN-340, Inner Mongolia, China; BR-35, North East Brazil; NA-3000, Hardap region, Namibia) against a global population of 35 sheep farms. The number in the farm code represents the number of ewes being run on a typical farm.

Conclusions and Implications

In general, rangelands based beef weaner and sheep meat production systems have the capacity to produce low cost meat protein and compete in a global market, however, the profitability of doing so is influenced by the prices and returns that can be achieved, as well as the cost of inputs (such as labour) and the system's capacity to achieve high enough resource use efficiency. The immediate constraints to achieving higher economic outcomes for many rangelands based systems are their limited capacity to achieve higher reproductive and growth rates and finish young animals, and subsequent total meat production. In the future, the comparative performance of rangelands based systems in providing meat protein will also be influenced by their capacity for achieving adequate animal welfare outcomes, dealing with climate change and variability challenges, their capacity in sourcing quality labour, and the economics of adopting innovative technology.

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Canadian Rangeland Development

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Key Words: rangeland, Canadian, agriculture, policy, land management.

Introduction

Special Areas, Alberta, Canada, a rural municipality in southeastern Alberta, is an interesting case study of how Canadian rangelands have been influenced by a variety of factors including market and supply chains, technology, socio-demographic, and public policy.

These lands had been inhabited for centuries by nomadic Indian bands following the bison as they found good grazing. The explorer, John Palliser, spent three years (1857 – 1860) on behalf of the Canadian Government, inspecting lands in what was then called the Northwest Territories. His report warned much of the land he had travelled would never support human life. He saw a barren prairie in the drought portion of the weather cycle that continues to mold and challenge inhabitants today.

Discussion

Canadian agriculture is an area of joint federal, provincial, and territorial jurisdiction. Canada is the fifth largest exporter of agriculture and food products in the world. Special Areas producers contribute a variety of commodities to that export market. Technological advances to meet the demands of climate and market demands have long been the source of prosperity in Canadian agriculture.

The last decade has brought significant challenges for the Canadian and Alberta cattle sectors. Drought in 2002 forced many to sell to bring down cattle numbers because the pasture grass to support them was not there. In May 2003 the industry was rocked by the discovery of bovine spongiform encephalopathy (BSE) which closed the border to exports. Through the last half of 2007, the rising Canadian dollar and high feed costs created significant additional financial hardship for cattle producers. This was followed by the global economic crisis of 2008 that further eroded sale prices for cow/calf producers. In addition, in late 2008 the United States implemented Country of Origin Labeling (COOL) causing a significant negative impact on Canadian beef export prices. It is only very recently that cattle prices and climate have begun to favour the cattle industry again.

In today's climate agriculture's growth in productivity will be critical but innovation will become king. This innovation will be supported by policy, research and technology. Good policy support from the three shared jurisdictions and industry association will also be needed to support research and technology needs by the agriculture sector.

The people of the Special Areas are descendants of colonists who settled in the area in the early twentieth century, coming from other provinces in eastern Canada, Europe and the USA. Organized into communities, they built their farms based on a mix of livestock and rain fed cultivated agriculture.

By the early 1920s it was becoming apparent the farming systems being used were not sustainable. The land was very susceptible to wind erosion. The extreme fluctuations in rainfall had a serious effect on amounts of agriculture production. Families were leaving and the social fabric of the area was unraveling. After an economic depression and drought in the 1930s decimated the area, the Alberta Government established a special governing body to provide municipal services.

It was federal government policy in late 1800s that encouraged the cultivation of the native grasslands. However, it is now Special Areas policy that encourages the retention of rangelands.

Land use management in Special Areas is influenced by a mosaic of federal, provincial and municipal division of power and responsibility in the areas of agriculture and environment. In the future it will likely be increasingly influenced by different stakeholders asking for more transparency and accountability for the environmental and animal care performance of its management practices.

Conclusion

The viability of these working landscapes is in question. Decreasing agricultural income raising questions regarding the ranch viability for the next generation. Increasingly volatile weather challenges the raising of traditional crops. Demands for accountability stretch human resources.

Although there are numerous and significant economic and social challenges in this region there is also a strong sense of community and a spirit of cooperation. The majority of the residents do see the area as special, with a natural beauty in the native grass lands and its wildlife.

Linking Seed Banks of Tame, Native and Invaded Parkland Pastures to Historical and Contemporary Management Practices

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Key words: Community dynamics, disturbance history, legumes, rangeland health, seed bank

Introduction

Healthy seed banks (SBs) are valuable for maintaining grassland productivity, range health, and biodiversity, serving as a reservoir of desirable species (i.e. forage grasses, legumes). Seed banks are shaped by disturbance, and in grasslands this occurs primarily through grazing. Grazing influences SBs via the timing and intensity of defoliation (Kinucan and Smeins, 1992), where biomass removal reduces seed production (Sanderson et al., 2007). Richness and diversity of plant communities and SBs benefit from low to moderate grazing, while cultivation, manure application, continuous grazing, etc., result in disproportionately more annuals (Kinucan and Smeins, 1992; Sanderson et al., 2007). Disclimax fescue grasslands in western Canada were historically maintained by fire and grazing but there is limited research on their SBs (Johnston et al., 1969; Willms and Quinton, 1995; White et al., 2012), particularly in relation to how they are shaped by contemporary and historical disturbance. Our objectives are to: 1) Evaluate the relative importance of biophysical and management (i.e. disturbance) factors in regulating pasture vegetation and corresponding SB composition and diversity, 2) Quantify similarity between above- and belowground communities, and 3) Identify the suite of disturbances and environmental indicators that promote a healthy SB (i.e. forages) and deter weedy SBs.

Materials and Methods

We sampled 102 sites in late May through June of 2012 and 2013 in counties surrounding Edmonton, Alberta, Canada. Landowners were surveyed using in-person interviews to identify land use practices on the property. Survey data were intended to identify disturbances that may influence the current seed bank including: grazing history, whether the land was seeded, last cultivation date, fertility regime (chemical or manure), previous herbicide treatment, and if the land had been otherwise disturbed (i.e. subject to burning, pests, oil and gas developments, etc.). Range health assessments (RHA) were also completed. At each site 53 cores were extracted to characterize the SB, with other cores used to assess soil properties. SBs were identified in a greenhouse. Data analysis was done using multivariate techniques in R software with the packages *vegan* and *indicspecies* to perform perMANOVA, non-metric multidimensional scaling (NMDS), CCA, and ISA on community data.

Results and Discussion

Across all pastures 165 species emerged from the SB, 159 species from the aboveground plant community, and 100 species were found jointly with a mean similarity of 34%. High dissimilarity was accounted for by abundant ruderal native and introduced species in the SB, while perennial forages dominated aboveground (not shown).

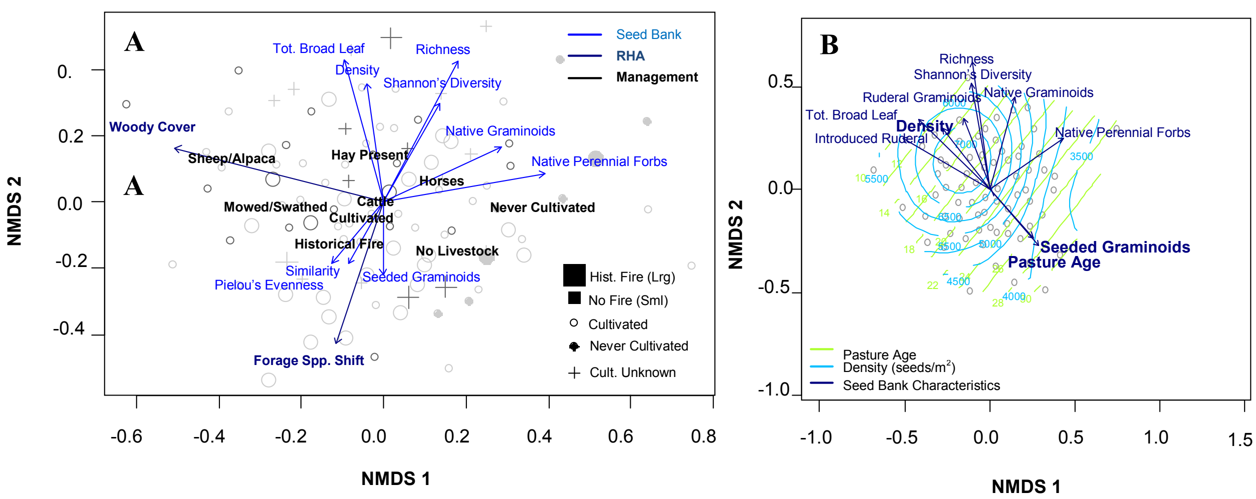

Figure 1. NMDS of SB composition. A) Composition in relation to management factors and rangeland health (P < 0.05). Vectors for RHA Scores (Woody Cover and Forage Spp. Shift) indicate plant communities that scored well in the categories. B) Composition shifts with pasture age (n=71 pastures with known cultivation dates).

Using perMANOVA, historical disturbances like fire (P = 0.001) and cultivation (P = 0.017) affected SBs, while contemporary management like timing of grazing and system (P = 0.006), feeding hay in pastures (P = 0.021), and herbicide treatment (P = 0.018) significantly affected SBs. RHAs detected shifts in SB composition in association with changes in forage cover and woody cover scores (P < 0.05). SB responses to management (i.e. disturbance) and RHAs are shown in Fig. 1A. Shifts in SB composition were evident with pasture age, where ruderals were abundant in young pastures and contributed to greater seed density, species richness and diversity; in contrast, forage grass density in the SB increased with pasture age (Fig. 1B).

Overall, these results indicate Parkland SBs are altered by management regimes, and RHAs can detect shifts in composition. Some studies suggest SBs are an ecological legacy explained by disturbance history. Our results provide evidence for this in northern temperate grasslands, with cultivation and fire being two historical events that alter plant communities and their corresponding SBs.

Conclusions and Implications

These results indicate SBs may be highly divergent in composition from above-ground vegetation, in part because of legacy effects of historical disturbance regimes, particularly fire and cultivation. It remains unknown how this may alter long-term vegetation dynamics over time.

Acknowledgements

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Constraints to Forage Production and Rangeland Management in Afghanistan

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Key words: Agropastoral, forage, post conflict, rangeland degradation

Introduction

Afghanistan covers an area of 65.3 million ha of steep and mountainous land which is not very conducive to farming. The availability of land and water resources for agricultural production is limited and marginal at best. Crop production is mostly confined to pockets of irrigated land, with some rain-fed areas in the north of the country and at higher elevations. Yet, agriculture is the main livelihood that provides resilience to poor farmers and is a major contributor to the war-torn Afghan economy. Livestock is the most important farming component and about 8 million farmers depend entirely on a crop-livestock system for their livelihoods. The prevalent livestock production systems are: sedentary villagers; settled transhumance; and nomadic pastoral. Insufficient feed production and availability is the key constraint for the livestock sector. The lack of forage of sufficient quality limits productivity, and the effect worsens during drought. While meager, rangelands and cultivated forages are the two major feed sources for livestock. Overgrazing, land tenure issues, conversion of rangelands into rain-fed cropping systems, and climate change, including drought, have caused widespread rangeland degradation (Pittroff, 2011). Improving the supply of quality fodder could contribute to reducing household food insecurity and poverty in Afghanistan. Although substantial investments have been made in the development of agriculture in Afghanistan (Pittroff, 2011), forage development has drawn limited attention by donors and implementing agencies (Motamed, 2008). This paper outlines the major constraints to forage production and rangeland improvement in Afghanistan.

Status and Vegetation Cover of Rangelands

Rangelands cover 45% of country's geographical and 79% of the agricultural area of Afghanistan. They are quite diverse, and are associated with a topography that exerts a tremendous influence on rainfall pattern, climate and natural productivity. The vegetation types of the rangelands vary from desert to subalpine and alpine, from *Pistacia* and *Juniperus* woodlands to deciduous forest to temperate coniferous forest to riverine forests and steppe to shrub lands (Schloeder and Jacobs, 2010).

Rangelands Management and Improvement

Rangelands play an essential role in the agricultural economy, not only for agro-pastoralists, but also for a large component of the settled population. Rangeland grazing is vital for maintaining livestock in rural communities, especially in times of widespread feed shortages. Short-season perennial grasses have the potential to bridge these periods by providing a reasonable amount of feed, but only for a limited period during spring and early summer (Thieme, 2006). However, the ever increasing demand for both forage and fuel wood has reduced the productive capacity of rangelands due to over-exploitation. Land tenure has contributed to the decline in rangeland productivity. Pastures are owned by the state but are used by communities that graze their herds on these mainly semi-arid lands. This grazing is normally free of charge but in some cases pastoralists pay grazing fees to those who claim traditional ownership. Such informal arrangements quite often lead to disputes (Schloeder and Jacobs, 2010), and often lead to poor management of these lands. Currently, Afghanistan has no policies for the sustainable use of rangelands as the traditional systems of governing have disintegrated due to the long conflict in the country.

Cultivated Forage Production under Limited Resources

Afghanistan has a comparatively small arable area of 7.8 million ha, out of which about 50% is under cultivation. The amount of land either under cultivation in pasture has been dwindling over the last three decades, a result of: abandonment due to damage to the irrigation infrastructure, or lack of water availability; urban development; soil degradation due to erosion; salinization: and/or poor fertility. The area under fodder crops comprises less than 10% of the cultivated area (Thieme, 2006), and the majority of this production is for on-farm use. Commercial fodder production occurs in areas around cities for both on-farm use and for marketing to the urban population that keep livestock. A number of constraints limit the production of high quality forage, namely: competition with food crops; lack of quality seeds; low adoption of improved technologies; poor rangeland management; lack of research based knowledge on forage production and management; poor soil fertility; inadequate irrigation practices; low rainfall; frequent droughts; poor control options for insect, diseases and weeds; and no access to rural finance, all contributing to the forage deficit in the country (Oushy, 2011).

Conclusions and Implications

A rangeland policy needs to be developed at the national level, focusing on conserving rangelands and meeting the needs of the community. Expanding the area of fodder crops is unlikely, as forages directly compete with field crops for land and water resources. Thus the primary option available is expanding production through techniques such as intercropping, alley cropping and under-seeding cultivated crops such as wheat. This could be possible with the right kind of forage crop, a high yielding and high quality adapted variety, and the appropriate agronomic management practice. It must be noted that improving the forage and feed situation is not just about new technologies, but requires knowledge management (including indigenous), an understanding of the behavior of local communities, and the ability to communicate and facilitate gender inequalities.

Acknowledgement

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1.3 CONSERVATION OF WILDLIFE AND NATURAL AREAS

The Environmental Impacts of Harvesting Caterpillar-Fungus on the Tibet-Qinghai Alpine Meadows

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Key words: *Cordyceps sinensis,* Traditional Chinese Medicine, medicinal panacea, landscape degradation

Introduction

Tibet-Qinghai Plateau has the largest area of alpine meadow in China; the average altitude is 4,000 masl and it is widely distributed from longitude 82 to 103°E and from latitude 27 to 39°N (Fig. 1). Alpine meadow covers an area of about 700 000 km^2, accounting for nearly 50% of the total usable grassland area on the plateau (Wang and Fu 2004). Historically, this unique, high altitude, natural landscape has supported only Tibetan pastoralists; however, in recent years it has become most famous for the production of *Cordyceps sinensis*, also known as caterpillar fungus. *Cordyceps sinensis* is a fungus parasitizing the larvae of a moth of the genus Thitarodes (Hepialus), which lives in alpine grasslands of the Tibetan Plateau. Collection and trade of the caterpillar fungus is one of the most important sources of income for pastoral Tibetan communities. Tibetans know the fungus as *Yazagombou*, "summer grass-winter worm", and often derive over 86% of their annual cash income from its collection in spring and summer. Written records in Tibet date back at least 500 years, but the market is driven by Chinese consumers, who know it as chongcao (dongchong xiacao), a highly valued tonic in Traditional Chinese Medicine. China harvests 98% of the world's production of caterpillar fungus. Caterpillar fungus can be produced from ~2,800 to 4,500 masl where the annual precipitation varies from 350 to 850 mm while the average annual temperature is 4 ℃ (-20~+24 ℃). The temperature regime is classified as frigid while the moisture regime is Aridic or Torric; these produce Aridisols with a Mollic epipedon.

There are three ecological divisions of *Cordyceps sinensis* based on the province of their origin (Lin et al. 2002):

- *Xi Zang (Tibet).* This is considered the king of the Cordyceps.
- *Qing Hai (Qinghai).* This is considered to be the most aromatic of the three.
- *Si Chuan* (Sichuan). This has a smaller dark, brownish body with what is described as having an " ordinary" aroma.

The above three are distinguished by size, aroma, and color, which are the key criteria for defining their quality.

Many studies have demonstrated that oral administration of caterpillar-fungus alleviates fasting hyperglycaemia and more recently that its' extract has an immuno-regulatory function (Tsai, *pers. comm.*). Many people believe caterpillar-fungus is a panacea or cure all, which has increased its demand.

The Tibet-Qinghai alpine meadows are the main source of water for Asia and are the backbone of the plateau's economy. South-East Asia, where 48% of the world's population lives, is downstream of the caterpillar-fungus production pastures.

Traditionally the primary economic driver on the plateau is animal husbandry, which is mainly dependent on the alpine meadows; however, as a result of disturbances caused by over grazing and caterpillar-fungus harvesting, combined with global warming, the efficiency of animal husbandry is rapidly decreasing.

Since the 1990's caterpillar-fungus has become the primary source of income for local people. During the harvesting season, all local residents and many people from other provinces go to the alpine meadows to harvest the fungus. School is even closed for two months to allow the students to help with the harvesting. Income from caterpillar-fungus is more than 10 times that of livestock production, but it is a double-edged sword because it degrades the landscape.

Market analysis

At the local market, a piece of dry caterpillar-fungus is worth up to 30 yuan (US$3.75) and the price is still increasing (Lopsong Tashi, pers. commun.). A market analysis by Vining (Pers. commun.) for the Hong Kong market shows that the supply of caterpillar-fungus has decreased from 24,000 kg in 2000 to about 12,000 kg in 2003 while the price increased from about $700 to $900 kg^{-1} US. In Lhasa, the weight of caterpillar-fungus collected in 2000 was 130,000 kg but only 12,000 in 2005. Over this time, the price increased from $600 to $6,700 US per kg (Lopsong Tashi, pers. commun.).

Environment impact from harvesting caterpillar-fungus

Since the early 1990s, harvesting caterpillar-fungus has had a devastating environmental impact on the alpine meadows on the Tibetan Plateau. During the harvest season (early April to later July) around 2,700,000 people dig for the fungus on alpine meadow (Wangmu and LoZhang, 2005). The human impact on the grassland is both direct and indirect.

Direct impact consists of digging around the plant to extract all the roots, which creates a bare patch that takes many years to revegetate in this environment. On average, each fungus that is harvested disturbs 30 cm^2 of meadow (Wen, 2004). If each person digs on average 10 fungi per day, and harvests for 60-days, then the area of grassland that is disturbed is 4,860,000 m^2 or 4,860 km^2 (Wangmu and Lozhang, 2005).

Indirect damage is caused by people building sheds and stoves in support of their activity. Their transportation and living at these temporary facilities produces soil compaction and pollution, which further exacerbates the impact. This damage is many times greater than the damage caused by harvesting the caterpillar-fungus (Wangmu and Lozhang, 2005). We estimate that the combined effect of harvesting and other disturbances can eventually result in desertification of the grassland. We assume the area of desertification equal to the sum of direct and indirect damage, which has been estimated to be about 27,000 km^2 year^{-1}.

Recommendations for conserving alpine meadows in the Tibet-Qinghai plateau

<u>Short term:</u>

The government health care institutions need to advise the Chinese society that caterpillar-fungus is not a medicinal panacea and the environmental cost of harvesting the fungus and the importance of the Tibet-Qinghai plateau as the main water source for many rivers in China. This will require that local governments must provide environmental education and subsidies.

<u>Long term:</u>

Enable property ownership. Traditionally, the property rights of alpine meadows belonged to local people. After "Liberation", the Chinese government confiscated these rights and made them public so that local people only have the right to use the land. This is the root of the problem of the "Alpine meadow public tragedy". Property ownership will ensure that the land will receive proper care.

Strengthen scientific research to produce caterpillar-fungus artificially. Efforts have been made to produce the fungus but so far it has been unsuccessful. There are many reasons for this but lack of funding is a major one.

Charge Resources Tax versus subsidies. In recent years, the government has begun to charge caterpillar-fungus harvesters "the resources tax". This would provide an economic disincentive.

Appeal to the Tibetan Culture. This is an initial, as well as a final, strategy to protect the environment of the Tibet-Qinghai Alpine Meadows. Traditionally in Tibet, people have always had a close relationship with nature – respecting and preserving nature is a principle theme of Buddhism. Through the Buddhist prism of interdependence, people believe that the environment in which we live sustains our existence. We believe that there are other sentient beings–such as "Lha" (gods) and "Lu" (naga's) that live around us, sharing the same environment. If we are not careful with our treatment of nature, we might unintentionally hurt these beings (Tashi Tsering, pers. commun.). As a result, respecting nature becomes a part of traditional Tibetan culture, which is the main reason that the environment was sustained over thousands of years. The best way to conserve the Alpine meadow is to learn the local knowledge and respect the Tibetan culture.

Conclusions and Implications

People believe that caterpillar-fungus is a medicinal panacea and the demand for it has rapidly increased. Each year this economic benefit attracts more than 2,700,000 people to the alpine grasslands to harvest the fungus which has created huge damage on the meadows. A sustainable approach to watershed preservation on the alpine grasslands is to return property rights to the indigenous people and respecting their local knowledge and culture.

Traditionally, the local economic back bone on the plateau is animal husbandry, which is mainly dependent on the alpine meadows. But in recent decades, millions of people from other provinces come to the Tibet-Qinghai plateau to harvest caterpillar-fungus. Those people not only exploit the benefit from alpine meadows, but then destroy the grass land that reduces the efficiency of local animal husbandry, and push local people into the abyss of economic ruin.

From my many years work experiences, I have realized that poverty goes with environmental tragedy, and unbalance social justice is at the root of environmental tragedy. I will continue this research after I go back to Tibet, and will lobby the local government for change. Respect local culture and knowledge, and return the property right to local people. This is not only good for the Tibetan people but for all of China.

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The Territory Conservation Agreements Program: Promoting Integrated Conservation Management in Australia's Northern Territory

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Key words: Conservation, pastoral, partnerships, off-reserve, production

Introduction

Ecological condition across the Australian rangelands has declined since European Settlement relating to the introduction and spread of exotic plants and animals, altered fire regimes and intensive land use associated with production (Woinarski and Fisher 2003). In addition, the protected area estate in the rangelands of Australia is small and not representative (Greiner 2015). Maintaining ecosystem health and biodiversity in this region therefore relies on sustainable management of land outside of the formal reserve system. Research suggests that regional networks of lightly grazed or non-grazed land can help in conservation management (Fisher et al 2004). Private land holders in the Australian rangelands therefore have an important role to play in biodiversity conservation.

Territory Natural Resource Management (TNRM) is a not-for-profit community organisation partnering with a range of stakeholders to sustainably manage natural resources in the Northern Territory of Australia. TNRM represents the second largest NRM region in Australia, covering 1/6th of the total land area within which over twenty bioregions exist. Approximately 46% of this land is under pastoral lease. In 2011, TNRM introduced the Territory Conservation Agreement (TCA) Program to encourage pastoral landholders to protect areas on their property with high conservation significance. The program is funded by the Australian Government Biodiversity Fund and National Landcare Programme.

Materials and Methods

TNRM provide funding to offset the costs of establishing conservation management on these sites which may cover a broad range of management actions and infrastructure. Funding is usually up to AUD$50,000 to establish and manage the TCA, with the bulk of the funds being received and utilised in the first year. Agreements made are voluntary.

TCAs aim to encourage innovative multiple use strategies which can demonstrate production benefits as well as delivering conservation outcomes. The contract is valid for ten years and commits the landholder to manage the nominated site during this period. The hope is that the TCA will bring enough economic benefit to the landholder that they would continue to manage the land in the same way once the contract has ended. Although the landholder signs a contract of agreed management actions at the start of the TCA contract term, these actions can be modified in response to changing conditions at the specified site during the agreement period.

Appropriate management does not always have to mean exclusion of cattle but can involve other sustainable grazing practices with active management of fire, feral animals, erosion and weeds. These sustainable grazing practices could be around wet season spelling and adoption of conservative stocking rates appropriate to the season and land. While TCAs allow landholders to conserve key parts of their property it is important for landholders that are running a commercial operation that they can enhance the sustainability of their production operations and generate good business outcomes.

Baseline flora and fauna surveys are carried out at the site, including a review of land types and vegetation communities identifying key increaser and decreaser species. Subsequently, annual survey monitoring is performed for the ten year period.

Results and Discussion

One of the key outcomes has been about engaging landholders in sustainable land management actions and putting them in touch with experts that can help them design tailored plans for their properties. Currently 27 TCAs have been established bringing the total amount of land under conservation protection in the program to date to 28,978 hectares. These TCAs are located across nine bioregions, mostly concentrated in the Tropical Savannas., with six of the nine covering underrepresented bioregions in the National Reserve System. Feedback from the landholders involved in the program for more than one year has been positive, with reports including good business outcomes as well as increased protection to assets such as water quality and native species on their property. Annual monitoring is showing that land condition at TCA sites is being maintained or improved and there has been a recorded decrease in invasive species and increase in native species at some sites.

Conclusions and Implications

Overall the program is proving to be successful. The findings so far illustrate that by involving the landowner in the process of developing the management actions appropriate for the site, the outcomes are more likely to include both conservation and productivity benefits.

Site inspections and communications with land managers can be challenging due to remote locations. Accessibility of these remote locations can be hampered further by the extreme weather characteristics of the Northern Territory. Generating interest in the program was an initial challenge but now that it's up and running it is less of an issue as word of mouth has encouraged its spread and uptake. Unfortunately, whilst to date the sites cover a range of bioregions only a few habitat types are represented in the program, especially waterholes and river banks, therefore more work needs to be done to encourage a broader range of habitat types covered by the program.

To increase the opportunity for more land to be managed for conservation outcomes there is scope to extend the program to other land tenure types. Since 50% of the NT is under Aboriginal Land Trust, TNRM is looking into ways to make TCAs more applicable on indigenous owned land.

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Degradation of Natural Rangelands as a Result of Human Activities in Saudi Arabia

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Key Words: Arid environment, Arabian peninsula, land degradation, overgrazing.

Introduction

The Kingdom of Saudi Arabia (KSA), with an area of approximately 1,969,000 km^2 is the largest country in the Arabian Peninsula and has the largest human population. The KSA extends from latitude 32° N to latitude 12° N. Considerably more than half of the country is desert with an annual rainfall between 100 and 150 mm. The area of natural rangeland in the KSA exceeds 175 million ha. The ecological issue of land degradation has gained increasing attention worldwide in recent years. Human activities such as agriculture and grazing have great impact on soil degradation, which eventually lead to land degradation. This manuscript will raise awareness of factors that affect rangeland degradation as a result of human activities, (Alwelaie, 1985).

Human Activities Affecting Rangelands in Saudi Arabia

Overgrazing

The effects of overgrazing on rangelands have been highlighted by several studies. Al-Rowaily et al., (2012) reported that continuous overgrazing threatens the productivity, biodiversity and sustainability of rangeland in KSA. Furthermore, the native vegetation is considered a major source of fuel wood in Saudi Arabia. Thus, the gathering of fuel wood represents a form of overgrazing because it causes the land to be exposed and produces decreases in plant productivity and increases in soil erosion (El Kattib, 1980). The destructive fuel wood gathering focuses on slow growing woody species such as Acacia spp, Haloxylon persicum and Calligonum spp. (Abuzinada, et al, 2005).

Agricultural expansion

The growth of the agricultural sector began in the late 1970s and the early 1980s. Total water withdrawal in KSA in 2006 about 23.7 BCM, agriculture only consumes approximately 88% of the total water withdrawals (FAO 2008). As a consequence of excessive irrigation, water levels have declined. For example, the water level in Qassim province (the central region of KSA) decreased between 1983 and 2008. In addition, a 95-m decrease in the water level occurred in Hail province (northern KSA). Soil salinization has begun to appear and land degradation has become a major crisis in some areas of the country.

Industrial expansion

Saudi Arabia is experiencing rapid growth in many sectors, including construction, which means more demand for raw materials, including stone. The increased demand for stone in recent years is also a result of increases in population and the advancement of urban areas and increases in the standard of living and well-being. Such activities have led to significant damage to rangelands in most parts of the country.

Conclusion and Implications

It is clear from the findings reviewed here that degradation is a crisis that threatens Saudi Arabia's rangeland. Short-term plans should be implemented to control the impacts of rangeland degradation. Therefore, it is the obligation of the government to regulate human activities to maintain land and native vegetation. Fencing as a simple management tool for excluding animal grazing and restoration of degraded rangelands (Kröpfl et al., 2013). Long-term plan is necessary to protect the damage of rangeland. The KSA was established a national strategy for conservation of biodiversity (Abuzinada.et al 2005). The purpose of this strategy is to draw a road map to protect the natural environment with all its biological components from the harmful activities of man. Implementing research and technology use is important to help areas affected by degradation. The KSA was established a research center for rehabilitation a native plants. The center conducted approximately 30 metric tons of 40 range of plant species. Agriculture strategy aims to: 1- Reduce hectarage under wheat by 94% from 523.000 ha in 2004 to 33700 ha in 2030. 2- Stop alfalfa and other high water consuming crop productions. Finally, in the absence of a long and short term plans, fighting degradation in the Twenty-First Century, particularly in arid and semi-arid regions will be a challenge.

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MULTISAR: Partnering for Species at Risk Conservation

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Key words: Species at risk, partnership, grazing, wildlife, range health

Introduction

The Grassland Natural Region of Alberta is home to 75% of Alberta's species at risk. Conservation efforts to maintain and enhance wildlife habitat and rangelands for both species at risk and cattle production are the primary objectives of MULTISAR (Multiple Species at Risk program) and the Habitat Conservation Strategy (HCS). An HCS is a tool utilized by MULTISAR to guide stewardship activities to improve the ecological integrity of habitat for multiple species of wildlife, as well as to improve the sustainability of the ranching operation. Detailed wildlife, vegetation and key habitat inventories are completed on each ranch, and the information collected is analysed and discussed with the MULTISAR team. This data is used to direct the development of jointly agreed upon enhancement priorities. The management goals, objectives and implementation of the strategy are based on a collaborative process involving the stakeholders on the MULTISAR Habitat Conservation Strategy Team who work together to balance the needs for healthy rangelands and quality fish and wildlife habitats through managed grazing and habitat improvement projects. The strategy includes a five-year stewardship commitment agreement among all HCS partners and a monitoring and evaluation program.

Materials and Methods

The MULTISAR process involves a series of criteria to determine where to focus stewardship activities in order to have the greatest impact on multi-species and habitat conservation and meet other requirements to assist in species at risk recovery. Ranches are selected based on the following criteria:

- Priority area for multiple species at risk conservation
- Close proximity to other areas of high potential for multiple species conservation
- High value for individual species at risk
- Connects areas already under stewardship initiatives to those that are protected
- Includes Critical Habitat as defined by federal recovery teams
- High value as a demonstration /educational site
- Opportunity for rehabilitation or improvement of a site

Field work includes both detailed wildlife surveys and range surveys. Prior to conducting field work, the ranch is mapped using a geographical information system (GIS). The Grassland Vegetation Inventory (GVI) range site (soil based) polygons are applied to maps as survey units. Survey points, with 200 meter survey buffers, are randomly placed within all GVI polygons, ensuring no overlap of survey points with neighboring points, polygons or fence lines. Keeping survey point buffers within GVI polygons ensures that observations at each survey location include only those species located within that GVI polygon. This

allows for easier correlations between species presence/abundance and range health. Survey points with buffers of 100 meters and 50 meters are then used to cover remaining areas of the polygons. This was done using the above protocols until approximately 50% of the ranch had wildlife survey point coverage.
The range surveys include detailed vegetation transects, Robel pole vegetation measurements and range health assessments. Rare and invasive plants are incidentally recorded when they are observed.
Wildlife surveys are completed to provide detailed baseline data on wildlife occurring on the ranch and to aid in the development of wildlife management recommendations. Several survey methods are incorporated into the detailed wildlife inventory including multi-species surveys and habitat specific surveys for amphibians, snakes and fish. This information, combined with results from the range and riparian (if applicable) inventory and health assessments, is used to develop each MULTISAR HCS.

Results and Discussion

Wildlife and range health data collected during field work form a baseline inventory for each ranch. A detailed report of the findings is produced for each member of the HCS team, which includes all wildlife observations made and their locations, range and riparian health scores by pasture, plant communities present on the ranch and their location, and suggested stocking rates for each plant community type and pasture. From this, general and pasture specific management recommendations, suggested habitat improvements, and a monitoring and evaluation program is discussed and agreed upon by all members of the HCS team.

Conclusions and Implications

MULTISAR is a collaborative and voluntary process to help maintain, improve, and restore the habitat of multiple species at risk in priority areas of Alberta’s Grassland Natural Region. This stewardship approach is landscape-based, combines the principles of wildlife management and range management, and incorporates the expertise of wildlife biologists, range agrologists, land managers and landowners in a group setting. One of the biggest keys to MULTISAR’s success is reliance on this partnership. By building a cooperative relationship, many stewardship activities can become reality and be beneficial to all involved. A positive relationship continues into the realization of the recommended enhancements where MULTISAR assists where/when possible with the implementation(s). On-going monitoring of the enhancements and discussions about the HCS evolve into long-term relationships centered around open and honest communication. These long-term relationships are key to on-the-ground implementation of enhancements for wildlife habitat. They also foster respect for one another and increase the willingness of the landowner to work on additional habitat projects.

Planning for Rangeland Biodiversity at the Regional Scale: Highlights from Alberta's Biodiversity Management Frameworks

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Key words: Biodiversity, grasslands, indicators, management, conservation

Introduction

Biodiversity conservation has been recognized as an international priority, demonstrated by the 168 signatories to the United Nations Convention on Biological Diversity. Canada has developed both a national biodiversity strategy and framework, along with 2020 Biodiversity Goals and Targets, to support these international efforts. However, the need for development of biodiversity indicators and thresholds at the regional and landscape scale is increasingly highlighted (Johnson, 2013). What is happening in practice at the regional scale to address identified biodiversity outcomes, specifically for rangelands? How do high-level commitments to biodiversity conservation scale down?

Materials and Methods

One of the Government of Alberta's seven land-use planning regions, the South Saskatchewan Region (SSR) encompasses over 80,000 km^2, an area approximately the size of the European country of Austria. The majority (78%) of the region is grassland, comprising the northern extent of the Great Plains, considered North America's most endangered ecosystem. As such, grassland conservation and management in this region will have global implications. The landscape of the region has been significantly modified by land use pressures, including those related to agricultural, oil and gas, and urban and rural development, and grazing by domestic livestock is extensive within the region. Approximately 46% of this grassland extent is in native condition, and the majority (80%) of the province's species at risk are found within the region.

In Alberta, environmental management frameworks, including Biodiversity Management Frameworks, are being developed and implemented as the main tools for management of regional scale cumulative environmental effects, defined as the combined effects of past, present and foreseeable human activities over time on the environment in a particular place (Government of Alberta, 2012). Objectives defined within the Biodiversity Management Framework for the SSR (the Framework) include maintaining terrestrial and aquatic biodiversity; sustaining intact grassland habitat; and recovering species at risk and avoiding designation of new species and risk. Main components of the Framework highlighted here include indicators and thresholds, but also include monitoring and modelling, and evaluation, reporting and management. Although currently in the draft phase, the development of the Framework represents one of the first examples of cumulative effects management for biodiversity at the regional scale.

Indicator development for the Framework was informed by literature establishing characteristics of effective biodiversity indicators (e.g., Collen and Nicholson, 2014). In contrast, the setting of thresholds has been a major challenge in biodiversity management (Johnson 2013), and thus the ability to adopt established thresholds for this application is limited. Framework development was also informed by estimates of past and potential biodiversity change from predictive models, and input from stakeholder, Indigenous, and community groups.

Results and Discussion

We developed and utilized the following indicator selection criteria: relevant to planning objectives for the region, representative of regional scale biodiversity, ecologically-relevant, responsive to land use, and feasible to measure and monitor. From this, twelve primary indicators were defined for the Framework. A suite of supporting indicators was further developed to incorporate additional aspects of biodiversity, varying from values identified by Indigenous groups, to spatial trends in the primary indicators.

Two examples of the primary indicators include landscape fragmentation and a multispecies index. Fragmentation of grassland habitat by human activities is considered a major pressure on biodiversity in the region. The effective mesh size (Roch and Jaeger, 2013) metric reflects both the size and connectivity of habitat patches, and has been suggested as an appropriate indicator of landscape fragmentation for this region (Roch and Jaeger, 2013). Similarly, multispecies indices have been proposed as integral to addressing targets developed through the Convention on Biological Diversity (Vackar et al., 2012). The specific multispecies index selected reflects both species abundance and occurrence, is linked to land use pressure, and is currently monitored locally by the Alberta Biodiversity Monitoring Institute: all desirable properties.

Each indicator has corresponding quantitative thresholds identified; that is, an acceptable amount of loss before a management response is required. These thresholds are bounded between a minimum decline of 1% and maximum decline of 4% in the absolute condition of any indicator. This magnitude is based on the level of risk associated with current condition of the indicator, as per risk assessment methodology for species and habitats established by the International Union for the Conservation Nature. In addition to risk level, the stringency of the management response is informed by past and anticipated trends in the indicator, and any further information which can be used to inform risk, such as relation of indicator condition to known ecological thresholds. Any management response will be developed in a collaborative manner with relevant local agencies and stakeholders.

Conclusions and Implications

An ambitious endeavour, the Framework is intended to follow adaptive management principles and continuously incorporate current science, data and information. Challenges and future directions in Framework development include understanding and incorporating climate change, defining reference state for the indicators, and integrating linkages among media (e.g., air, water and biodiversity). The Framework also creates and reinforces the need for high quality, cost-effective biodiversity monitoring data. As proposed, the Framework demonstrates the use of a collaborative, scientifically-credible approach to ultimately achieve regional scale biodiversity objectives.

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Pastoral Wildlife Conservancies in Kenya: A Bottom-up Revolution in Conservation, Balancing Livelihoods and Conservation?

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Keywords: Pastoral development, governance, community-based, community land

Introduction
Major critiques of community-based conservation often emphasize weak local power and control over the design, leadership and management of these initiatives (Nelson 2010). Local communities often do not own or control local land and resources and receive few of the benefits from those resources (Shackleton et al., 2010).

Kenyan conservationists were early adopters of community-based conservation and experimented with benefit sharing as early as the 1980's (Western 1989). But many of these efforts were not locally controlled and some were designed and managed by foreigners. Recently, however, local Kenyan communities, especially in pastoral areas, began establishing new, bottom-up conservation efforts, in the form of wildlife conservancies. This accelerated during the devolution of power from the national to local level as Kenya implemented a new constitution in 2013.

Here, we describe what might be called a 'conservation revolution' in Kenya. We describe where these conservancies are, their numbers and land tenure. We also describe why they got started and what they see as their major successes as well as their remaining challenges.

Materials and Methods
Our goal was to get a broad view of conservancies across Kenya through a large sample size. First, we conducted interviews with 57 conservancy managers in December 2014. Then we analyzed a list of all conservancies in Kenya as of December, 2015, provided by the Kenya Wildlife Conservancies Association. The conservancy list includes information on conservancy establishment date, type (private, community or group), and status (established or emerging).

During our interviews of conservancy managers, we asked the following 3 questions: 1) why did your community / landowners want to start your conservancy?, 2) what are your four biggest successes so far?, and 3) what are your four biggest remaining challenges? Fifty-five of the respondent managers were male and two were female. Most of the community conservancy managers were chosen by the communities living in each conservancy and thus were either from the conservancy itself or from the local ethnic group. Most of the managers on community land described using a bottom-up process for establishing their conservancy.

We analyzed the conservancy list data with simple statistics. For the interview data, we used a grounded theory approach and coded these qualitative data with thematic codes that arose from the data, cross-checking codes among three investigators. We analyzed the codes with frequency statistics.

Results

As of December 2015, there were 178 conservancies in Kenya, with 120 'established' and 58 'emerging' conservancies. There were 13 regional associations communicating among these 178 individual conservancies, organized together under the national Kenya Wildlife Conservancies Association. The first conservancy was established in 1953. Most early conservancies were established on private land and were largely held by non-indigenous or non-pastoral owners. But by 2015, conservancies on community land made up 67% of all conservancies. Community conservancies in Figure 1 are conservancies on indigenous lands, held either in common or recently privatized (Fig. 1).

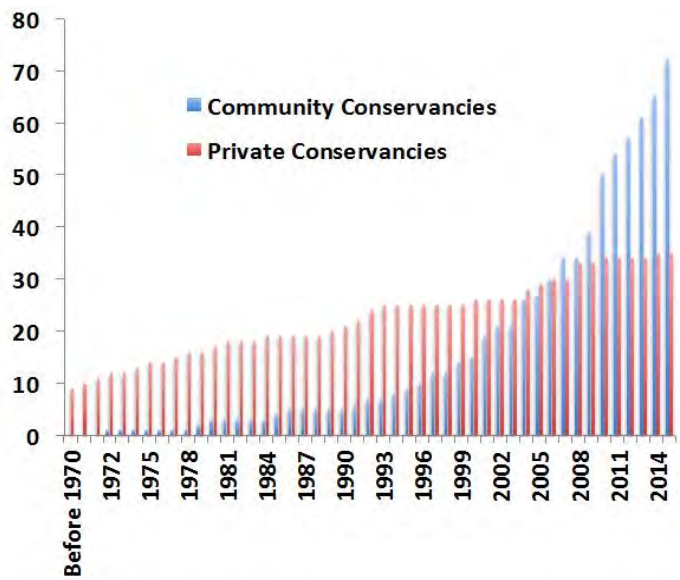

Figure 1. Numbers of conservancies established on community and private land 1953-2015 in Kenya.

Conservancies are now found in 30 of Kenya's 47 counties, widely spread across the country (Fig. 2). Most conservancies are located in pastoral lands in savanna environments with a growing number in forested or marine environments.

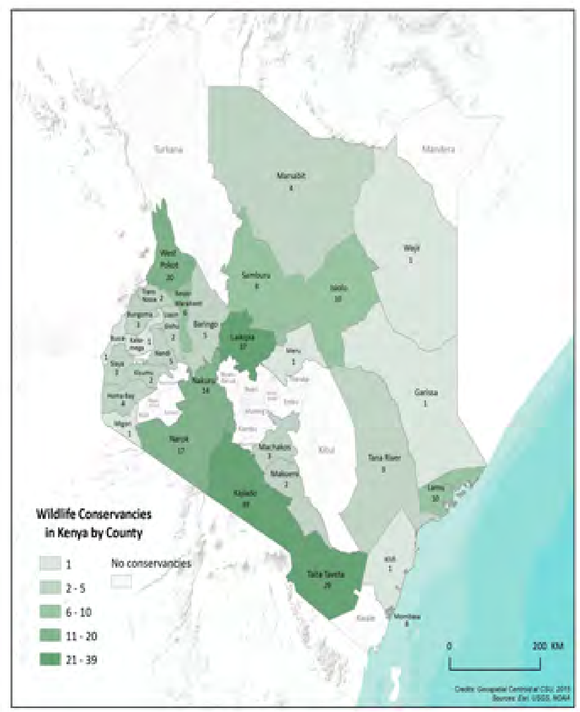

Figure 2. Geographic location and number of wildlife conservancies per county in Kenya.

Conservancy managers gave several social and ecological reasons for starting the conservancy (Fig. 3a). About 50% of the respondents established conservancies to conserve wildlife habitat and create jobs / improve income. Many also established conservancies to improve range management, access land and water, and improve security for people, livestock and wildlife. A few aimed to reduce poverty, develop the community and conserve cultural heritage.

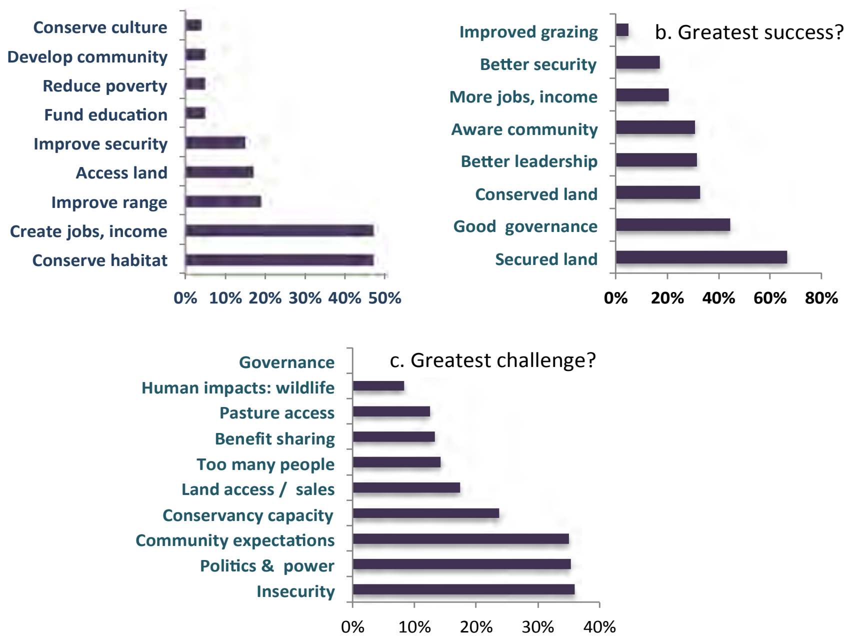

Figure 3. Frequency of codes for the reasons for starting a conservancy (a), its greatest success (b) and its greatest challenge (c).

Conservancy managers described their first greatest success (Fig. 3b) as their ability to secure land for use by the local community. They also thought the conservancy established good governance of land and achieved conservation of land. Many saw that the conservancy built the capacity of local leaders and also built awareness and support for conservation in local communities. Some also saw successes with more jobs, better security and improved grazing.

Significant remaining challenges for conservancy managers (Fig. 3c) are improving security, managing political problems and power and managing large community expectations of the conservancy. They also see the need to build more conservancy management capacity, improve community access to land and reduce land sales. Some also are concerned about human population growth, the low levels of benefits available to share, the need for more pasture and maintaining good governance.

Discussion

Can this really be called a 'conservation revolution' in Kenya? We think it is a revolution, despite the long-term existence of conservancies on private land for decades. This is a revolution in *community-based conservation*, driven largely by local communities. Communities largely control their own resources and decide how to share benefits from conservation locally. These efforts directly address the major weaknesses of community-based conservation efforts of the past. Even so, they are far from perfect, and still face many significant challenges.

Conclusions and Implications

Wildlife conservancies in Kenya are a needed evolution in our worldwide efforts to improve community-based conservation in rangelands (Reid, Fernandez-Gimenez and Galvin 2014). The question for the future is this: can these conservancies overcome their significant challenges and sustain their efforts over the long term?

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The Status of Biodiversity in the Grassland and Parkland Regions of Alberta

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Key words: Native grasslands, High Value Landscape, human footprint, biodiversity intactness, ecosystem services

Introduction

Temperate native grasslands are among the most threatened ecosystems in the world (Samson & Knopf, 1994). In Alberta, approximately 68% of native prairie has been converted to other land uses, predominantly agriculture. Notwithstanding, it's one of few jurisdictions in North America that contains large tracts of native prairie. To support land-use planning efforts aimed at managing native grasslands, the Alberta Biodiversity Monitoring Institute assessed the status of human footprint, habitat, and species for the Parkland and Grassland Natural Regions (known as the Prairie Region), as well as for the High Value landscape, a sub-region defined by native vegetation, species at risk, ecosystem services, and more.

Data is presented on several indicators of environmental health, including the provision of ecosystem services, which provides a baseline to evaluate change in biodiversity in the Prairie Region. Given habitat loss is a major driver of biodiversity decline on the planet (Brooks et al., 2008), a comparison of the indicators for the Prairie Region and the HVL also sheds light on the complex regional interactions between human footprint, species, and their habitat.

Materials and Methods

Between 2003 and 2014, the ABMI collected field and remotely sensed data for 204 sites across the Prairie Region. The data is used to assess the status of human footprint, native habitat, and species. With respect to footprint, satellite imagery is employed at two spatial scales. Coarse resolution data (1:15,000) circa 2012 was used to determine total human footprint and its components, whereas, fine resolution data (1:5,000) was used to evaluate trend in human footprint over the period 1999-2013. Human footprint status is presented as the percentage of land directly altered by human activities where 0% is no visible human footprint and 100% is completely modified by human footprint. To calculate native habitat, three buffer distances were applied to total human footprint to account for the varying ability of different species to utilize territory in close proximity to human activity.

With respect to the status of species, the ABMI implemented a range of field protocols to determine the relative abundance of species from four taxonomic groups: birds, vascular plants, bryophytes, and armoured mites. The data is used to calculate the Biodiversity Intactness Index—a metric pioneered by the ABMI—for each species. The Index is evaluated by: 1) generating statistical models to describe the relationship of each species with human footprint; 2) evaluating the models to predict the current and reference abundance of each species at every quarter section; and 3) summing the predicted current abundance and reference abundances of each species across the region. The Index ranges on a scale from 0% to 100%, where 100% is the expected relative abundance for that region if there is no human footprint. A decline in the Index means either species abundance is lower-than-expected or higher-than-expected relative to an area with no human footprint, given it is any perturbation in relative abundance.

Results and Discussion

Human footprint

As of 2013, human footprint covered 63.1% of the Prairie Region; agriculture was the largest footprint type covering 55.2% of the area. Transportation, energy and urban, rural and industrial footprints were 2.7%, 2.5% and 2.3%, respectively. Human footprint was two to three times higher outside the HVL compared to inside, with the exception of energy footprint which was higher. Between 1999 and 2013, percent area of human footprint in the Prairie Region increased from 61.3% to 63.1% (1.8%), with a larger increase in the HVL of 2.4%, from 28.4% to 30.8%.

Native habitat

As of 2012, 37% of the Prairie Region is composed of native vegetation when no buffer is applied. The largest patches of native vegetation occur in the HVL, and 69% of the HVL is composed of native vegetation compared to 18% outside. When a buffer of 200 m from human footprint is applied, native vegetation is highest in the HVL (23%) compared to outside (2%).

Species

In the Prairie Region, 197 species from 4 taxonomic groups exhibited, on average, a Biodiversity Intactness Index of 53%; inside the HVL, intactness was 69%, whereas, outside of it, intactness was 43%. As a whole, intactness in the Prairie Region ranged from 51% for armoured mites to 63% intactness for native birds.

Conclusions and Implications

The biggest ecological changes in the Prairie Region are associated with the lower-than-expected abundances of species that require native prairie habitat such as Baird's Sparrow, Sprague's Pipit, and in particular grassland-associated plants. With respect to Baird's Sparrow and Sprague's Pipit, loss and fragmentation of native habitat due to agriculture and other developments are considered the main reasons for their regional population declines. Strong negative responses to human footprint give these two species some of the lowest intactness values of all prairie species. Further, species that thrive in agricultural landscapes or disturbed habitat, such as the Coyote, Chipping Sparrow, and Foxtail Barley, were more abundant than expected.

With biodiversity 53% intact today, there are challenges associated with the management of native prairie species and habitat in the Prairie Region. As the region's population and economy continue to grow, pressure on regional ecosystems is continually increasing. The information provided by the ABMI can be used as a foundation for evaluating the sustainability of resource development in the Prairie Region.

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Conservation of Wildlife and Natural Areas in Southern Saskatchewan, Canada, through Nature Saskatchewan's Stewardship Programs

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Key words: Stewardship, conservation, wildlife, prairie

Introduction

Active stewardship by landowners and land managers is integral to the conservation of species at risk, other wildlife species, and remaining prairie in Saskatchewan, Canada; since only 21% of Saskatchewan's grasslands remain (Michalsky et al., 2009), of which, 85% are privately managed (Saskatchewan Watershed Authority, 2002). For nearly thirty years, Nature Saskatchewan's voluntary Stewards of Saskatchewan (SOS) programs have enabled rural landowners and land managers to become actively and concretely involved in habitat conservation and monitoring of plant and wildlife species at risk (SAR) in southern Saskatchewan. These voluntary programs have shown to significantly increase conservation of wildlife habitat and natural areas, as grassland retention has been found to be higher at enrolled program sites (66%), compared to random sites (49%) (Warnock et al., 2004).

In addition to their conservation value, the SOS programs have also collected and shared valuable SAR data. A study by Follett et al. (2015) showed that the number of peer reviewed articles that used data from programs such as SOS, increased from less than 10 in 2004 to 250 in 2014; suggesting an increased interest in citizen science monitoring data among researchers. The SOS programs are a model example of this connection and have made significant data contributions to the Saskatchewan Conservation Data Centre (SK CDC) and Canada's national SAR recovery teams.

Materials and Methods

Through 730 signed voluntary stewardship agreements, conserving 120,794 hectares of habitat important to target SAR (e.g., Burrowing Owls, Loggerhead Shrikes, and Sprague's Pipits) at 1,755 sites, landowners and land managers have become SOS program participants and agree to conserve and not negatively impact the habitat on their land. As participants, they agree to actively report SAR and habitat information (e.g., changes) for their enrolled sites each year. Some target SAR are also actively located through staff field surveys. Legal land locations of SAR are then reported to the SK CDC and the national SAR recovery teams each fall.

The SK CDC houses a database accessed by many stakeholders, such as consulting/developing companies, researchers, and government. The SK CDC was consulted to determine what portion of their species specific records came from Nature Saskatchewan. Additionally, the SK CDC shared how often data were accessed and by whom. National SAR recovery team leads were also consulted to determine how and to what extent Nature Saskatchewan's search and monitoring data have been used.

Results and Discussion

Since the initiation of Operation Burrowing Owl (and the SOS programs) in 1987, Nature Saskatchewan has submitted at least 1,731 records of Burrowing Owl (49%) out of the 3,534 total records in the SK CDC database (Benville, personal communication). Assuming even usage of all data in the SK CDC's database, Nature Saskatchewan's SAR records were also accessed an average of 188 times each day between 2010-2014. The public sector (e.g., consulting companies, academics, the general public) accounted for 90% of total SK CDC database usage (including SOS program data), the provincial government accounted for 8%, and the federal government for 2% of usage (Bryshun, Cameron and Morken, 2015, unpublished data).

Through field searches, public reports, and annual monitoring data provided by participants (at known sites), the SOS programs have contributed to the downlisting of federally-listed species at risk, the expansion of species' distributions, and accessibility of SAR data . For example, Nature Saskatchewan's data have been (or will be in the near future) used in four federal recovery documents: the Western Spiderwort Recovery Strategy (2013), Smooth Goosefoot Recovery Strategy (2015), Hairy Prairie-clover Recovery Strategy (will be written in the next year), and Dwarf Woollyheads Management Plan (2016) (Lee, personal communication).

Conclusions and Implications

Through Nature Saskatchewan's SOS programs, active stewardship allows for landowners and managers to engage in conserving habitat for SAR and wildlife that rely on these natural areas. As it has been since 1987, SAR locational information will continue to be shared as much as possible and used for project planning by industry to minimize impacts on SAR, scientific research, to assist in species rankings, and in the development of recovery planning for prairie SAR. Without these programs the number of sites being conserved would be reduced and the use of a significant amount of SAR monitoring data would be lost. Ultimately, the contributions of the SOS programs, both in the past and for generations to come, are critical to the conservation of wildlife and natural areas in Saskatchewan.

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Managing Cattle and Wildlife Species at Risk on Crown Rangelands in British Columbia, Canada

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Key words: species at risk, wildlife, cattle, habitat, grazing

Introduction

British Columbia (BC), Canada, public 'Crown' lands have been actively grazed by livestock since 1846 (McLean, 1982). BC is home to 61 species at risk listed as being of 'special concern' and 164 species listed as extirpated, endangered or threatened. The American Badger (*Taxidea taxus*) is ranked "Red Listed" in BC Provincial Conservation status, meaning they face imminent extirpation or extinction. The Great Basin Spadefoot (*Spea intermontana*) is ranked as "Blue Listed" meaning they are of species concern and are sensitive or vulnerable to human activities or natural events. Often, the habitat requirements of wildlife are not in direct conflict with the ability to safely graze livestock. However, there are cases where intervention is necessary to enhance riparian ecosystem health (Fleischner, 1994) and wildlife habitat (Weir and Almuedo, 2010).

Materials and Methods

This is not a formal research study, rather, an approach of applying principles of sustainable range management to current issues, using social, extension, and legislative tools. To design a solution to the intrinsic conflict of overlapping land values (ranching and wildlife), wildlife habitat was identified and mapped, meetings were facilitated between stakeholders (Ministry of Environment, Ministry of Forests, and three Ranches), livestock grazing practices adapted, and on-ground practical solutions of fencing and water developments were installed. The following is the process we used to achieve the objectives of managing for wildlife and livestock.

Identification of wildlife habitat

The area of study is in the interior of BC in the South Cariboo region, within the Interior Douglas-Fir dry-cool (IDF dk3) biogeoclimatic zone, approximately 37 km south of the town of 100 Mile House in the Meadow Lake and Alberta Lakes area.

In 2004 and 2005, professional agrologists and biologists conducted rangeland health assessments. Crown range health is measured by comparing the functioning ecological processes in riparian and upland areas of rangeland to a standard such as an ecological site description or reference area.

In freshwater ponds, soil compaction from livestock was a major concern for amphibian breeding and hibernation. Hoofprints along the edge of water sources cause soil compaction, which limits burrowing ability. Additionally, hoofprints fill with water but rapidly dry out which harm amphibian larvae metamorphosing into the young adult stage and attempting to leave the pond. It was a concern that an improvement needed to be made to provide amphibian breeding opportunities. Wildlife habitat area was mapped for Spadefoot in the area.

The large territories, number of dens and hunting territory of badger were mapped for the area. Cameras were installed to record sightings, and short pieces of single strand barbed wire were placed at the top of the entrances to capture stray hairs. Population size and the home ranges of the badger were estimated through DNA testing of hair and scat and sightings.

The mapped wildlife habitat areas for Spadefoots and Badgers began to overlap and increase in size, covering nearly every freshwater source that was being used by grazing cattle. Spatial information of areas deemed ‘necessary to meet habitat requirements’ for wildlife were mapped, and designated Wildlife Habitat Areas (WHAs) by the Ministry of Environment, the purpose being to conserve these habitats by connecting them to a Government Approved Order with specific limited natural resource activity prescribed for these areas.

Identification of conflict

Existing fencing and a basic grazing schedule was in practice for livestock management, and it was identified that maintaining the availability of freshwater sources was very important for the health of livestock. Coniferous seedlings and tree encroachment into grassland areas was shrinking available grasslands, forage, and reducing overall biodiversity. Multiple stakeholder meetings were conducted along with site visits to disseminate and collect information and brainstorm solutions.

Resolution of conflicts

The solution was to monitor rangeland health, identify and map the wildlife habitat, communicate with stakeholders, improve freshwater access for cattle, and distribute away from wildlife areas. We worked towards these goals along the following timeline:

- 2005 to 2009: Rangeland health assessments and wildlife surveys conducted.
- 2005 to 2013:
    - Change in range practices by amending grazing schedule in operational plan, to optimize distribution of livestock and reduce grazing pressure.
    - Professional range technician and biologist designed and constructed several infrastructure projects to mitigate livestock impact.
    - Configuration of fences provided ungrazed wetland habitat.
    - Ecosystem restoration of native grassland by removal of coniferous seedlings.
- 2005 to current: Inclusion of the rancher in the management and decision process.
- 2005 to 2009: Ecosystem restoration of native grassland by removal of coniferous seedlings.
- 2008: Wildlife Habitat Area defined and approved for the American Badger
- 2010: Wildlife Habitat Area defined and approved for the Great Basin Spadefoot
- 2011 and 2013: Nocturnal auditory surveys were conducted to monitor amphibian activity in water developments sites.
- 2011: Livestock water developments designed by the range technician were constructed to protect amphibian breeding areas in three wetlands (Fig. 1).
- 2013: Two additional water developments were constructed.

Figure 1.
Fence around 90% of wetland, with 10% dugout area for livestock watering.

Results and Discussion

In 2014, nocturnal auditory surveys were conducted again to monitor amphibians and gather information of efficacy of the new fencing and water developments. Long-term wildlife data is needed to question if the management decisions of altering the livestock grazing distribution paired with creating fencing was successful. To support ecological connectivity and habitat requirements of wildlife, landscape level projects need to be implemented (Rannap et al., 2009). Working with ranchers to foster 'buy-in' and compliance in use and maintenance of Crown rangeland projects will be a key to long term success. With changes in livestock tenure ownership and management, there will need to be continual extension and awareness brought to these projects.

Conclusions and Implications

Research on the adaptability of species at risk to changes in their habitat is continual. Altering grazing practices to support the habitat requirements of these species is a challenge that needs to consider the requirements not only of the species at risk but also the economic livelihood of the graziers.

Inventory of wildlife species and wildlife habitat mapping was an important first step to managing overlapping land values. Continuous consultation with ranchers, technicians, and biologists was important to designing appropriate structures and timely management of livestock. Construction of infrastructure to support both livestock and wildlife, along with managing timing and distribution of livestock was successful in enhancing wildlife habitat and providing adequate livestock forage and water. Continuing adaptive management is needed to support both values. The inclusion of ranchers in the decision making process was a critical part to gain compliance and sustaining achievable objectives for wildlife and ranching.

By adapting the operational plan of the livestock and mitigating needs of ranchers by developing appropriate infrastructure, we successfully reduced impact on wildlife habitat allowing species at risk to co-exist as they have in the past with cattle grazing, as supported by Fuhlendorf and Engle (2001). Future adaptive management will be needed to maintain biodiversity, habitat, and forage to co-support ecosystem values and agricultural productivity.

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Alberta Prairie Conservation Action Plan 2016-2020: Strategies and Outcomes for Future Prairie Conservation Initiatives

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Key Words: prairie conservation, action plan, collaboration, outcomes, stewardship

Introduction

The Prairie Conservation Forum was established by the Government of Alberta in 1989 to convey Alberta's support and commitment to implementing the Prairie Conservation Action Plan (PCAP). The PCAPs are five-year blueprints for conserving, protecting, and managing native prairie and parkland species, communities, and habitats using collaborative approaches among our diverse member stakeholders and partners. Our vision is that the biological diversity of native prairie and parkland ecosystems is secure under the mindful and committed stewardship of all Albertans. The 2016-2020 PCAP is the sixth conservation plan developed in Alberta; it builds on accomplishments of past action plans and highlights our key strategies, outcomes, and approaches for our future work to support prairie conservation in Alberta. PCAP 2016-2020 recognizes the need to focus activities around three primary strategies: to complete inventories and assessments of native biodiversity in Alberta; to share knowledge and foster a dialogue around prairie conservation; and to promote stewardship of native prairie and parkland ecosystems. Three important strategic or long-term environmental outcomes are also necessary to bring the PCAP vision to reality: maintain large native prairie and parkland landscapes; conserve connecting corridors for biodiversity; and protect isolated native habitats. These outcomes require close linkage to management and planning decisions by all levels of government and private land owners. Our educational approach to achieving all outcomes includes educational and awareness programming, as well as providing web-based access to prairie conservation information.

Materials and Methods

Prior to development of the 2016-2020 PCAP, a review was done on the 2011-2015 PCAP to see which actions were successful, which actions weren't successful, and why. The 2016-2020 PCAP follows the format of the previous PCAP by including three long-term outcomes, but builds upon work that began in the previous PCAP. Approaches and actions were identified to address each of the outcomes and highlight activities that will be led and implemented by the PCF, as well as some activities that could be led by members. This direction for the PCAP requires a more involved and active membership and Board of Directors. As such, input on the direction and approaches of the PCAP was sought from the membership at our spring and fall meetings; through a questionnaire that was emailed to all members; by facilitated workshops held with the membership on approaches and actions and the validity of using them in the PCAP; and a breakout session at the annual general meeting to get input on the top priorities across the three outcomes. Throughout this process, members were given a chance to voice their opinions on the direction of the PCAP. The involvement of the membership ensures that the PCAP is relevant and important to them, and that it can be implemented within the acknowledged constraints and capacity of the PCF. It is the responsibility of the PCF Board of Directors to develop a work plan to address and carry out the activities under each of the three outcomes, and members are invited to join any working group that forms as a result of the activities.

Results and Discussion

To bring the PCAP vision to reality, important strategic or long-term environmental outcomes must be achieved. These outcomes require close linkage to management and planning decisions by all levels of government and private landowners and are closely connected to existing functional ecosystems in prairie and parkland Alberta.

The first outcome is to maintain large native prairie and parkland landscapes. The existence of intact and fully functioning native prairie and parkland landscapes in Alberta are the best guarantor of future regional biodiversity and environmental quality. Approaches include: promoting large landscape conservation; understanding of change analysis and intactness; minimal disturbance and restoration of industrial footprint on native prairie; and encouragement of stewardship among land managers.

The second outcome is to conserve connecting corridors for biodiversity. Habitat connectivity is essential to maintain native biodiversity and ecosystem function. The conservation and restoration of important corridors will help to maintain functional native prairie and parkland landscapes. Approaches include: analysis of location and significance of corridors; building awareness and networking; promoting stewardship; and establishing trans-boundary connections.

The third outcome is to protect isolated native habitats. Within fragmented landscapes there exist small, isolated pockets of ecological *refugia* that may be as important for native biodiversity conservation as larger prairie and parkland landscapes. These require identification, study, and, where required, the promotion of stewardship. Approaches include defining ‘isolated’ habitats/fragments and defining what we have—and the location of—isolated habitats. This includes confirming a definition based on GIS analysis and literature review and identifying the value, or values, of these isolated parcels.

Educational approaches, such as education and awareness programming and providing web-based access to prairie conservation information, are integral to our goals and communicate the work we are doing.

Conclusions and Implications

The strength of the Prairie Conservation Forum and its Action Plans rely solely on the strength and commitment of the membership, as well as continued funding to implement the actions in the PCAP. The diversity of the membership, which includes all levels of government, non-profit environmental organizations, academia, industry, agricultural groups, and dedicated individuals, is essential to the success of each action, as well as to be taken up, promoted, and implemented by those not only making policy, but by those working and making a living on the prairie landscape. Collaboration is key, and the PCF strives to make a difference in prairie conservation through positive partnerships.

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Biodiversity Conservation of Riparian Grassland by Conversion of the Harvested Biomass into Bioenergy

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Key words: biodiversity conservation, bioenergy, riparian grassland

Introduction

Natural and semi-natural grasslands in riparian areas of Poland have been identified as having extraordinary biodiversity value. In the past, the species richness of these landscapes has been managed through grazing or/and cutting. However, livestock numbers are now in decline, many grasslands are abandoned, and consequently the diversity of these landscapes is under threat. In order to prevent these habitats from turning to scrublands, these areas have to be extensively harvested. Many riparian grasslands are protected under the Bird and Habitats Directives in the European network Natura 2000 and their management is financially supported by the introduction of agri-environmental schemes (Goliński and Golińska, 2011). Regulations dictate a late harvest time (in the middle of July or beginning of August) to allow reproduction of the flora and fauna, and a removal of biomass. Farmers receive financial support for such management. The biomass harvested from those grasslands is not suitable for animal feeding, but can be used for bioenergy production (Wachendorf and Soussana, 2012). The aim of this study was to analyse the possibilities of biodiversity conservation of riparian grassland in western Poland by converting the harvested biomass into bioenergy.

Materials and Methods

The study was carried out in 2012-2013 in Wielkopolskie and Lubuskie voivodships, located in western Poland. Riparian grasslands are largely concentrated in the river valleys. We focused on two areas – the valleys of the Noteć and Szprotawa rivers included in the European network Natura 2000 as areas of special bird and habitat protection. The botanical composition and yield of harvested biomass from 20 meadows located in both valleys was estimated and samples of biomass for chemical analyses were collected. In the samples the crude protein (XP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and ash (XA) using standard methods (Kjeldahl, van Soest, dry oxidation, respectively) were determined. In the representative samples from each valley following ensiling the biogas and methane yields were evaluated using gas chromatograph Varian 4900 Micro-GC.

Results and Discussion

Lower dry matter (DM) yield was measured in the Szprotawa River Valley (Table 1). The riparian grasslands of this valley were mainly represented by tall-sedge and *Molinia caerulea* communities. The sward of these communities was dominated by *Carex riparia*, *Molinia caerulea*, *Calamagrostis stricta*, *Phalaris arundinacea*, and *Scirpus sylvaticus,* with a high proportion of dicotyledonous species such as *Lotus uliginosus*, *Lathyrus palustris*, *Selinum carvifolia*, and *Cirsium palustre*. In the Noteć River Valley, the *Phalaridetum arundinaceae* association was dominant. In terms of botanical composition, this association is characterized by high proportions of *Phalaris arundinacea, Phragmites australis* and *Carex* species. In the Noteć riparian grassland, a lower quality of harvested biomass in terms of XP was found. The mean content of XP in the collected samples reached 84.6 g/kg DM for the Noteć River Valley, 13.7% lower than that of Szprotawa River Valley. The Noteć grasslands, in comparison to Szprotawa, had a higher ADF content, 367.0 and 352.2 g/kg DM, respectively. The mean content of XA in harvested biomass was also higher by ca. 20% in riparian grasslands of the Noteć River Valley.

Due to high concentrations of structural carbohydrates, the most common way to utilize biomass from these grasslands for bioenergy production is combustion. Another solution is conversion into biogas. One of the potential sources of substrate for biogas plants is biomass collected from riparian grasslands, especially from Natura 2000 sites. This kind of substrate is not competitive with maize, which is the most popular crop for biogas production but is often eco-inefficient, e.g. due to the increased risk of soil erosion and nutrient losses, and associated ethical and socio-economic problems (Wachendorf and Soussana, 2012). In our study, the yields of biogas and methane after ensiling of harvested biomass from riparian grasslands of the Noteć River Valley were lower in comparison to the Szprotawa River Valley (Table 1).

Table 1. Characteristics of biomass from riparian grasslands in two locations in western Poland.

Quantitative and qualitative parameters	Unit	Noteć River Valley		Szprotawa River Valley	
		Mean	Range	Mean	Range
DM yield	t/ha	5.4	4.0-7.0	5.2	3.0-6.5
DM content in cut biomass	% of FM	36.4	30.2-39.1	35.5	26.3-41.1
Crude protein (XP)	g/kg DM	84.6	65.0-102.5	98.0	71.3-111.3
Neutral detergent fibre (NDF)	g/kg DM	563.1	510.1-592.0	579.1	551.3-623.6
Acid detergent fibre (ADF)	g/kg DM	367.0	301.5-396.6	352.2	333.1-396.3
Ash (XA)	g/kg DM	64.5	49.5-83.5	53.8	42.0-69.0
Biogas yield	L_N/kg oDM	267	-	315	-
Methane yield	L CH_4/kg oDM	184	-	213	-

The results showed that the biogas and methane yields from riparian grasslands are in general lower than those from standard substrates like maize. A new challenge is to improve the conversion efficiency of biomass from natural and semi-natural grasslands in riparian areas into bioenergy. A solution to this is the introduction of the Integrated Generation of Solid Fuel and Biogas from Biomass (IFBB) system (Wachendorf et al., 2009) in Poland (Bühle et al., 2014). This technology is especially adapted to fibre-rich materials. The IFBB technique aims to divide grassland silage into a solid part for combustion and a liquid fraction for biogas production. The extraction of minerals and easily digestible compounds into the liquid fraction, significantly improves the combustion performance of the solid fuel (pellet or briquette from solid part).

Conclusions and Implications

Riparian grasslands in western Poland are high nature value areas, mainly in terms of biodiversity. In the Noteć and Szprotawa River Valleys, the grasslands are mostly contained within the Natura 2000 network and are included in agri-environmental schemes. Due to late cutting, the harvested biomass is fibre-rich and can be used for bioenergy production. The IFBB technology helps to improve the process of such biomass conversion into bioenergy. This way of riparian grasslands management is a good tool for their biodiversity conservation.

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1.4 GRAZING MANAGEMENT PRACTICES

Herbivore Assemblages as a Crucial Factor in Future Grazing Management on Steppe Grasslands

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Key words: Mixed grazing, productivity, diversity, soil heterogeneity, N cycling, C flux

Introduction
Grasslands occupy about 40% of the world's land surface and support diverse services. Unfortunately, many grasslands are in a degraded state and total global pasture area has significantly declined by 62 million ha over 15 years due to increasing stock number or overgrazing (Kemp et al., 2013; Sills, 2016); therefore, a pivotal challenge is to optimize grazing management practices. The intent of grazing management is thought to be to maximize livestock production on a sustainable basis, indicating the significance of the maintenance of grassland multifunctionality. Most previous research has indicated that grazing intensity, as one of the core management factors, can exert various impacts on the processes and functions of grasslands, and that overgrazing always negatively affects grassland vegetation productivity, diversity, Carbon and Nitrogen cycling, and ultimately, animal production. Little information is available on how different herbivore assemblages influence potential grassland multifunctionality in the optimal grazing contexts, despite the fact that mixed grazing by the domestic herbivores with different body-sizes or of different species is adopted in many grasslands around the world, from traditional extensive nomadic to intense livestock-production systems.

Materials and Methods

A set of grazing manipulation experiments was conducted in 2008 in the Eurasian steppe grasslands. Six replicate blocks were arranged in this area, and each block was divided into four plots for different grazing treatments: no grazing (NG), cattle grazing (CG), sheep grazing (SG) and mixed grazing (MG). Grazing was maintained at a moderate intensity in each herbivore treatment: there were sixteen sheep in SG plots, four cattle in CG plots and sixteen sheep plus four cattle in MG plots. The plots were 25 m × 25 m for all treatments, except MG, which had 25 m × 50 m plots to equalize the grazing pressure between mono-species and mixed-species herbivore treatments. Grazing was allowed twice a day, 06:00 - 08:00 and 16:00 - 18:00 from June to September each year. Above-ground net primary productivity (ANPP) and plant diversity were measured during the growing seasons of 2008 and 2010. We estimated ANPP by clipping biomass to 2.5 cm at peak biomass in mid-August in a 50 × 50 cm area in five locations per plot. In 2013, we randomly chose two blocks with high and low plant diversity to examine spatial heterogeneity of limiting soil resources (available soil N; NH_4^+ and NO_3^-). Semivariation analyses were conducted to quantify the structural attributes of spatial variation using GS+7.0. Furthermore, the soil N mineralization rate was determined using ion-exchange resin membranes. In 2014, ecosystem carbon fluxes (NEE) were measured once a month over the growing seasons from May to September using a LI-COR 6400 portable photosynthesis system.

Results and Discussion

Herbivore assemblage and plant diversity
Plant diversity is a driving factor for ecosystem multifunctionality, and Olff and Ritchie (1998) argued that herbivores often, but not always, increase plant diversity. Our experimental results showed that grazer effect on plant diversity strongly depended on herbivore species and combination. Single-species grazing

by cattle and mixed grazing of cattle and sheep significantly increased plant diversity, while single-species grazing by sheep significantly reduced plant diversity (Fig. 1). Such increasing effects of cattle grazing can be attributed to the fact that cattle had more inhibition on the competitive dominant grasses than sheep. Consequently, seedlings of forbs and legumes had higher survival and establishment rates, in turn enhancing plant species richness. Interestingly, mixed grazing had a consistently positive effect on plant diversity. It is most likely that the additive effect of mixed grazing enhanced plant diversity through the reduction of competition from grasses (Liu J. et al., 2015).

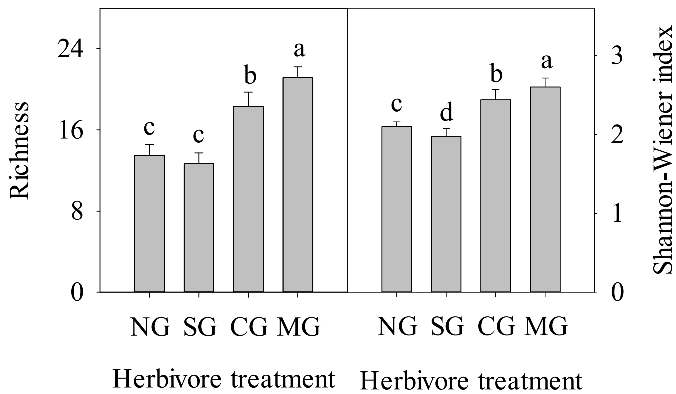
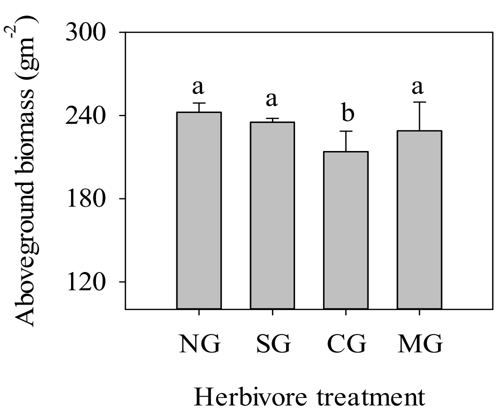


Figure 1. Effects of herbivore assemblages on plant diversity. Different letters indicate significant difference between treatments (*P* ≤ 0.05). *Bars* represent standard error.

Herbivore assemblage and soil heterogeneity

Grazing by large herbivores is a key determinant of soil spatial heterogeneity in grasslands (Liu C. et al., 2015). We found that grazing generated and maintained spatial patterns of soil nutrients, depending on herbivore assemblage and the level of pre-grazing plant diversity (Table 1). Cattle grazing increased the spatial heterogeneity of available N in the soil of *Leymus chinensis*-dominated steppe, which was independent of pre-grazing plant diversity. However, the effects of sheep grazing and mixed grazing strongly depended on grassland plant diversity, with an increased spatial heterogeneity of available soil N in the high diversity sites, but not in the low diversity sites. Thus, in the eastern Eurasian steppes, cattle ranching could be considered an optimal grazing management protocol to improve soil spatial heterogeneity, because cattle grazing consistently increased soil spatial heterogeneity in the context of both low and high plant diversity. In grassland systems with high plant diversity, herbivore grazing and plant diversity would jointly improve soil spatial heterogeneity, thus feeding back to maintain higher plant diversity.

Figure 2. Effects of herbivore assemblages on aboveground biomass.



Block	Treatment	Model	R^2	RSS	Range (A_0)	Proportion ($C/C+C_0$)	Class of structural dependence
High	NG	L	0.423	34.52	>7.50	0.670	Moderate
	MG	S	0.350	550.00	1.12	0.942	Strong
	CG	S	0.726	537.00	2.23	0.950	Strong
	SG	S	0.831	487.30	2.61	0.786	Strong
Low	NG	L	0.719	33.56	>7.50	0.533	Moderate
	MG	L	0.506	46.15	>7.50	0.620	Moderate
	CG	S	0.256	9.38	1.06	0.886	Strong
	SG	L	0.653	2.62	>7.50	0.565	Moderate

Notes: L, linear; S, spherical; R, random; High, high plant diversity; Low, low plant diversity

Herbivore assemblage and plant productivity

Animal production is mostly dependent upon plant productivity on grasslands. Based on our studies, herbivore assemblages had significantly varying effects on plant biomass. Single-species grazing by cattle significantly decreased plant biomass, while grazing by sheep alone and mixed grazing of cattle and sheep didn't significantly affect plant biomass (Fig. 2). Cattle, a large-bodied and less selective herbivore that commonly coped with the low plant nutrient content but requires a higher abundance of energy-rich plants, tended to negatively affect plant biomass accumulations by consuming dominant grasses.

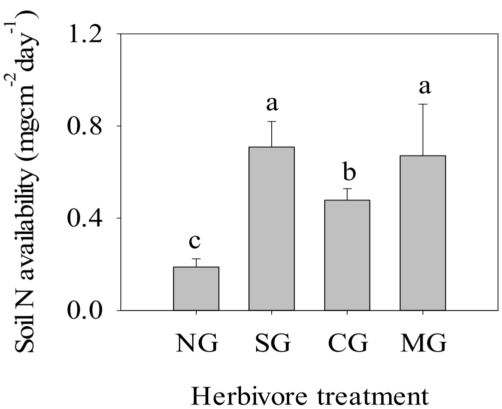


Figure 3. Effects of herbivore assemblages on soil N availability.

Herbivore assemblage and grassland nitrogen cycling

Large herbivores are an integral component of most grasslands that affect plant community composition and productivity, often by regulating soil N cycling. In our experiments, it was shown that herbivore grazing significantly improved soil N availability regardless of herbivore assemblages (Fig. 3). Furthermore single-species sheep grazing and mixed grazing of cattle and sheep had a greater effect on soil N availability than single-species cattle grazing. Overall, our study demonstrated that herbivore grazing had a predominantly positive effect on N cycling rate under moderate grazing intensity. Herbivores could influence soil N availability by two distinctly different pathways: directly through manuring, or indirectly by shifting grassland species composition and the quality of plant litter available to soil decomposers. Different members of an herbivore community may variably affect N cycling by feeding preferentially on different forage species in grasslands. However, nutrient cycling generally is enhanced by herbivores returning nutrients in dung and urine that are more readily accessible to soil microbes than nutrients in plant litter (Mikola et al., 2009). We therefore presumed that animal excreta might be an important pathway by which herbivores speed up N c ycling rate.

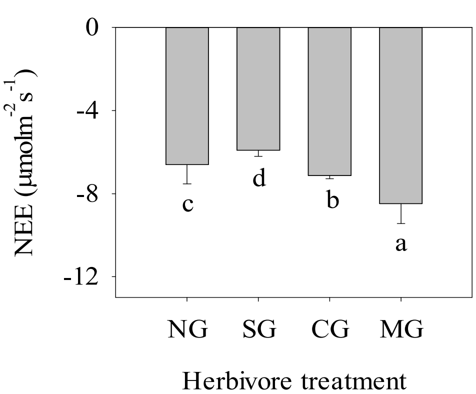


Figure 4. Seasonal means of NEE under herbivore assemblages.

Herbivore assemblages and ecosystem carbon flux

Grassland ecosystems carbon fluxes are critical for predicting future uptake of CO_2 in terrestrial ecosystems, and the variation of carbon fluxes greatly depends on how grasslands are managed for large herbivore. Grazing by large herbivores can alter ecosystem carbon fluxes by a series of biological and edaphic processes, and usually intensive grazing may change the strength of carbon flux or storage by decreasing plant biomass, and increasing soil respiration in grasslands (Wilsey et al., 2002). Our experiments showed that effects of grazing on ecosystem carbon fluxes strongly depended on herbivore assemblages ($F= 108.89$, $P < 0.001$, Fig. 4). Grazing by cattle alone significantly increased net ecosystem CO_2 exchange, but exchange was reduced under sheep grazing. However, the NEE was significantly higher under mixed grazing of sheep than under single-species cattle or sheep grazing. Therefore, mixed grazing of sheep and cattle could be considered an optimal grazing management protocol to help mitigate greenhouse gas emissions.

Conclusions and Implications

Effects of herbivore grazing on plant diversity, soil heterogeneity, and productivity, C, N cycling, strongly depended on herbivore species and combination. Herbivore assemblages should be considered an important affecting factor in future grassland management besides grazing intensity. Herbivore assemblages have varying effects based on different grassland functions. Sheep grazing can reduce plant diversity and NEE, but did not reduce productivity, nor improve the N cycling rate. Cattle grazing can improve diversity, soil heterogeneity, NEE and the N cycling rate, but may also greatly reduce productivity. However, mixed grazing could improve grassland multifunctionality including diversity, soil heterogeneity, productivity, NEE and N cycling rate. Thus, we suggested that mixed grazing of cattle and sheep could be considered an optimal grazing management protocol in steppe grasslands.

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Grazing Management for Biodiversity Conservation and Landscape Function in Semi-Arid New South Wales

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Key words: Conservation, grazing management, biodiversity, landscape function

Introduction

Domestic livestock are often seen as a threat to biodiversity, and exclusion of domestic livestock is the predominant method of conservation in western New South Wales (NSW). However, the adoption of alternative grazing strategies such as rotational, tactical and conservative grazing, as well as greater control over total grazing pressure, is leading to significant improvements in land management. There is evidence to suggest that appropriately managed livestock grazing is compatible with maintaining conservation values (Foran et al. 1982, Curry and Hacker 1990, Fensham 1998, Fensham et al. 2014), and can play an important role in enhancing the biodiversity value of agricultural landscapes, complementing the reserve system. Little research has been undertaken in the semi-arid rangelands of western NSW to understand this role. This study was a component of a broader PhD project exploring the implications of commercial grazing management practices for achieving biodiversity conservation and landscape function objectives, with an aim to determine the potential to integrate livestock production and conservation in the semi-arid rangelands of NSW.

Materials and Methods

Floristic surveys and landscape function analysis (LFA) were undertaken across 13 paired sites throughout north-western NSW, on both clay and sandy soils. Ungrazed areas currently managed for conservation, traditional grazing management (e.g. continuous or long rotation), and alternative grazing strategies (e.g. rotational, cell grazing, conservative stocking methods) were compared. Average annual rainfall at sites varied from 275 mm to 400 mm. At each site, three 1-ha plots were selected on either side of the fence separating each grazing treatment, and twenty-five 1-m^2 quadrats were arranged systematically within each plot. In each quadrat the percent cover of live plant material, litter, cryptogam, dung, coarse woody debris and bare ground was recorded. All herbaceous species (<1 m high) were identified and the percent cover of each recorded. Mammalian dung was also counted and assigned to species. Floristic surveys were undertaken in spring 2014 and repeated in autumn 2015. LFA was undertaken in autumn 2015 along a 100-m transect aligned through the center of each plot, following the protocols of Tongway & Hindley (2004). Indices of stability, infiltration and nutrient cycling potential, along with other landscape function indices, were generated. Species richness, evenness, Shannon's diversity and turnover were calculated from the floristic data collected. Multivariate analyses and linear mixed-effects models were used to explore the data and determine significant effects. Further analysis of functional trait composition and species rarity is currently being undertaken.

Results and Discussion

As expected, multivariate analysis revealed strong floristic differences in understory species composition between soil types and between property clusters of sites (due to local biogeographic differences). Recent and long-term rainfall was also an important driver of floristic variation. Differences between grazing treatments were less obvious and were inconsistent. Species richness and diversity were significantly lower under traditional grazing management compared to ungrazed and alternatively grazed sites in spring. However, no differences were detected between the grazing treatments in autumn (Figure 1a). There was no difference in species turnover between treatments. Total groundcover was significantly higher under no grazing, followed by alternative grazing (Figure 1b). There was no significant difference in the proportion of annual and perennial species between grazing treatments. Soil stability was significantly greater under no grazing (Figure 1c), but there was no difference in infiltration or nutrient cycling potential between grazing treatments. Total patch area, patch area index and landscape organization index were all significantly higher under no grazing, while average interpatch length was shorter.

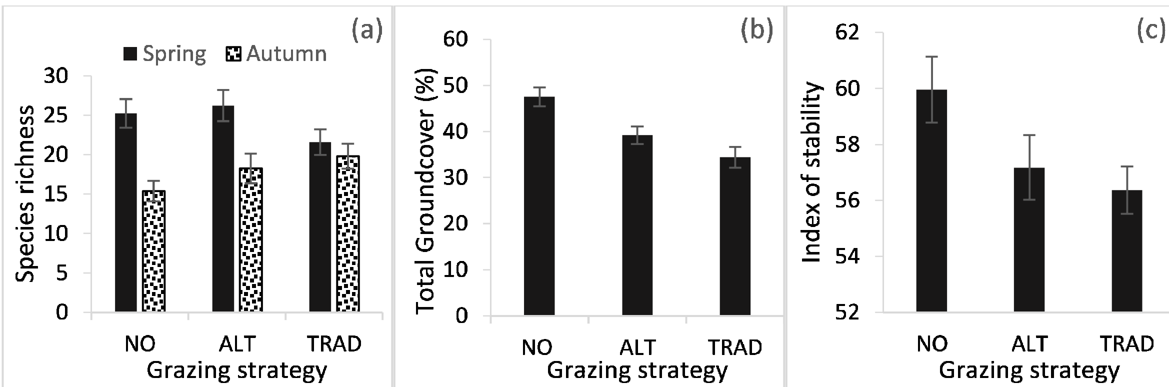

Figure 5. Pooled results (mean ± 1 s.e.m.) for (a) Species richness, (b) Total groundcover, and (c) Index of stability (NO = no grazing; ALT = alternative grazing; TRAD = traditional grazing management)

Conclusions and Implications

Initial results show differences in species richness, diversity and landscape function of rangeland vegetation under different grazing systems, although rainfall, substrate and bioregion were the dominant drivers of floristic variation. Alternative grazing strategies may be better at times than traditional approaches for biodiversity and landscape function. Further research is required to better understand the circumstances in which grazing might be compatible with achieving biodiversity conservation outcomes in the semi-arid rangelands, and the trade-offs associated with this.

Acknowledgements

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Efforts for Sustainable Pasture Management in Central Asian High Mountains: Implementation of the "Law on Pasture Use" in Kyrgyzstan – A Case Study

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Key words: Pasture management, grazing, resource degradation, Kyrgyzstan

Introduction

The predominant part (86.5%) of the land used for agriculture in the Kyrgyz Republic is permanent pasture (Ludi, 2003). Overgrazing has been a major problem, resulting in serious degradation of the vegetation (Liechtli, 2012). To improve this situation, a new "law on pasture use" was introduced in 2009. "Pasture Committees" are in charge of implementing grazing plans to allocate livestock on the pasture plots according to their actual carrying capacity (CAMP Alatoo, 2010). The aim of this study was to document and evaluate the implementation of the new grazing system on the basis of the animals' movements throughout the year and to show whether the law that took effect in 2009 has had initial positive results in terms of a more regulated use of the allocated pastures.

Materials and Methods

The study was conducted from June 2013 until August 2014 in the mountainous region of Naryn/Kyrgyzstan (2525 m ASL -3008 m ASL). The three investigated herds (herd A: 19 adult horses; herd B: 7 dairy cows; herd C: 200 sheep/goats) belong to one farmer, and the pastures he uses belong to the "Pasture Committee" of Zhergetal, which was amongst the first in Kyrgyzstan to have developed and adopted a binding pasture use plan (Camp Alatoo, 2010). The management of the observed herds is supposed to be representative of animal husbandry in Kyrgyz high mountain regions. All herds grazed freely in the mountains around the farmer's home (with herd C penned up during nights). The location of the farmer's home changes during July and August, as the family moves to the summer pasture with all the animals.

One adult, female, healthy animal from each herd was equipped with a GPS tracking collar (GPS PLUS by VECTRONIC aerospace). In herds A and B the collars stored one global position tracking point every 5 minutes (12 tracking points per hour, 288 per day, about 8640 per month) and in herd C only every 30 minutes (2 per hour, 48 per day, 1440 per month). Tracking points were assigned to the pastures ("summer pasture", "winter pasture", "outside own pasture") with ArcGIS 10.2. The percentage of tracking points on every "pasture type" was calculated with Excel 2010 for the whole observation period and per season (summer: June-August; autumn: September, October; winter: November-March; spring: April, May).

Results and Discussion

During the entire observation period, herds A and B grazed predominantly (A: 77.5%; B: 82.8%) outside the pastures allocated to the farmer owing them. They grazed only very seldom on the summer pasture (A: 1.1%; B: 0.3%) and occasionally on the winter pasture (A: 21.4%; B:16.9%). In contrast, herd C (ewe) stayed mostly (61.2%) on the winter pasture, only 0.1 % on the summer pasture and 38.7% outside the farmer's own pastures. Considering that herd C was penned up during the nights on the winter pasture in 11 out of 15 observation months, 61.2% also implies a rather low percentage of utilization of the farmer's own pastures during the actual grazing time. Figure 1 shows that the use of external pastures occurs the most during summer (for horses also during winter) and the least during spring and autumn. The rather good use of the farmer's own pastures seems to be due to a better fodder supply in spring (most vegetation growth) and autumn (2 month rest for the vegetation during the time of "summer pasture"). The high utilization of external pastures in summer is partly due to the farmer's summer residency on the "summer pasture", which is not located on his own (leased) pastures. During winter, horses and cattle mainly used external pastures (A: 88.4%; B: 76.0%), probably due to shortage of fodder on the farmer's own pastures.

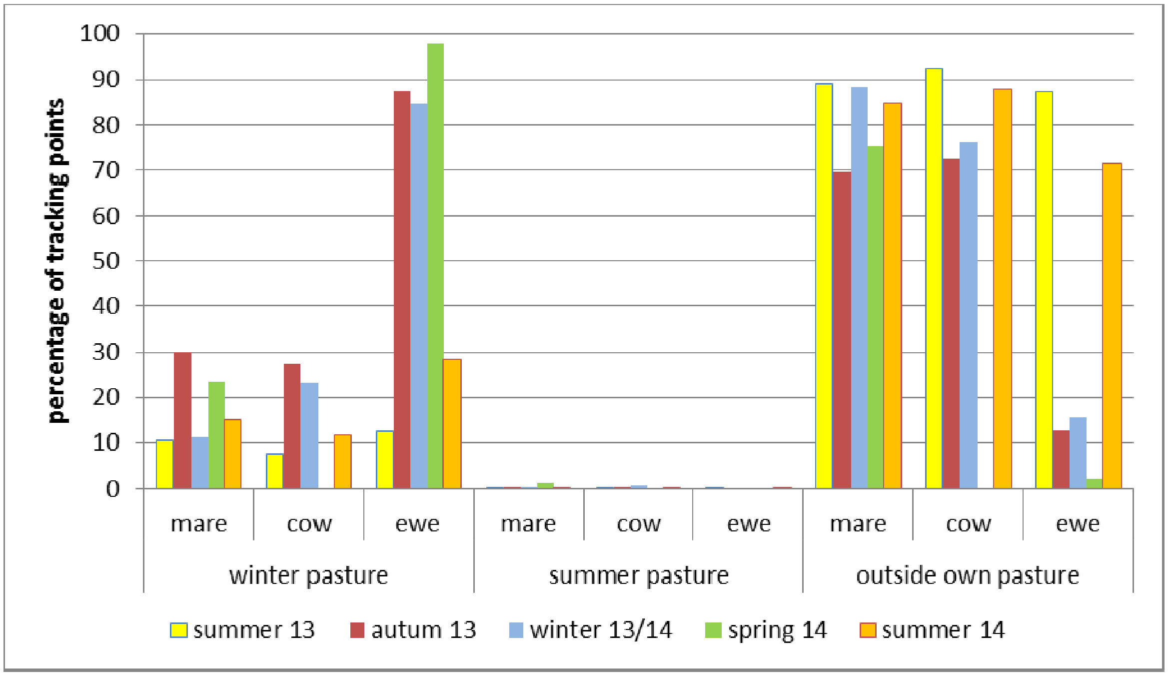

Figure 1. Utilization of pastures per type of pasture and season (cow: no data available for spring 14).

Conclusions and Implications

The current study shows that the new "law on pasture use" did not lead to a more regulated grazing system in Naryn. Considering that pasture users have to pay fees for their right to use certain pastures (based on the quantity and composition of their livestock; CAMP Alatoo, 2010) it is astonishing that the pastures found to be actually grazed on by the animals match only to a small degree with the areas the farmer leased for them. The animals continue grazing unattended in the mountains, which makes a selective use of pastures actually impossible. The current grazing practice does not allow resting periods for heavily used pastures, nor does it enable the allocation of livestock on the pasture plots based on their actual carrying capacity, as the "law on pasture use" demands. In order to reduce degradation, it would be vital to know how many animals are on which pasture plot for how many days. To achieve this knowledge, more efforts are required to keep the animals in their allocated pastures.

Acknowledgments

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Spinescence and the Keystone Plant *Acacia tortilis* ssp. *tortilis* in the Arid Middle East: Adjusting Architecture to Deter Different Herbivores

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Key words: Herbivory, niche partitioning, branching intensity, dry matter allocation

Introduction

Plant communities in arid regions of the Middle East experience heavy ecological stress. Livestock grazing by camels, goats and sheep exerts severe pressure on the keystone tree, *Acacia tortilis* (Forssk.) Hayne subsp. *tortilis*. However, these herbivores have different foraging strategies, where camels browse entire twigs, goats and sheep pick at leaves, and they do not all compete for the same parts of the tree (Bartolome et al., 1996; Anderson et al., 2014). *Acacia tortilis* uses avoidance and tolerance (*sensu* Hegazy and Lovett-Doust, 2016) as strategies to resist the impact of multiple grazing animals. Here, we test the hypothesis that patterns in spinescense and other functional traits reflect localized, modular responses to contrasting livestock grazing.

Materials and Methods

Acacia tortilis may grow up to 6-8 m in height. The spiny stipules are either straight and sharp, or hooked/recurved and short. Acacia trees are an important fodder year-round for domestic livestock. Camels usually browse the upper and intermediate zones of the crown, while goats and sheep graze intensively in the lower strata. We identified four broad zones in the tree canopy: first the ungrazed zone (> 4 m above ground); second, the upper grazing zone (accessible only to camels (at 2-4 m); third the intermediate zone, grazed by a combination of camels and goats (at 1-2 m); and fourth the bottom zone (0-1 m above ground), which is grazed by goats and sheep.

In each canopy zone, branching density was estimated as number of branches per 20 cm^3 of canopy volume. Internode lengths were determined using 10 cm lengths of twigs or old branches, and counting the number and type of spines. Dry matter allocation to different tissues was measured in flowering twigs during the peak flowering season. There were five replicates from each of the four strata, on each of five different representative trees. ANOVA, LSD and Duncan's multiple range tests were used in data analysis.

Results and Discussion

The trees of *A. tortilis* are defended by plastic traits, which limit damage to plant organs and tissues due to intensive camel browsing and grazing by goats and sheep. Changes in canopy shape reflect localized responses to the different grazers active in different vertical zones of the tree canopy. The camel-browsed and ungrazed zones in the upper part of the tree show less branching and longer internodes (which helps "move" foliage and fruits out of reach of camels). In contrast, in the lower zone that is heavily grazed by goats and sheep, we see significantly more branching and shorter internodes (Fig. 1). This creates an impenetrable interior to the canopy with more hard, straight spines and fewer hooked spines. Upper layers have more "hooked" spines (Fig. 2).

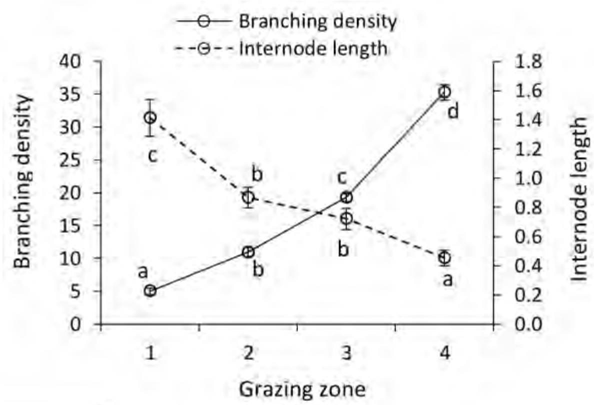

Figure 1. Branching density (solid line) (#per 20 cm³), and average length of internodes (cm) (dotted line) in the four vertical zones of *A. tortilis* trees. Vertical bars around the means are the standard errors. Different letters indicate significance at P≤ 0.05. Zones correspond to 1 = unbrowsed/ungrazed (> 4m); 2 = camel-browsed (2-4 m), 3 = grazed by goats and browsed by camels (1-2 m), and 4 = grazed by goats and sheep (0-1 m).

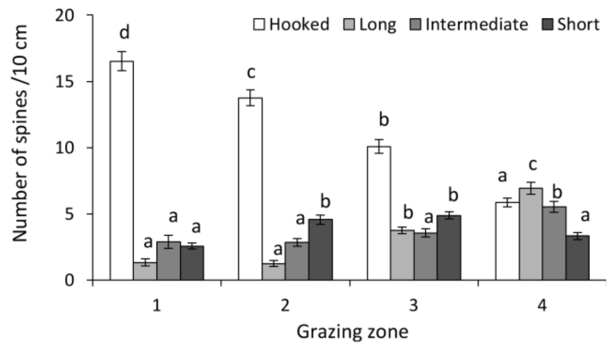

Figure 2. Density of spines (# per 10 cm stem). Vertical bars around the means are the standard errors. Different letters indicate significant differ-ences at P≤ 0.05 within the same category of spines. Hooked spines (0.1-1.0cm). Straight short spines (1-2cm), straight intermediate spines (2-4cm), and straight long spines (4-6cm).
Grazing zones: 1= unbrowsed/ ungrazed (> 4m); 2= camel-browsed zone (2-4 m), 3= zone grazed by goats and browsed by camels (1-2 m), and 4= grazed by goats and sheep (0-1 m).

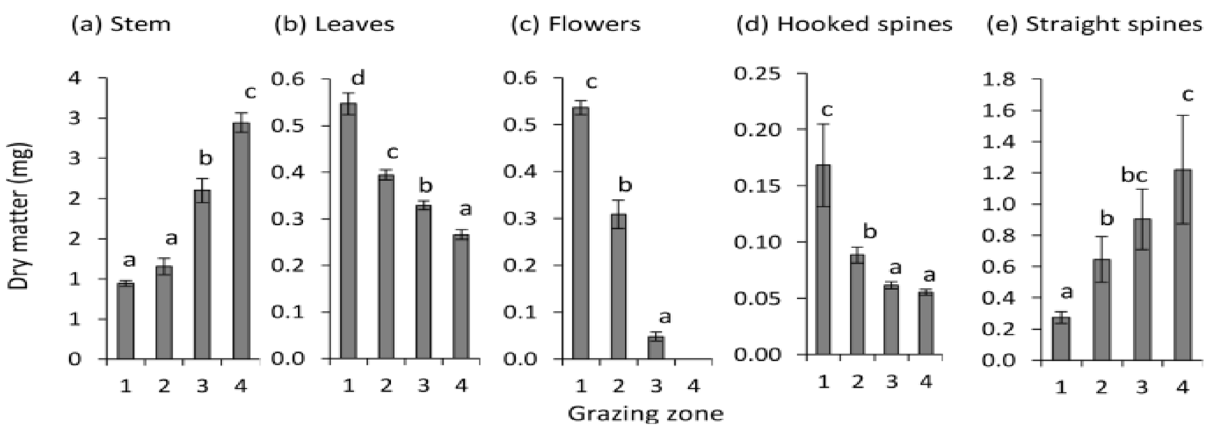

Figure 3. Dry matter allocation to different plant organs in the four grazing zones. Vertical bars around the means indicate the standard errors. Different letters indicate significant differences at P≤ 0.05 within the same organ or tissue type. Grazing zones correspond to 1 = unbrowsed/ungrazed (> 4m); 2 = camel-browsed zone (2-4 m), 3 = zone grazed by goats and browsed by camels (1-2 m), and 4 = grazed by goats and sheep (0-1 m).

Dry matter allocation to different tissues differed among the four vertical zones of individual *A. tortilis* trees (Fig. 3). Allocation to foliage and reproductive organs was greater in the upper, unbrowsed and camel-browsed shoots (zones 1 and 2) than in the shoots grazed by goats and sheep in the lower zones. In contrast, dry matter allocation to hard, straight spines was significantly greater in the lower two zones than in the upper zones of the tree. Flowering in (lower) grazed shoots was sporadic and tended to occur later than flowering in the upper ungrazed and browsed shoots, which showed peak flowering in spring.

Conclusion and Implications

The contrasting, “re-modelling” of vertical zones within *A. tortilis* trees enhances plant fitness, and reflects responses to the particular impacts of herbivores (Marquis, 1996). Vertical niche partitioning, within the canopy, induces different responses. Plasticity is seen as induced defenses (hooked spines being used to defend against camels, straight spines against sheep and goats), resistance mechanisms (dense branching) and avoidance (longer internodes) (see also, Fornoni 2011). The overall effect is to enhance individual survival and maximize evolutionary fitness.

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Multi-Decadal Cow Size Changes and Rangeland Grazing: A Cryptic Trend Altering Plant–Animal Interaction Ecology and Impacts for Grazing Decisions

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Introduction

Cows have been getting bigger over the last four decades due to rapid advancement of genetic sources and selection information. In contrast, rangeland forage production has likely not increased. The result is that cattle genetics and forage requirements may have surpassed low-production rangeland environments. I will present data demonstrating these multi-decadal changes and evidence indicating these trends have been cryptic and un-recognized until recently. I will demonstrate this cow size trend has altered ecological interactions between plants and animals and management implications using data from a Wyoming study that assessed cow size in a semi-arid rangeland environment. This study assessed 80 cows stratified by five weight classes [1,000 lb (454 kg), 1,100 lb (499 kg), 1,200 lb (544 kg), 1,300 lb (589 kg), and 1,400 lb (635 kg)] over a four year period from 2011-2014.

Temporal Dynamics of Cow Size and Rangeland Productivity

Data from the United States Beef Improvement Federation (BIF) and the National Slaughter Cattle Summary have quantified multi-decadal trends related to animal size and milk production in beef cattle. The average mature beef cow in the United States weighed 1,047 lb (475 kg) in 1975, but in 2009 weighed 1,350 lb (612 kg), an increase of 303 lb (137 kg) (McMurry 2009). Furthermore, an estimated 16% of beef cows in the United States weighed over 1,500 lb (680 kg) in 2010, or more than 5 million cows (American Cattleman 2010). This increase in cow size has largely been driven by selection of genetics that optimize growth traits. Growth-based genetic strategies have been applied via breed selection, cross-breeding heterosis, and Expected Progeny Difference (EPD) data. This genetic influence on growth and size is evident in adjusted across-breed EPD comparisons for yearling weights that indicate a > 100 lb (45 kg) increase for Hereford, Red Angus, and Black Angus since 1972 (Kuehn and Thallman 2013). Similar comparisons indicate that growth and milk production are related as several breeds have demonstrated a ~10 lb (4.5 kg) increase in maternal milk EPDs (Kuehn and Thallman 2013). In contrast, forage production from rangelands, although it is dynamic and non-equilibrial relative to precipitation patterns, has not appreciably increased during the same time window (Lauenroth and Sala 1992). If any trend has had an effect on forage production, it is an increase of the frequency and magnitude of droughts that reduces production. Although predicted changes in precipitation and temperature are variable geographically across the US (i.e., Northern Great Plains expected to be wetter but hotter while Southwestern US and Southern Great Plains expected to be drier and hotter), forage biomass production from rangelands has not increased and may decrease episodically in some regions.

Cryptic Trends?

Because these trends have occurred across several decades, they have been incremental and arguably cryptic, unnoticed until lately. This lack of recognition is evident in the way state and federal grazing fees are based on a per head basis, rather than an Animal Unit (AU) basis (Russell and Feuz 2015). Furthermore, as ranches have been passed down through generations, new generations may perceive ranch carrying capacity to be a set number of animals. This perception is likely not true for most ranches because the cows of today are much larger than the cows of yesterday. These trends alter the plant-animal interaction ecologically because larger cows require more forage for maintenance. Other effects include reduced longevity of larger cows as Doye and

Lalman (2011) reported that 1,400 lb (635 kg) cows produce one fewer calves than 1,100 lb (499 kg) cows. Furthermore, the larger cows may have a reduced calving rate up to 7% lower (Doye and Lalman 2011).

Impact on Rangeland Grazing

As cow size increases, forage intake requirements also increase proportionally because larger cows have a larger rumen, larger proportion of body mass comprised of visceral organs, probably higher milk production, and greater nutritional maintenance requirements. In high-production environments, such as improved pastures, larger cows may wean heavier calves, however in low-production environments, such as western North American rangelands, this is not the case. Our study in Wyoming reported that across years, there was no weaning weight advantage associated with larger cows as 1,000 lb (454 kg) cows weaned similar weight calves as 1,400 lb (635 kg) cows (Scasta et al. 2015). Furthermore, the smallest cows always had higher relative efficiency measured as calf weight:cow weight and only the 1,000 lb (454 kg) cows achieved an efficiency of 0.5, indicating they weaned 50% of their body weight (Scasta et al. 2015).

If the slow and incremental trend of increasing cow size has been unnoticed, and the assessment of grazing fees or determination of stocking rates do not account for the effect of relative cow size to forage supply and demand, areas grazed by the same number of cows long-term may be over-grazed. Although this cow size trend is recently recognized in the animal science discipline and livestock production sector in general, rangeland managers that are making grazing decisions need to made aware and factor this into stocking rate calculations using Animal Unit Equivalents (AUE) that relate the concept of metabolic weight to daily forage intake (Allen et al. 2011). Although the AUE concept is not new, using actual cow weights for calculations is not always possible or applied. It is also prudent to not only consider production EPDs like Weaning Weight and Yearling Weight, but also consider maternal EPDs such as Maternal Size and Maternal Milk. These maternal EPDs can be optimized to exert downward pressure on size and milk and eventually reverse the trend by obtaining more moderate sized cows as replacements enter the herd. Finally, it is important to consider that more small to moderate size cows can be economically advantageous because overhead costs can be spread over more animals and more cows equal more calves and potentially greater total pounds weaned. This focus on smaller more-efficient cattle has been the focus of ranchers in Wyoming (Waggener 2015). Because rangeland forage grazed by roaming cattle is the most economical nutrient source, matching cow size to forage resources to optimize forage utilization should be integrated into the grazing decision.

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Litter Retention – Some Is Good, But Can There Be Too Much of a Good Thing?

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Keywords: Litter carryover, rangeland health

Introduction

Litter retention in rangelands improves soil moisture conditions by reducing evaporation and runoff; the improved moisture conditions frequently will improve grassland productivity (Deutsch et al. 2010; Xiong and Nilsson 1999). These well-known relationships have been incorporated into many rangeland health assessment methods (Saskatchewan PCAP Greencover Committee 2008). Such methods, however, often do not incorporate an upper limit to litter. In other words, while there is consensus that increasing litter carryover on sites with little litter retention will be beneficial, the consequences of very high litter accumulations are not considered. Here we assess the effects of very high litter mass on grassland productivity and diversity in a native, mixed-grass prairie.

Materials and Methods

Litter addition experiments were conducted on 18 sites on loam ecosites over brown and dark brown Chernozem soils in central Saskatchewan, Canada in 2011-12. Full site descriptions and methods can be found in Letts et al. (2015). Briefly, at each site 30 plots were established in the fall and a series of litter additions ranging from 0 to 2290 g m^{-2} were made to each plot. Annual net primary productivity (ANPP) and plant community composition were measured in the following growing season. Generalized additive models (GAM) were used to examine the non-linear relationships between litter mass and the response variables. AIC based model selection was used to identify significant differences between soils and sampling years.

Results

Total ANPP peaked at a moderate amount litter mass in both the brown and dark brown Chernozems. The shape of the litter-ANPP relationship was significantly different between soils with ANPP peaking between 50 and 380 g m^{-2} litter on the brown Chernozems and between 30 and 180 g m^{-2} in the dark brown soil (Figure 1). Plant community diversity declined with increasing litter mass in both soils, with the steepness of the decline increasing at litter mass greater than 100 g m^{-2}.

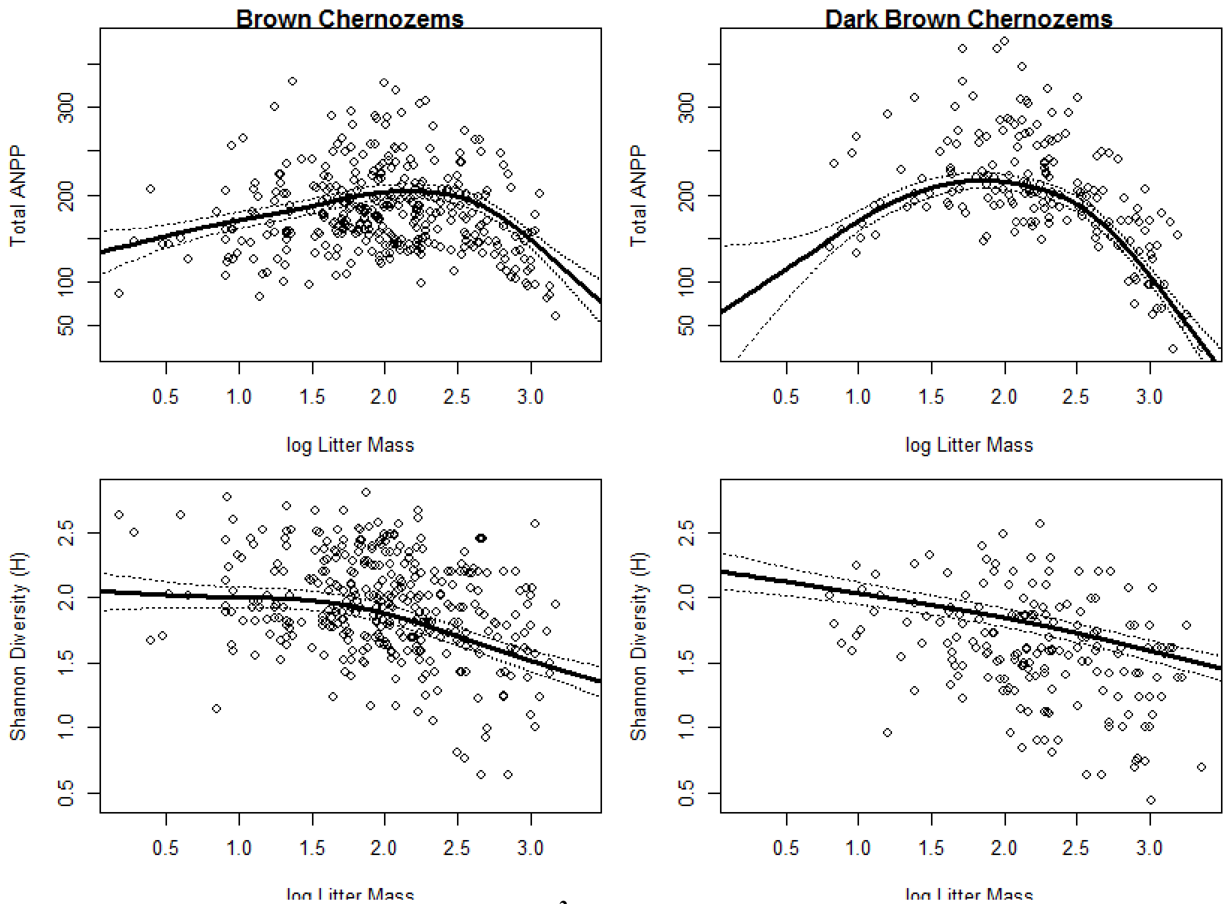

Figure 6. Relationships between ANPP (g m^{-2}) and plant community diversity and litter mass (g m^{-2}) in the brown and dark brown Chernozems in Saskatchewan. Dark lines represent the best fit Generalized Additive Model (GAM) relating the two variables; dotted lines are 1 standard error around the predicted line.

Discussion

Moderate amounts of litter clearly provide significant ANPP benefits in this semi-arid system. Current recommendations are that a healthy mixed grassland on a loam ecosite should have 672 kg/ha of litter (Saskatchewan PCAP Greencover Committee 2008). Here peak ANPP of 2040 kg ha^{-1} was achieved with 1380 kg ha^{-1} of litter on brown Chernozems and peak ANPP of 2166 kg ha^{-1} with 690 kg ha^{-1} litter on dark brown Chernozems. The declines in diversity with increasing litter are in large part caused by the selective removal of forb species from the system, resulting in greater grass dominance at intermediate to high litter mass (Letts et al. 2015). The current recommendations for litter in the rangeland health guides work well in the moister dark brown Chernozem soil zone, however these results suggest that guidelines for litter retention on drier mixed grass rangeland on brown Chernozems need to be revised.

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Grazing Management Practices in the Rangelands of Nepal

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Key words: Rangeland, grazing, livelihood, management

Introduction

Rangelands are part of Nepal's historic as well as religious heritage. They occupy 22.60% of the total area of the country and occur in each of three ecological zones, comprising high, mid and terai regions of the country (Rangeland Policy, 2011). Out of the total area of 3.326 million hectares occupied by the rangelands, about 94% of the rangelands are situated in the hills and mountain regions while only 6 % rangelands are in the Siwaliks and Terai regions of the country. Beside these, 28.27% of the total rangeland area is occupied by the rangelands inside the Protected Areas (LRMP, 1986). About 57% of the country population reside either in rangeland ecosystems or adjacent areas, and are directly or indirectly dependent for their economic development on rangeland resources. Rangelands also provide habitats for a variety of wildlife and large grazing animals, which share rangelands with a host of birds and other mammals (including some endangered species like snow leopards). Vegetation cover of rangelands increases infiltration, and reduces run-off and erosion. Finally, the tourist industry in Nepal is based, in part, on the attractiveness of its rangelands' wildlife and surrounding magnificent mountain landscapes (Dong, *et. al.* 2007).

Rangeland policy endorsed in 2011 recognizes the rangeland of Nepal as a rich source of biodiversity of food and forage crops, animals, medicinal plants, and its conservation and utilization has been given a high priority. However the productivity of these rangelands has been adversely affected due to overgrazing, human encroachments and tourism has also lead to the deterioration of these rangelands along with the loss of valuable diversity. Only 37% of the forages produced in rangeland are being utilized at present. Production and productivity of these rangelands however vary from 0.65mt DM/ha/Yr to 3.60 mt DM/ha/Yr (Rangeland Policy, 2011). Thus, a proper management and utilization strategy of rangeland is necessary to improve the livelihood and income generation opportunity for the Nepalese people.

Materials and Methods

The study is primarily based on desk reviews of available secondary information, workshops, and consultation meetings. Secondary data were obtained from concerned offices of Department of Livestock Services, National Pasture and Animal Nutrition Center, Pasture and Fodder Division, Khumaltar and Pasture Research Station, Rasuwa. Similarly consultation was done with rangeland experts and responsible personnel. Their experience, suggestions and approvals for the future strategies of rangeland management and its implementation were obtained for the preparation of this manuscript.

Results and Discussion

Status of rangelands of Nepal

Range and pasture production is heavily reliant on the biophysical characteristics of the natural resource base; soil quality and water availability influence a region's suitability for grass production and are among the primary determinants of rangeland productivity in Nepal (Shrestha and Sanjyal, 2010). A series of change within the climatic pattern of vegetation, increase in livestock number and life style of the people as more and younger generation attracted towards city jobs has resulted in the deterioration of the rangeland conditions over many years. Loss of palatable species, invasions of poisonous plant species, low dry matter productivity of range plant species, overgrazing and high stocking density, and poor animal healthcare practices are major issues for rangeland improvement (Pariyar, 2014). Over and continuous grazing has negative effect on the existence of rangeland species like *Carex* and *Poa* and replacement with invasive weeds like *Anemone elongata*, *Chorophytum spp*. and *Pieris Formosa* has made it worse. Most of the rangelands are over-stocked, and are severely overgrazed. As result, experts estimate that the rangeland productivity has been declined by 50% nation-wide over the years. . Furthermore, migration of youths in search of better jobs has exacerbated the fortune of these rangelands. The only figures left behind to look after these rangelands are elderly people with less energy and poor health.

Rangeland Management practices followed by herders in Nepal

Herders in Nepal have been utilizing their traditional knowledge in the management of rangelands for centuries. They basically follow three systems of rangeland management. A sedentary system of grazing is followed in terai regions (<500 masl**)** where winters are not so severe to pose serious problems of feed scarcity. A sedentary-cum-transhumance system of grazing prevails in the hilly regions (500- 2500 masl), and a transhumance system of grazing prevails in the mountain regions (> 2500 masl) where animals are moved seasonally from lower altitudes to higher altitudes and vice versa. This system is practiced in the mountain region where winters are very severe, leading to feed scarcity (Pariyar, 2014).

Herders usually use indigenous indicator to move the animals from one plot to the other in every 10-15 days. They practice rotational grazing on a regular basis and also manage the stocking density according to herbage availability. Grass cover, species composition, soil appearance from the vegetation, production parameters like milk yield, body weight, mating frequencies are other indicators used by the herders. As a management option, some cover the land with stones or reseed their grassland as they move to another grassland. There are fixed migratory routes established and maintained for each livestock species (cattle, sheep, goat and yak) in response to variations in topographic features, climatic conditions, demand for forage and availability of pastureland. The carrying capacity is also calculated using a well-defined method by the herder groups to ascertain the stability of each pasture for a fixed number of animals. Besides the indigenous knowledge of the farmers, research and extension services have also been working with herders in an integrated approach to improve the rangelands.

Conclusions and Implications

Rangelands are the major source of feed for a large proportion of livestock population, and are socially and culturally linked with the peoples of Nepal. Currently, the rangelands have been managed by herders based on the their indigenous knowledge, however there is still room to improve the productivity of these rangelands and make the business lucrative for the young people by developing techniques that can be locally adaptive and also profitable. Finally, a holistic approach to the implementation of rangeland management strategies should be undertaken from the research and development agencies jointly.

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Interactive Effects of Grassland Plant Diversity and Herbivore Grazing on Litter Decomposition

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Key words: Herbivore grazing; leaf litter decomposition; plant functional group diversity

Introduction

There is general concern that loss of plant diversity will impact litter decomposition (Gessner et al., 2010). Large herbivore grazing, as a major land use in grasslands, might change the plant diversity effects on litter decomposition through directly altering species composition and average quality of litter mixtures (Sasaki et al., 2008), and by indirectly changing soil microenvironment (Bardgett and Wardle, 2003). But there is as yet little evidence for whether and how herbivore grazing modifies plant diversity effects on litter decomposition. This study examined the effects of altering plant functional group diversity and herbivore grazing on litter decomposition in meadow steppe of China.

Materials and Methods

This study was conducted in a fenced area (~750 ha) at the Songnen Grassland Ecological Research Station, China. Within the fenced area, six 100 m × 100 m plots were randomly selected in 2010, three of the plots were grazed by sheep at a moderate intensity (SG), the other three plots were ungrazed (NG). Two pairs of 4 m × 4 m subplots with low and high plant functional group diversity (LFD and HFD) were selected within each plot. Within each subplot, litterbags with dominant species (*Leymus chinensis*) leaf litter were randomly distributed in three locations in June 2012. Litterbags were collected after 2 months (short-term) and 14 months (long-term) respectively, and the litter dry weight was then measured. Soil samples were collected for analysis of soil microbial biomass C. A vegetation survey was conducted and plant functional group diversity index (FDI) was calculated.

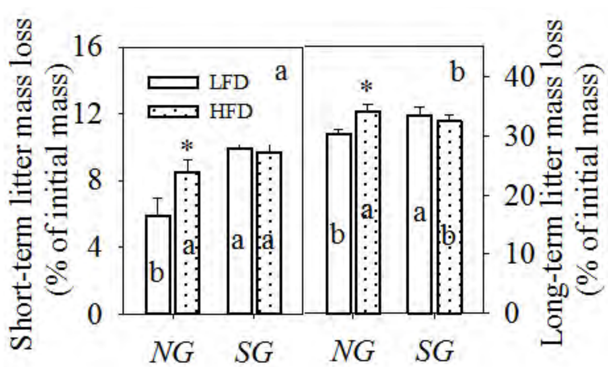

Figure 1. Effects of plant diversity on litter mass loss in the NG and SG treatments. Asterisks indicate significant difference between the LFD and HFD. Different letters indicate significant difference between NG and SG within plant functional group diversity（P<0.05).

Results and Discussion

Plant functional group diversity significantly increased litter mass loss (short-term: t_{10} = -2.827 P = 0.018; long-term: t_{10} = -3.494 P = 0.006; Fig. 1). However, there were not significant differences in litter mass loss between low and high plant functional group diversity (PFD) treatments when herbivore was present (short-term: t_{10} = 1.212 P = 0.253; long-term: t_{10} = 1.662 P = 0.128; Fig. 1). We found that herbivore grazing has contrasting effects on litter decomposition at different diversity sites. Herbivore grazing

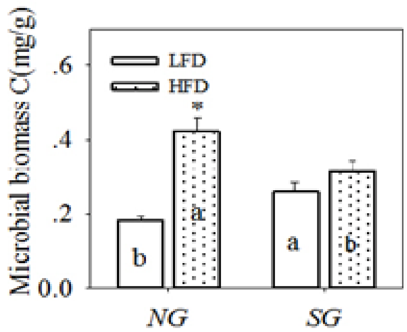

Figure 2. Effects of plant diversity on soil microbial biomass C in the NG and SG treatments. Asterisks indicate significant difference between the LFD and HFD. Different letters indicate significant difference between NG and SG within plant functional group diversity (P<0.05.)

significantly increased litter mass loss at low diversity sites (short-term: t_{10}= -5.488 P = 0.000; long-term: t_{10}= -2.557 P = 0.029; Fig. 1), while grazing had no effects on short-term litter mass loss (t_{10}= -0.348 P = 0.735; Fig. 1a) and significantly reduced long-term litter mass loss at high diversity sites (t_{10} = 2.365 P = 0.040; Fig. 1b). Plant diversity and herbivore grazing could affect litter decomposition rate by influencing the organisms that drive decomposition (Guenay et al., 2013). Our results showed that soil microbial biomass was significantly higher in high PFD treatments than in low PFD treatments under ungrazed conditions ($t_{6.002}$ = -6.641 P = 0.001; Fig. 2), which could promote litter decomposition. Furthermore, herbivore grazing significantly increased at low plant diversity sites ($t_{6.984}$ = -2.847 P = 0.025; Fig. 2), but decreased soil microbial biomass at high plant diversity sites (t_{10}= 2.369 P = 0.039; Fig. 2). At low diversity sites, the improved soil microbial biomass probably resulted from herbivory-induced increases in root exudate of grass species. At high diversity sites, sheep grazing significantly decreased plant diversity due to high preference for forbs and legumes ($t_{6.758}$= 4.516 P = 0.003; Fig.3), which could result in reduction of soil microbial biomass.

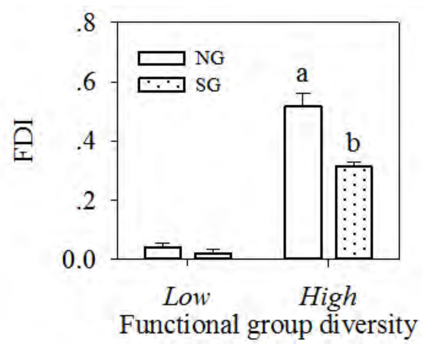

Figure 3. Effects of grazing on plant functional group diversity index (FDI) in the LFD and HFD treatments. Different letters indicate significant difference between NG and SG within plant functional group diversity (P<0.05)

Conclusions and Implications

Plant functional group diversity significantly accelerated litter decomposition in grassland. This result highlights the importance of protecting plant diversity to nutrient cycling and ecosystem functions. Herbivore grazing resulted in disappearance of plant functional group diversity effects on leaf litter decomposition, which was attributed to different responses of litter decomposition to herbivore grazing in low and high plant diversity grasslands. At low diversity, grazing greatly improve litter decomposition. This study indicates that herbivore grazing can alleviate the negative effects of loss of diversity on litter decomposition. Therefore, herbivore grazing might have a regulatory role in keeping litter decomposition rate at a moderate level in the face of plant diversity decrease in grassland ecosystems.

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Managing the Land and Vegetation: The Conundrum of Livestock Performance versus Vegetation Response

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Key words: Grazing management, monitoring, indicators, decisions

Introduction

Grazing management is the application of the science of both livestock performance and plant response to defoliation. The best managed systems find an optimum mix of these two primary outcomes. However, the outcomes are predicated on much more complex systems of processes than one would initially assume. Individual plant and community responses are driven by ecological processes. The animal response is driven by forage quality on offer relative to the needs of the animal. This relationship is dynamic over time and space. Because ecological processes cannot be seen or directly measured, it often must fall to "monitoring" indicators of response. These indicators are based on the best known science and consistent observation of system dynamics. Managing the system must rely on operational knowledge of response variables to adequately determine reliable outcomes. This paper will discuss use of science-based qualitative monitoring, observation of indicators of response, and of longer term measures to manage grazing responses.

Materials and Methods

The approach discussed here is a combination of many field research and 40 plus years of experience as both a grazing manager and field advisor to those managing grazing.

Results and Discussion

Animal Responses

It is often assumed that the best grazing approaches maximize livestock performance. In rangeland environments, this is both unachievable and is undesirable; given that maximizing anything in an ecological system always constitutes losses in other system attributes. Thus determining acceptable livestock response is a function of the risk that the operator is willing to accept on both the livestock and plant responses. As relative forage quality on offer declines per unit of time (hour, day, month, season) and per unit of demand (kg/100 weight of body size) the per animal performance declines) with it. (Hart et.al, 1988), i.e., the stocking rate relationship. As stocking rate increases, performance decreases. The universal truth of this means that the manager must chose an outcome acceptable to him or her, then manage within that forage environment. The forage environment is also dynamic over time. As animals consume forage they inherently consume the highest quality, palatable material within their search path. This causes a depletion of the high quality material. This rate is determined by the stocking rate and the renewal of green material. This is accentuated by the seasonal decline in forage quality caused by plant growth and development (Rittenhouse and Roath, 2002). The gains achievable early in the season cannot be maintained toward the end of the season without reducing stocking rate or moving animals to a new forage environment to begin the depletion process again. Lower stocking rates sustain gains longer in the season but will not compensate for seasonal changes in forage quality. (Rodriguez and Roath, 1987)

There is no one correct stocking rate. The choice of lower requirement animals and/or smaller body size reduces the apparent stocking rate and increases the per capita output from the forage environment. It also reduces the risk of not achieving an acceptable outcome. Monitoring of this is a function of recognizing the forage environment over years and adjusting both the total demand and choosing the best animals to fit the environment.

Plant Responses

Individual plant performance is a function of degree of defoliation, frequency of defoliation and the opportunity of the plant to grow or to regrow each year. It is critical for plants to achieve a full array of green leaves every year (Briske et. al, 1991). When this is precluded, the individual plant is harmed and ultimately, the plant community is impugned. While this full array of green leaves is critical to the plant, the same material is the driver for grazing animal response. It becomes incumbent on the manager to understand the needs of the plant because the future of the ranch operation is dependent on the health the plants and the plant community while balancing animal performance outcomes.

The individual and composite plant performance is not only a driver for those plants but it manages the ecological function of the system. The array of leaves fixes photosynthate required by the plant to produce tillers, growing points and roots, but also manages water capture and infiltration in the physical environment. The invested carbon structures in the soil in the form of soil organic matter and the root exudate feed the soil microbes. The complex below soil surface environment determines the plant nitrogen availability, manages water, and determines soil aggregates.

Most plants that are defoliated are defoliated severely removing and much or most of the highly active photosynthetic material is removed. It becomes critical to allow the plant an opportunity to produce a full array of leaves outside of the grazing period, either before or after defoliation. This means the grazing manager must arrange for some grazing deferment during the growth period of the plant to allow the full array of leaf material to develop. Partitioning the growing season in to time of use or use then allows the plant to achieve its needed allocation energy and provide of the function of the system while meeting the needs of some animals. It becomes obvious that deferring all use plants during the growing season maximizes plant response but also minimizes forage quality on offer to the animals.

Conclusions

The informed grazing manager uses indicators of both plant and animal response to achieve desired outcomes. The animal indicators can be rate of gain, body condition and total gain while the plant response indicators are frequency, intensity and opportunity of grow (Reed et.al, 1999).

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Improving the Production of Grazing Lands Using Different Management Practices in West Shoa Zone of Ethiopia: The Case of Ejere District

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Key words: Grazing land improvement, ash, manure, lime, urea.

Introduction

Ethiopia has the largest livestock population in Africa. It is also among the 28 smaller countries (25 in Africa) where grazing land accounts >60% of the total land area (White *et al*., 2000). However, the grazing lands are degrading due to increased conversion of grazing lands to croplands and other factors (CSA, 2012).This study examined the effect of applying different improvement techniques on biomass production and grazing capacities of the grazing lands.

Materials and Methods

The study was undertaken in Ejere district, West Shoa zone, Ethiopia, having a mean annual rainfall of 900 to 1,200 mm and mixed crop livestock production system. Crop residues, natural pasture, improved forage, hay, agro-industrial by-products and others contribute as livestock feed (CSA, 2012). In site selection, which was undertaken with the help of farmers, livestock experts and development agents, the representativeness of the site for grazing lands in the mid altitude (2,378 meters above sea level), and poor herbaceous production condition of the site was taken into consideration. Fifteen plots of 4 m x 4m were laid out to apply 5 treatments, i.e., Urea and Diammonium phosphate (DAP), wooden ash and cow manure from farmer, limestone purchased from local market, and untreated control randomly in 3 replications. The plots were fenced during the main growing season (July to November, 2015). The distance between plots and replications/blocks was 1 and 2 meters, respectively. The amount of urea and DAP, limestone, ash and dry manure applied on 16-m^2plots were 0.24 kg and 0.16 kg, 3.2 kg, 4.8 kg and 12 kg, respectively. The plots were ripped to incorporate the treatment materials into the soil. The manure was decomposed for three months at backyards of farmers and dissolved in water and added into the soil in form of slurry. Ash and lime were scattered over the plots. Urea and DAP was over sown by broadcasting. The treatments were applied after the beginning of main rainy season. At the end of the growing season, the different plots were harvested using hand sickles and sorted into grass, and non-grass components. The sorted materials were oven-dried at 65 °C for 72 hours. Analysis of variance (ANOVA) was conducted to verify the significant differences among the treatments using the STATA/SE 14 program. Grazing capacity (GC) was estimated using the formula proposed by Moore *et al*. (1989). The GC was calculated using tropical livestock unit (TLU) for an animal weighing 250 kg consuming 2.5 % of its body weight and utilization factor of 0.5 (50%) was used (ILCA, 1990).

Results and Discussion

Grass dry matter yield was highest ($P<0.02$) in urea and DAP -treated plots (Table 1). Compared with the control, application of ash, limestone, or manure increased grass production although it was non-significant ($P>0.05$). On the other hand, the non-grass biomass was the highest in manure-treated plots although not significant. Application of ash produced more non-grass biomass than the control and limestone plots. Urea significantly increased ($P<0.02$) total biomass production. While the control and limestone treated plots were the least in total biomass production, ash and manure applications were comparable in total biomass. Urea and DAP application improved total biomass because they are excellent source of soluble nitrogen (Khoi, et al., 2010). The grazing capacity (ha/TLU) was the highest for the urea-applied plots.

Table 1. Application of different treatments on mean herbaceous dry matter production (kg/ha).

Treatments	Grass	Non-grass	Total biomass (TB)	GC (grass) (ha/TLU)	GC (TB) (ha/TLU)
Control (no treatment)	1042.7 [b]	1786.7[b]	2829.3 [c]	0.11	0.04
Ash	1170.7 [b]	2773.3 [b]	3944 [bc]	0.09	0.03
Urea and DAP	3620.80 [a]	2122.13 [b]	5742.93[a]	0.03	0.02
Lime stone	1633. [b]	1361.33[b]	2994.7[c]	0.07	0.04
Manure (cow)	1716 [b]	2986.7[b]	4702.7 [ab]	0.07	0.03
SEM	151	121.6	178		
Significance level	0.02	0.2361	0.02		

Means with different superscripts down the column are significantly different ($P<0.05$); DAP

Conclusions and Implications

The study revealed local wooden ash, cow manure, urea with DAP applications improved TB production. A long-term study is required to examine the effects of the different treatments on productivity of grazing lands, livestock productivity, soil and plant nutrients and economic considerations.

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Improvement of Cattle Grazing Distribution through Genetic Selection: Challenges and Opportunities

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Key words: Grazing behavior, beef cattle, genomics, terrain use, global positioning system

Introduction

Grazing distribution is an important issue for rangeland managers. Cattle typically avoid high and steep terrain and areas far from water (Holechek, 1988). Areas where cattle congregate are often overgrazed and become degraded. Development of new water sources, fencing, and herding can be effective tools to improve animal distribution and minimize localized overgrazing. However, these practices can be expensive and require additional labor. Recently, Bailey et al. (2015) reported that cattle grazing distribution is a heritable trait. Initial estimates from this research suggested that the heritability of grazing distribution may be similar to weaning weight, which has been successfully used as a selection criteria by beef cattle producers for decades. Bailey et al. (2015) based these conclusions on observed associations of genetic markers (single nucleotide polymorphisms or SNP) and terrain use indices obtained from global positioning system (GPS) tracking. One genetic marker on chromosome 29 accounted for 24% of the phenotypic variation in use of steep slopes and high elevations. Another marker on chromosome 17 accounted for 23% of the phenotypic variation in terrain use, and the combined effect of six genetic markers accounted for approximately 35% of the phenotypic variation.

Although the associations of genetic markers and terrain use indices reported by Bailey et al. (2015) are very promising, the terrain use indices they developed and used are not effective metrics to use for calculating breeding values needed for genetic selection because they are trait ratios. Expected progeny differences (EPD) are a common tool used to compare bulls during selection. Genetic progress from selection for EPD on trait ratios is unreliable due to unequal selection pressure on the numerator versus denominator of the ratio. The objective of this study was to develop and evaluate alternative terrain use metrics.

Materials and Methods

Using linear regression and recommendations from Holechek (1988), we developed equations predicting the time cattle would spend at varying horizontal distances from water and on variable slopes. A similar equation was developed for vertical distance from water based on data from Roath and Kruegar (1982). We also developed categorical estimates of cattle grazing use based on these criteria. For example, cattle would be expected to spend 50% of their time grazing areas 1600 to 3200 m from water and would not be expected to use areas farther than 3200 m from water.

Tracking data from three ranches used in the Bailey et al. (2015) study (College Ranch, Thackeray Ranch and Todd Ranch) were used to evaluate the new terrain metrics. A 3990 ha pasture containing rolling terrain was used at the College Ranch (Las Cruces, NM). A 336 ha mountain pasture was used at the Thackeray Ranch (Havre, MT). A 9065 ha pasture containing both gentle and mountainous terrain was used at the Todd Ranch (Willcox, AZ). Sixteen to 19 cows were tracked at each ranch. Relationships of the rolling and rough terrain use indices developed by Bailey et al. (2015) were compared to the new expected terrain use metrics using Pearson correlation coefficients and tracking data from the three ranches. The rolling index was based on slope use and horizontal and vertical distance to water, while the rough index was based on slope and vertical distance to water (Bailey et al., 2015).

Results and Discussion

The developed expected use metrics were more correlated to the rolling terrain index than the rough terrain index. At the College Ranch, correlations between expected use indices and the rolling terrain index varied from 0.83 to 0.93 and 0.72 to 0.85 for the rough terrain index. At the Thackeray Ranch, correlations between developed expected use indexes and the rolling index varied from 0.58 to 0.61, but correlations between the expected use indices and the rough terrain were only 0.29 to 0.35. At the Todd Ranch, correlations between the expected terrain use indices and the rolling index varied from 0.75 to 0.80 and correlations for expected use indices and the rough index varied from 0.59 to 0.69. Indices based on categories were roughly equivalent those based on the equations. We expect that the terrain use indices developed from the equations would be a more efficient approach.

The terrain use indices showed that some cows spent less than 5% of their time in areas they were not expected to use (bottom dweller cows) while others spent as much as 50% of their time in areas they were not expected to use (hill climbers cows). Differences among cows were more pronounced at ranches with more mountainous terrain (Thackeray and Todd Ranches). The rolling and rough terrain indices used by Bailey et al. (2015) assumed that the effects of slope and horizontal and vertical distance to water were roughly equivalent, but the new expected use indices do not account for horizontal distance to water in smaller pastures where cattle cannot travel more than 1600 m from water or in situations where water is more abundant. The horizontal distance to water adjustment was developed for extensive arid and semi-arid pastures with relatively gentle terrain and require additional research to refine for mountainous pastures.

Conclusions and Implications

Genetic selection appears to be a promising approach to manipulate grazing patterns in cattle. The developed indices can provide direct numeric estimates of terrain use and appear effective in identifying animals that prefer rugged terrain (hill climbers) or gentle terrain near water (bottom dwellers). The expected terrain use indices appeared to be superior metrics relative to ratios for development of breeding values to select beef cows for grazing distribution in mountainous rangelands.

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Effects of Arbuscular Mycorrhizal Fungi on Aboveground Biomass in Relation to Distance from Livestock Watering Points in Typical Steppe

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Key words: Grazing intensity; arbuscular mycorrhizal fungi; watering point; aboveground biomass

Introduction

In arid and semi-arid rangelands, grazing gradients tend to develop around artificial watering point. Grazing intensity is usually highest close to water and weaken with distance away from watering point. Previous studies reported that grazing pressure associated with watering points has effects on both vegetation composition and soil properties (Todd 2006; Shahriary et al. 2012). However, effects of arbuscular mycorrhizal fungi (AMF) on aboveground biomass in relation to distance from livestock watering points is still unknown. We conducted a field experiment to address two questions: (1) how do AMF affect plant community productivity along distance from watering point? (2) how do AMF mediate functional group growth along the gradient of grazing pressure?

Materials and Methods

This experiment was conducted in the permanent fields of the Institute of Grassland of the Chinese Academy of Agricultural Sciences, which is located on the Inner Mongolian steppe (44°15′N, 116°32′E), China. A grazing experiment were set up in June 2014, which include five levels of grazing intensity (GI = 0, 4, 8, 12, 16 sheep ha^{-1}). There were 3 replicates for each level in a completely random design.

Our experimental plots were was established at GI= 0, 8 in June 2015. In GI= 0, four 2 m×4 m plots were randomly arranged. In GI= 8, four same plots were conducted along 110 m-long transects placed at 10, 50, 100 m from artificial watering points. The distances from watering point stand for heavy (HG), moderate (MG) and light grazing (LG) respectively. The GI=0 represent no grazing (NG). Plots were subdivided into two 2 m ×2 m subplots. One subplot was suppressed AMF with fungicide benomyl dissolved in water while the other subplot was only watered. Plant samples were oven-dried, before being weighed. Because plant functional groups have been deemed to be vital to predicting plant mycorrhizal growth responses, the plant species were categorized into three functional groups: C_4 grasses, C_3 grasses and forbs. Two-way ANOVA was applied to examine the effect of grazing pressure, AMF suppression and their interaction on above-ground biomass. Tukey simultaneous test to detect differences between the control and the benomyl treatment.

Results and Discussion

Grazing intensity significantly decreased aboveground biomass (Fig.1a; $P<0.01$). AMF suppression decreased aboveground community biomass by 39.7, 7 and 10.3% at HG, MG and NG treatment respectively (Fig. 1a; T-test, $P < 0.05$). The shoot biomass of C_3 grasses was decreased by benomyl treatment 15, 30 and 17% at HG, MG and NG treatment respectively (Fig. 1b; T-test, $P < 0.05$). There was significantly interaction between benomyl treatment and grazing pressure for aboveground biomass of forbs (Fig. 1c; $P < 0.05$). AMF suppression decreased the biomass of forbs by 60% at HG treatment, but increased it by 38, 6 and 60% at MG, LG and NG treatment (Fig. 1c; T-test, $P < 0.05$). Grazing intensity significantly decreased the biomass of C_4 grasses (Fig. 1d; $P > 0.05$). This could be attributed to the foraging preferences of livestock. Compared with forbs, livestock could preferred foraging C_3 grasses. With the increasing distance from watering point， grazing increase the biomass of C_3 grass and decrease of forbs.

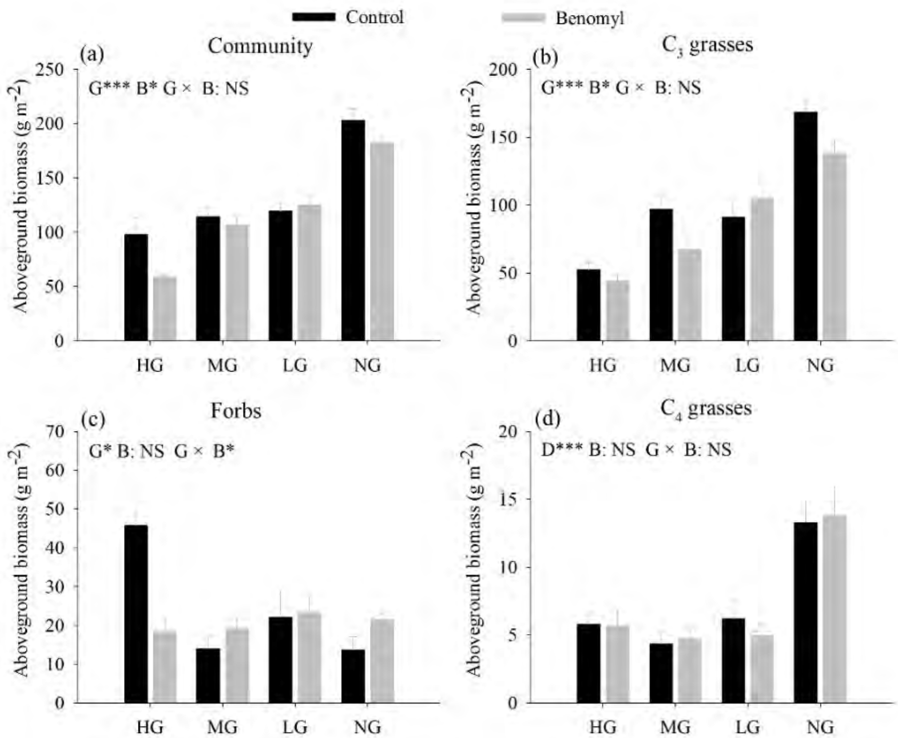

Figure 1. Effects of AMF suppression and grazing pressure on the shoot biomass of the community (a), C3 grasses (b), forbs (c) and C4 grass (d). Data are presented as the mean SE. *p<0.05; ***p<0.01.

Conclusions and Implications

AMF have a positive effect on community productivity along distance from water sources, which is mostly in relation to biomass change of C_3 grass and forbs. Move the location drinking water sites periodically may promote more uniform grazing in semi-arid grassland.

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Lessons on *Peste des Petits* Ruminants Disease Study of Sheep and Goats in the Rangelands of East Africa

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Key words: Pastoralism, East Africa, PPR, sheep and goats

Introduction

Africa's rangelands have co-evolved with grazing and browsing herbivores and depend on the herbivores to maintain an ecological balance. By grazing and trampling the pasture, livestock can improve pasture health, transport seeds, and embed seeds into the earth while providing manure to nourish the seeds. Provided livestock management is effective and seasonal movements remain possible, grasslands thrive under pastoralist care. The dry-lands of East Africa occupy over 70 percent of the Horn of Africa and range from 95 percent in Somalia and Djibouti, to more than 80 percent in Kenya, and between 30–60 percent in Tanzania. As the most effective livelihood system in these dry-lands, pastoralism is vital to the sustainable development of most of East Africa and its inhabitants. Small ruminants, with their high reproduction rate and easy disposal process are favorites as income generators. Since Peste des petitis ruminants (PPR), an infectious disease of small ruminants was first identified in Côte d'Ivoire in 1942, is now endemic in most of Africa mainly due to rapid movements of small stock and their products across borders. Controlling trans-boundary animal diseases (TADs), such as PPR, at their source is a shared interest and is considered a Global Public Good. The Global Forum for control of TADS, GF-TADs Working Group on PPR has developed a PPR Global Control and Eradication Strategy to be achieved by 2030. The strategy depends on local networks to contribute and share information on prevailing PPR issues in their region. This study covered Kenya and Tanzania and was done from 2009-2011 through a RUFORUM supported grant.

Materials and Methods

Participatory epidemiology methodologies were used to determine risk factors associated with the spread of PPR in Turkana County. These findings were validated with field studies and RNA samples analyzed with real time reverse-transcriptase PCR (qRT-PCR) both in fresh frozen samples and formalin fixed tissues (Kihu et al., 2015). Positive samples were sent to IAEA, Vienna for sequencing. The level of herd immunity was determined using cELISA tests to analyze in 969 serum samples (431 from sheep and 538 from goats) collected in six divisions of Turkana County. The socio economic impact of PPR in Turkana County and the current control strategies of PPR control were determined using participatory epidemiology methodologies. A stochastic PPR compartmental model comprising maternal antibody, susceptible, exposed, infectious and recovered was developed based on field parameters and was then used to evaluate the appropriateness of vaccination regimes applied in Turkana. The benefit cost analysis of vaccination was then determined from economic losses due to PPR and cost of vaccination in Kenya. In Tanzania, a similar study was carried out in 2011 in Tandahimba district following PPR outbreak in southern Tanzania in 2010(Muse, 2010).

Results and Discussion

Risk factors for PPR spread in both countries included: Indiscriminate mixing of stock, new animals entry, shared watering, entry of foreign livestock across international borders, nomadism and trans-humance; traditional borrowing and loaning of livestock; nursing of kids and lambs by sick dams. In Turkana, typical signs of discharges from eyes and nose with diarrhea were observed (Fig. 1). In Tanzania the clinical signs were as in Kenya but more severe including, generalized skin nodules (Fig. 2), abortion and orchitis.

Figure 1. Diarrhea in goats in Turkana, Kenya.

Figure 2. Widespread lesions in goats, Tandahimba, Tanzania.

Samples obtained from tissues and fixed in formalin could be used two years later to confirm the disease. The PPR from Turkana was identified as belonging to PPRV Lineage III. Full genome analysis revealed that the virus causing disease in Kenya in 2011 was 95.7% identical to the full genome of a virus isolated in Uganda in 2012 and that a segment of the viral fusion gene was 100% identical to that of a virus circulating in Tanzania in 2013 which indicates the trans-boundary movement of Lineage III viruses between Eastern Africa countries. Economic losses due to PPR in Kenya were estimated at US$19.1 million with mortality of small stock due to PPR constituting the greatest loss valued at US$16.8 million being 88% of the total losses. Milk and weight loss constituted 12% of total losses. PPR disease longer persistence in sheep than goats means sheep may act as reservoirs. Regular quarantine methods were in-effective in control (Kihu et al., 2015). A simulation of the model showed that vaccination coverage of 50% of small ruminants was enough to curtail the spread of the PPR disease within 254 days. A spreadsheet model found vaccination was the most viable control method with a cost benefit of PPR vaccination being 35. Overall in Tanzania, 56.7% of the samples (n=30) tested were positive for PPR by RT-PCR, which convinced authorities to initiate vaccination. PPRV strains from Tanzania were clustered within lineage IV and Lineage II.

Conclusions and Implications

Harmonized regional strategies and vaccination coverage of 50% of high risk herds in rangelands is adequate to eradicate PPR. Simple technologies like formalin-fixation of tissues can enhance PPR surveillance in Africa's rangelands characterized by poor infrastructure. Routine disease control strategies like quarantine are in-effective in the rangeland due to the vastness and remoteness and more viable strategies like adoption of traditional practices are needed.

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A Possible Way Forward with Pimelea Poisoning in Australian Rangelands

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Key words: Thymelaeaceae, rumen microflora, St George disease

Introduction

Pimelea poisoning of livestock can occur in cattle, sheep and horses in Australian rangelands and has confounded pastoralists and veterinarians for almost a century (Fletcher et al., 2009). Known colloquially as St George or Maree disease, cattle are the most susceptible livestock. The causal agent was eventually identified as a group of *Pimelea* (Thymelaeaceae) species but the pathway via which toxicity was induced has been contentious. Death can be rapid in some circumstances, associated with heart failure, pulmonary oedema, scouring and emaciation. Some animals appear to have an immunity which may be physiological or a learned avoidance of the toxic plant. The toxic principle has been identified as simplexin but analogues of it may also be involved. Past research centred on veterinary and enterprise management aspects for combating the problem (Clarke, 1973) but efforts to develop a vaccine failed in the 1990s.

Current State of Knowledge

Gross Signs and Remedies

Animals of all ages and classes are affected but those recently introduced to infested pasture or a new region are most susceptible. Signs include scouring, ill-thrift, swelling of the jaw and brisket and a prominent, pulsating jugular vein along the neck. Poisoning is most common in spring and early summer when plants are most abundant and flowering. Plant material may be ingested directly or inhaled but the toxin is believed to be liberated during the fermentation stage of digestion and then absorbed via the small intestine which becomes inflamed. Any stressful activity by affected animals can lead to sudden collapse and death from heart failure but some animals only suffer prolonged scouring, especially sheep. Feeding high quality hay and removal from infested pastures aids recovery of affected animals but their long term health and growth seems prejudiced. Oral drenching with a gastric stimulant sometimes helps but is expensive and labour intensive. One remedy in SW Queensland is to slowly move animals from sandy red mulga (*Acacia aneura*) country to nearby grey, heavy clay brigalow (*A. harpophylla*) or gidgee (*A. cambagei*) country.

The Plants

Toxin content of *Pimelea* and its relatives is variable but, in Australian species, seems worst in the Epallage section of the genus which has about 11 species. The taxonomic boundaries of some of these species is not clear and there may still be subtaxa or undescribed species with differing predisposition to accumulation of the daphnane orthoester toxins. The main problem species, all annuals or short-lived ephemerals, seem confined to 2 subspecies of *P. simplex* F.Muell., 2 forms of *P. elongata* Threlfall, and *P. trichostachya* Lindl. Because each of these taxa grow on different soils their presence in the spatially diverse rangeland landscape of southern Queensland is strongly influenced by the effectiveness of small (20-40mm), isolated falls of rain in germinating their seeds. They all have similar triggers and controls for seed germination (Silcock & Mann 2014) but many rainfall events result in effective germination and seedling survival only in microsites such as gilgais or shallow gullies, or on a particular type of soil texture. Thus *P. simplex* may be abundant on its preferred heavy clay Mitchell grass alluvial plains along major inland rivers while there is no *P. trichostachya* growing in the adjacent sandy mulga country that it likes. The differing land types may or may not be in the same paddock, so stock may or may not have a chance to avoid them.

Chemical analyses have found the toxins in all plant parts but they are most concentrated in the seeds (Fletcher et al., 2009). The concentration falls considerably in dead tissue but skeletons of plants may remain standing for months afterwards and the seeds may remain webbed on to upper branches if the sorghum seedhead caterpillar (*Cryptoblabes adoceta*) was active during the growing season.

Rumen Metabolism

Known quantities of *Pimelea* were fed to young, previously unexposed steers in steadily increasing doses and their rumen and tissue levels of simplexin were followed for 120 days (Fletcher et al., 2014). Only minor poisoning signs were seen around 30 days and levels in their blood were almost undetectable. However, rumen fluid from them was subsequently used for digestion of *Pimelea* foliage and found to release far less toxin than equivalent fluid from the control animals. Tests of the diversity of the rumen flora showed a marked change in populations of bacterial groups between the two rumen sources. Thus the rumen microflora composition, which is influenced by an animal's prior diet, is hypothesised to affect the potential toxicity of ingested *Pimelea* material. *Synergistes jonesii* works in this way for cattle consuming leucaena (Allison et al., 1992).

Conclusions and Implications

Current understanding leads us to believe that ruminants can build up an immunity to the toxins via a slow modification of their rumen microflora after regular ingestion of small amounts. This results in a reduced intensity of toxin release during digestion and thus reduced predisposition to pulmonary vein constriction and scouring. Such animals may also have learned to avoid eating these poisonous plants which only occur in significant numbers in particular seasons or are regularly present in well-defined locations such as ephemeral lakebeds. The diversity of toxic *Pimelea* species and subtypes with associated differences in germination triggers and microsite preference makes management of the problem in extensive rangeland regions challenging. Thus investigation into a possible prophylactic oral drench seems warranted. Similar challenges apparently exist in other parts of the world where plants of the Thymelaeaceae are common, such as China.

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Does Grazing Management Matter in the Arid Koup Region of the Karoo, South Africa?

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Key words: Rangeland condition, plant cover, stocking rate, grazing capacity.

Introduction

In the semi-arid regions of South Africa, such as the Karoo shrubland, many extensive livestock ranches apply some form of rotational graze-rest system, with rest periods varying from a few months to more than a year without grazing. When these rangelands are in a good condition they are the livestock farmer's cheapest source of forage and are his most valuable resource (Fouché, 1992). The overall objective of rangeland management is to conserve the natural vegetation (Barnes, 1989) through improvement of the plant cover, an increase in the palatability composition, quality and suitability, thereby improving the animal production.

The objective of this study was to determine what grazing management practice/s has the largest influence on the rangeland condition of the arid Koup region of the Karoo.

Material and Methods

The study was done in the Gamka Karoo vegetation type (Mucina and Rutherford, 2006) with an average annual rainfall of 120 mm, falling mainly in summer. The vegetation is dominated by dwarf shrubs and grasses, while trees are rare. The expected plant cover, coupled to the rainfall, is 15-25%.

Line-point plant surveys (Du Toit, 1998), to record plant cover and species composition, were done on 18 different farms during March of 2014 and 2015. Each survey started from a watering point towards the far end of the camp (1 000 m) to record possible differences in grazing intensity across the camp. Along these same line 10 density plots (5x5 m) were surveyed at different distances where the density of each perennial species encountered were recorded. The grazing management system, stocking rate applied by each farmer, farm size and number of camps were recorded. Relations between current rangeland condition score and grazing capacity, duration of rest, and the extent of overstocking relative to the estimated long-term grazing capacity were examined.

Results and Discussion

A total of 132 perennial species were encountered but only nine species occurred on all of the farms surveyed. These include the highly palatable shrubs *Rhigozum obovatum, Tripteris sinuata* and *Galenia fruticosa* and grasses *Stipagrostis obtusa* and *S. ciliata,* the less palatable shrubs *Lycium* spp., *Eriocephalus spinescens* and *Zygophyllum microphyllum* and the unpalatable, poisonous shrub *Chrysocoma ciliata*. The perennial plant cover ranged from 6.3 - 41.2%, with a mean of 25.3%, which was better than expected.

Farmers that follow a rotational grazing system with more than 6 months rest (Long-rest system) have a significantly better rangeland condition than those farmers that has no planned resting period and their current grazing capacity is better than the long-term recommended grazing capacity ($F_{14,16} = 6.45$; $p = 0.010$). There is however no significant differences between farms with a short-rest system and either no rest or long-rest systems.

There was a significant general decline in rangeland condition with increase overstocking ($F_{15, 16} = 6.61$; $p = 0.021$), but there was no overstocking x graze-rest system interaction, indicating a consistent decline in veld condition with increase overstocking across all graze-rest systems.

Farms where the current grazing capacity is better or similar to the long-term recommended grazing capacity

- follow a rotational grazing system where the camps rest for 6 months or longer;
- their rangeland is in a better condition;
- they have a higher perennial plant density ($p<0.001$); but
- the species richness ($p = 0.355$) did not differ.

Conclusion and Implications

Both stocking rate and the duration of the rest in a graze-rest livestock management system are important in this veld type, but further research is required on their interactive effects on rangeland condition, and the duration of complete rest from stocking required to militate against the effects of prolonged overgrazing.

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Grazing Strategy Effects on Herbage Utilization, Production, and Animal Performance on Nebraska Sandhills Meadow

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Key words: Ultrahigh stock density, mob grazing, grazing strategy

Introduction

Mob grazing, grazing at ultrahigh stocking densities, involves concentrating grazing livestock into small paddocks to achieve stocking densities of 200,000 kg ha^{-1} or greater. Maintaining animals at these densities usually requires moving animals through multiple paddocks each day. Practitioners report a wide variety of benefits including increased forage production, increased plant diversity, improved distribution of livestock grazing, improved soil function and rapid rate of soil development (Gompert 2010). The high stocking densities used in mob grazing systems reportedly result in even distribution of grazing pressure, hoof action, and excreta across a pasture (Peterson and Gerrish 1995). Objectives of the study were to compare mob grazing with other grazing strategies in terms of herbage production, utilization, and cattle weight gains on a subirrigated meadow in the Nebraska Sandhills.

Materials and Methods

The study was conducted on subirrigated meadow at the University of Nebraska Barta Brothers Ranch in the northeastern Nebraska Sandhills near Ainsworth. The study was initiated in 2010 with establishment of 2 replications of four-pasture rotational grazing with two occupations per pasture in an 80-day grazing season (4-PR-2), four-pasture rotational grazing with one occupation per pasture in a 60-day grazing season (4-PR-1), and a mob grazing system with one occupation per pasture in a 60-day grazing season (MOB), and an ungrazed control. In each of the six years (2010 – 2015), yearling beef cattle (340 kg) grazed the 4-PR-2 from mid-May through early August and the 4-PR-1 and MOB treatments from early June through early August. Stocking rates were equal among treatments within years but varied among years dependent on precipitation and forage production. Stock densities were 225,000 kg/ha, 7000 kg/ha, and 5000 kg/ha for the MOB, 4-PR-1, and 4-PR-2, respectively. Animal performance, trampled plant biomass and harvest efficiency (pre- and post-grazing hand-clipping) were estimated annually in all treatments. Herbage production was determined in grazing exclosures beginning in 2012.

Results and Discussion

There was a significant year by treatment interaction for herbage utilization (trampled + consumption) with MOB utilization greater than 4-PR-2 in all years and greater than 4-PR-1 in 2010 only (Table 1). Among years, utilization was lower in 4-PR-1 and 4-PR-2 in 2010, but not in the MOB treatment. Percentage herbage trampled in MOB (58.9%) was greater than 4-PR-2 (19.1%) and 4-PR-1 (38.3%). Harvest efficiency (percentage herbage consumed) for the 4-PR-1 and 4-PR-2 treatments did not differ (41.8%) and was less ($P < 0.05$) for the MOB treatment (28.7%) than the other two treatments.

In 2012 and 2013, aboveground herbage production averaged 4183 kg ha^{-1} (SE ± 217) and did not differ ($P>0.05$) between years or among grazed treatments and the control. Our research was designed with a target of 60% trampling in the MOB treatment. This level of trampling was reported to increase soil quality and function and potentially increase herbage production (Gompert 2010). While the target of 60% was nearly reached, there was not increased herbage production in the MOB treatment by the end of the fourth grazing season.

Animal performance differed significantly between grazing treatments and among years (Fig. 1).
Yearling steer daily gains in the 4-PR-2 treatment differed among years but were greater than the 4-PR-1 and MOB treatments in all years. The 4-PR-1 treatment had greater gains than the MOB treatment in 2011 and 2015 but gains did not differ in the other years. Johnson (2012) and Redden (2014) found higher forage quality in 4-PR-2 pastures during late summer compared to MOB and 4-PR-1. This was attributed to the earlier start of grazing and regrowth occurring after the first grazing cycle for 4-PR-2. The high grazing pressure and limited forage intake due to the high levels of trampling may have also contributed to depressed gains in the MOB and 4-PR-1 treatments.

Table 1. Herbage utilization (trampled + consumption) in a 4-PR-1, 4-PR-2, and MOB grazing treatments.

Treatment	2010	2011	2013
		- - - - - - - - - - % - - - - - - - - - - -	
4-PR-1	75$^{A\ a}$	85$^{A\ b}$	85$^{A\ b}$
4-PR-2	49$^{B\ a}$	71$^{B\ b}$	60$^{B\ c}$
MOB	88^{C}	88^{A}	86^{A}

$^{abc\ ABC}$ Treatments with unlike uppercase letters differ within year (columns) (P< 0.05). Treatments with unlike lowercase letters differ among years (rows) (P< 0.05).

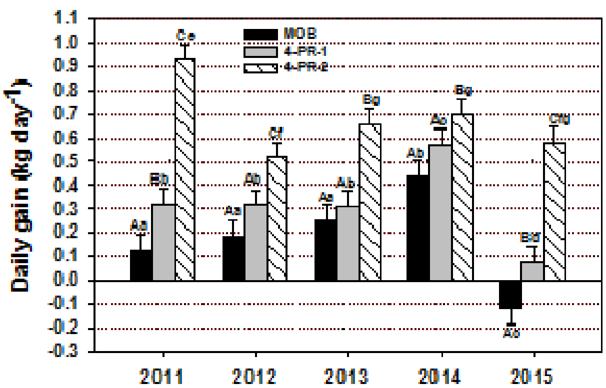

Figure 1. Daily gain (kg day-1) of yearling steers in a 4-PR-1, 4-PR-2, and MOB grazing treatments. Treatments with unlike uppercase letters differ within year (P<0.05). Treatments with unlike lowercase letters differ among years (P<0.05).

Conclusions and Implications

Herbage production was comparable among grazing strategies after four years of treatment application. Lower harvest efficiency associated with the ultrahigh stock density of mob grazing was likely a result of the high proportion of trampling that occurred, limiting forage available for consumption. The high level of trampling, high grazing pressure and reduced selectivity potential, and low forage quality during much of the grazing season are likely factors that reduced performance. Managing for high levels of trampling does not seem realistic from a livestock production perspective if satisfactory animal performance is desired. Significant increases in herbage production would be required to offset the relatively low animal performance and the additional infrastructure and labor costs associated with mob grazing.

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Effect of Utilization on Aboveground Biomass in Mongolian Rangeland

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Key words: Rangeland, degradation level, cutting frequency, cutting height

Introduction

About 80% of the Mongolian total land area can be considered rangeland and nomadic animal husbandry is based on natural rangeland and is an important part of the economy. Today Mongolia is one of the most heavily grazed countries in the world (Archer & Smeins, 1991). From 1990 to 2011 the total number of herding households doubled and livestock number increased by 28.7%. Heavy grazing can result in vegetation and land degradation through a series of direct and indirect effects on plant growth (Chognii, 1977, Archer & Smeins, 1991). Because of this and climate change it is important to gather information about the grazing tolerance of the land. Such data will serve as basic information needed for the assessment of the carrying capacity of the pastures and for management decisions for a sustainable use of the natural rangeland. We seek to test the effect of different grazing management intensities (cutting frequencies and cutting heights) and their duration on aboveground biomass. The research was applied in *Fescue-forbs* rangelands in a mountain forest steppe of Mongolia.

Materials and Methods

The study area belongs to the Forest steppe zone, Khangai mountain region which is located in Ikhtamir soum, Arkhangai province of Mongolia (47°47' – 47°50'N; 100°56' – 100° 54'E). Altitude of the area is 1844 m a.s.l. A 1 ha site was fenced off within the area in 2004 where vegetation was as homogeneous as possible and it has since been un-grazed. All measurements were made within this site. In total of 120 (1x1 m) plots were randomly chosen for the experiment and plots were separated from each other by 0.5 m buffer strips.

The cutting experiment included three factors; 1) *Cutting height*: aboveground biomass was cut at two different heights above ground surface, at 0 cm and 3 cm. 2) *Cutting frequency*: aboveground biomass was cut at four different frequencies within the same growing season; four times (May, June, July, August), three times (June, July, August), two times (July, August) and once (August). 3) *Duration*: spanned three different periods; three years (2006-2008), two years (2007-2008) and one year (2008). Each treatment was replicated five times. Biomass was obtained on the 20th of every month and cutting was done by hand. All plant material was air dried at room temperature for 20-25 days and then weighed.

To estimate effect on total biomass of different cutting height and cutting frequency during the years 2006-2008 we ran two-way ANOVA for block design on data from year 2009. The two-way ANOVA was used to get differences on biomass between cutting frequencies and different cutting heights and to indicate if there is interaction between those two factors. ANOVA was also used to estimate effect of duration and cutting frequencies on total biomass and indicate interactions for the two different cutting heights.

Results and Discussion

The results showed significant reduction of aboveground biomass due to different cutting frequency and cutting height, regardless of duration of cutting (Fig. 1). A cutting frequency more than two and the lower (0 cm) cutting height highly affected the aboveground biomass. No cutting frequency effect occurred when cutting height was 3 cm. On the other hand biomass decreased considerably with increased cutting frequency when cutting height was 0 cm.

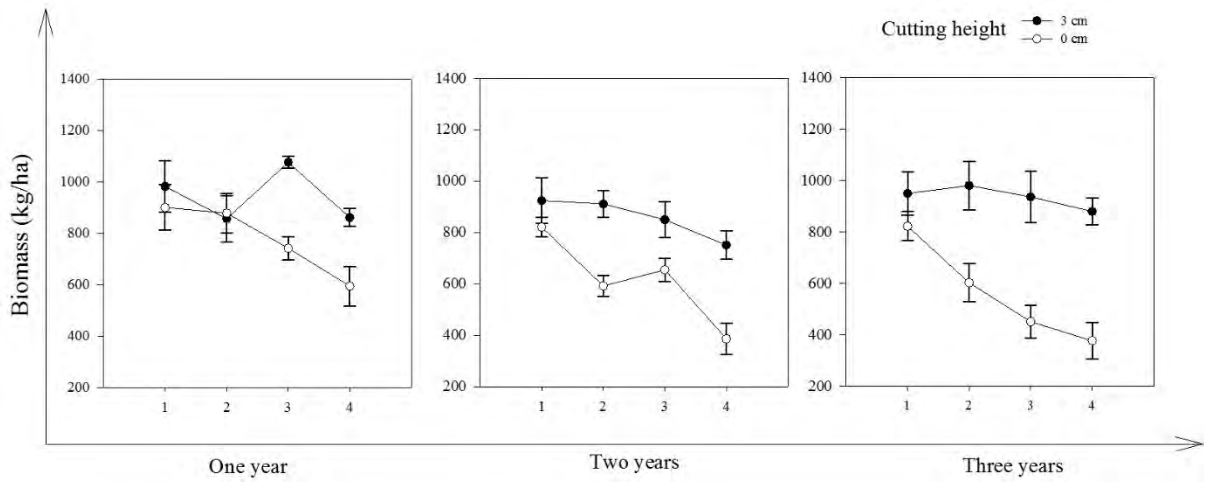

Figure 1. Weight (kg/ha) of aboveground biomass 2009 within Fescue-forbs site. The treatments included different cutting height (0 and 3 cm), different cutting frequencies (1=August, 2=July and August, 3=June, July and August, and 4=May, June, July and August) and different duration of treatments (One year=2008, two years=2007-2008 and three years=2006-2008).

Where treatment duration was one year the biomass decreased 34% more when cut four times compared with one cutting. Where treatment duration was two and three years the biomass decreased 53-54% more when vegetation was cut four times compared with one cutting at 0 cm (Fig.1). Interaction between cutting frequency and cutting height was significant ($P<0.04$) where duration of treatments was one year but not significant ($P>0.05$) for two and three years. Duration of treatments significantly affected biomass when cutting height was 0 cm. For example biomass was 594.2 kg/ha when cut four times for one year but 377 kg/ha when cut four times for three years (Fig. 1).

Conclusions

During recent years there have been changes in grazing patterns in Mongolia which has resulted in land degradation. Our results clearly show that total aboveground biomass was strongly influenced by the applied treatments and biomass decreased with more intense treatments. This is in agreement with other studies and it is well known that intensity of grazing matters when it comes to health and sustainability of rangelands (Liang et al., 2009). It is obvious that grazing intensity is important when it comes to utilization and sustainability issues. However, timing of grazing is also an important factor that strongly influences the biomass production. This study shows that rangeland production is easily disturbed due to utilization but rangeland recovery is slow in Mongolian dry condition.

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Stocking Rate and Grazing Systems affect the Relationship between Sheep Live Weight Gain and Plant Biomass and Diversity of an Alpine Meadow in the Tibetan Plateau, China

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Key words: Grazing, Sheep live weight gain, ANPP, Plant diversity, Alpine meadow

Introduction

Qinghai-Tibet Plateau (QTP) is named "roof of the world" because of its high altitude, and the "third pole of the world" because of similar environment. QTP holds approximately one fourth of the total national rangeland areas in China, and therefore plays an important role in yak and Tibetan sheep herding livelihood (Kang *et al*., 2007). The dominant rangeland, alpine meadow, is susceptible both to global climate changes and grazing management. Tibetan sheep, one of two major livestock species in QTP, provides meat, milk and cash income for the local people (Sun *et al*., 2015). Müller *et al* (2014) showed that intensive grazing does not reduce growth of individual animals in most years, but increases live weight gain (LWG) per unit of land area and thus farmers' income (Müller K *et al*., 2014). The aim of this paper is to study the effect of stocking rate on sheep LWG and aboveground plant biomass and plant diversity in alpine meadow of Qinghai-Tibet Plateau.

Materials and Methods

The research area was located at Azi Station (N33°42'21", E102°07'02", 3600 m a.s.l.), Maqu County, Gansu Province, China, the northeastern boundary of Qinghai-Tibetan Plateau. The soil types were classed by dark felty soils. The mean annual temperature is 2.4℃ and the mean annual precipitation is 616 mm (Sun *et al*., 2015). In 2010, the Tibetan sheep were established in 35 ha treatment paddocks. There were three stocking rates (SR) (no grazing, 8 sheep/ha and 16 sheep/ha) in rotational grazing where Tibetan sheep grazed from June through September in summer pasture and from October through December in winter pasture; and one SR of 8 sheep/ha in continuous grazing paddocks where sheep grazed from June through December. Each grazing treatment had three replicates. Aboveground biomass was measured for each species by monthly harvesting six 0.5 m*0.5 m quadrats at ground level in each paddock. All statistical analyses were carried out in SAS, Version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Aboveground biomass and plant diversity were affected by ingestion and trampling of livestock in the grazing systems. The above-ground biomass, sheep LWG and plant diversity (richness, Shannon-Wiener diversity index and evenness) were significantly affected by month, stocking rate, and grazing system ($P<0.05$). The above-ground biomass was not significantly affected by year, while others were significantly affected by year ($P<0.05$) (Table 1). The reason is that the climate factors included precipitation and temperature in 2013, 2014 were not different significantly. But the climate factors effected plant above-ground biomass significantly. The stocking rate and grazing systems affected the relationship between sheep LWG and aboveground biomass, plant diversity. In the rotational grazing (8 sheep/ha), the prediction model was $Y= - 0.0042 X_1 - 0.1521X_2 + 9.2454$, R=0.7050, F=16.3004, P=<0.0001 (Fig.1). In the rotational grazing (16 sheep/ha), the prediction model was $Y= - 0.0091X_1 - 0.1227X_2 + 9.4064$, R=0.5158, F=5.9817, P=0.0061 (Fig.1). In the continuous grazing (8 sheep/ha), the prediction model was $Y= - 0.0097X_1$ -

$0.0054X_2 + 6.4364$, $R=0.3670$, $F=1.7616$, $P=0.3378$ (Fig.1). In the rotational grazing system, the aboveground biomass and plant diversity can predict the sheep LWG with more accuracy.

Table 1. Effects of year, month, stocking rate, grazing system on sheep LWG, and plant aboveground biomass and plant diversity.

Source	Biomass(g/m^2)		LWG(kg/SM)		Richness		Shonnon-Wiener index		E.Pielou index	
	F	P	F	P	F	P	F	P	F	P
Y	3.67	0.0579	**8871.59**	**<.0001**	**34.12**	**<.0001**	**4.89**	**0.029**	**3.2**	**0.0764**
M	**174.23**	**<.0001**	**162.31**	**<.0001**	**75.62**	**<.0001**	**13.15**	**<.0001**	**4.85**	**0.0012**
Y*M	**7.52**	**<.0001**	**13.25**	**<.0001**	**10.41**	**<.0001**	1.79	0.1346	0.46	0.7615
SR	**5.81**	**0.0175**	**14.76**	**0.0001**	1.43	0.2336	2.28	0.1339	0.78	0.3793
Y*SR	0.65	0.4208	1.18	0.2777	0.04	0.8422	0.01	0.9236	0	0.9706
M*SR	1.23	0.303	0.96	0.4513	0.11	0.9772	2.22	0.0712	1.38	0.2462
Y*M*SR	0.37	0.8298	0.21	0.9741	0.45	0.7719	0.15	0.9606	0.2	0.9376
GS	**8.11**	**0.0005**	**7.47**	**0.0006**	**28**	**<.0001**	**11.18**	**<.0001**	**6.43**	**0.0022**
Y*GS	**8.82**	**0.0003**	0.81	0.4439	3.27	0.0414	0.34	0.7132	0.32	0.7291
M*GS	**6.95**	**<.0001**	1.49	0.1794	**3.22**	**0.0024**	**4.75**	**<.0001**	**3.57**	**0.0009**
Y*M*GS	**2.75**	**0.008**	0.42	0.8683	1.02	0.4219	**2.37**	**0.0209**	1.56	0.1455
SR*GS	1.2	0.2759	0.1	0.7579	0.81	0.371	0	0.9997	0.07	0.7921
Y*SR*GS	0.18	0.6709	0.61	0.4367	0.49	0.4863	0	0.9564	0.68	0.411
M*SR*GS	0.19	0.9409	.	.	1.08	0.371	1.41	0.234	1.49	0.2092
Y*M*SR*GS	1.04	0.392	.	.	2.15	0.0793	1.84	0.1248	0.96	0.43

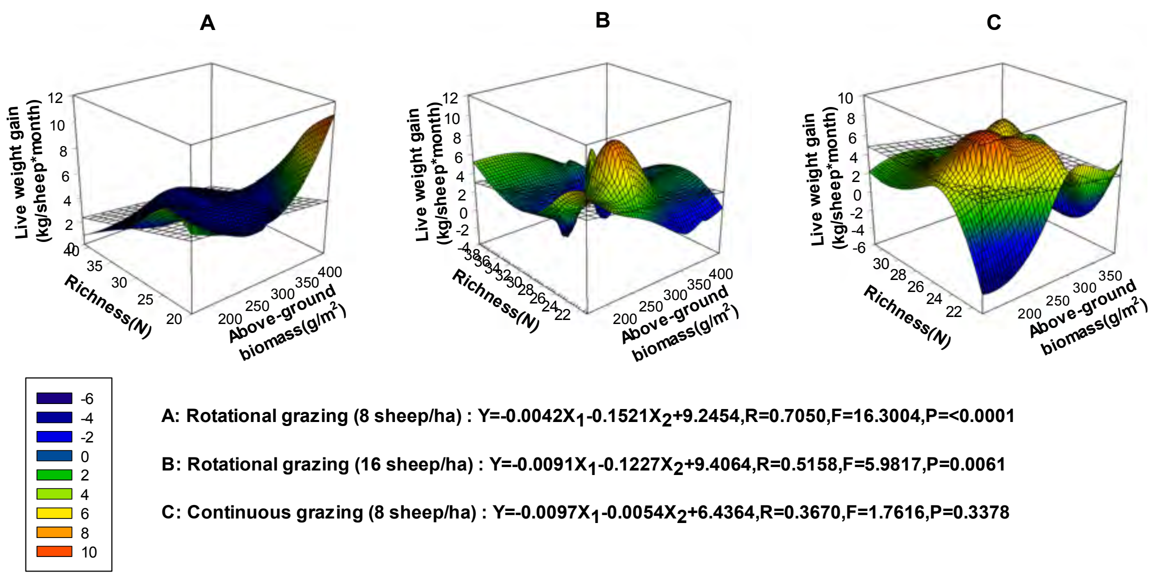

Figure 1. The prediction model of aboveground biomass and richness to sheep live weight gain by different grazing forms.

Conclusions and Implications

Tibetan sheep grazing effected above-ground biomass, sheep LWG and plant diversity ((richness, Shannon-Wiener diversity index and evenness). A grazing rate of 8 sheep/ha seems to provide the best predictive model of plant aboveground biomass and richness to sheep LWG.

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Effect of Range Protection on Activity, Voluntary Feed Intake, and Energy by Grazing Sheep in North Kordofan, Sudan

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Key words: Availability, digestibility, activity,

Introduction

Feed intake is one of the most important factors affecting available metabolizable energy for maintenance (ME_m) (NRC, 2007). Feed quality and quantity deteriorate during the dry season due to advances in maturity and scarcity of range near settlements. Animals therefore need to walk longer distances for forage with negative impacts on health and productivity. This paper is part of a wider study meant to evaluate seasonal variations in the nutritional status of sheep. The objectives were to study the effects of rangeland protection on activity, voluntary intake, digestibility and energy for maintenance by sheep.

Materials and Methods

The study was conducted at El Domokeya area, 31 km east of El Obeid town (13° 10' N; 30° 12' E). Two sites were selected; one was a protected forest reserve while the other was an open area close to a nearby settlement. The forest was established in 1959/60. Rainfall is unimodal falling during July-September averaging 300 mm/annum. Mean relative humidity is 34%, which decreases to 14% in the drier months of winter and summer, and increases to 60% during July-September. The mean evaporation is 15.5 mm/ month and increases to 20 mm/month in the summer months. The mean minimum and maximum temperatures are 20°C and 34°C, respectively and a maximum of up to 46°C can occur during the hot summer months. Sampling was done in August 2006 using seven healthy rams on each range site. Average body weight was 31.6 kg ± 1.12 (SE). Sheep diet botanical composition was estimated using the bite-count technique to allow sampling for IVDMD determination. Sheep were observed individually, twice a day for three days. A sheep was followed for 5 minutes, then the observer moved to another sheep, recorded bites until he covers the seven sheep (total 35 minutes). He then starts following the first sheep again. Grazing time was 8 hrs. (7-12 am and 2-5 pm). Feces were collected using faecal collection bags and harnesses with a seven-day adaptation period and a seven-day collection period. Samples of forage were collected using diet simulation based on observation of sheep selection of diet and picking plants and plant parts that were similar to what was selected. *In vitro* dry matter digestibility (IVDMD) was then determined according to Tilly and Terry (1963). Voluntary dry matter intake (DMI) was assessed by dividing fecal excretion by feed indigestibility (Fadlalla and Cook 1985). The ME was calculated according to NRC (2007). Distance walked was measured by following each sheep for five minutes and moving to the next till all five sheep were done and then starting again. This continued for 8 h/d for four days for a total observation time of one hour per sheep per day.

Results and Discussion

In the protected range DMI was 1200 ± 128 g/d, while in the open range it was 1340 ± 100 g/d. Differences were not significant between the two sites.

Distances walked differed ($P<0.001$) between the two sites. Sheep in the protected rangeland walked 4.9± 1.01 km/day; while those in the open walked 12.4 ± 2.21 km/day. The difference in distances walked was due to longer distances walked from settlement to the grazing area and to sparser grasses from lower plant density in the open range (260.9 plant/m^2 in protected and 181.9 plant/m^2 in the open). Assuming a value of 0.082 MJ/km/d as the NE_m requirement for walking on leveled ground (NRC,2007) the NE_m requirement for walking in protected rangeland equaled 0.402 MJ/animal/day, while in the open rangeland it was 1.017 MJ/animal/day.

Mean IVDMD (%) was 67.4 ± 4.82 and 69.7 ± 4.31 in protected and open range respectively. Diet NE was 6.57 and 6.78 MJ/kg DM in protected and open range respectively, while net energy intake (NEI, MJ/day) was 7.88 and 9.09 respectively. No significant differences were observed between parameters investigated.

Using NRC (2007) value of 176.4 kJ of $NE/W_{kg}^{0.75}$/d the maintenance requirement of grazing sheep (fasting metabolism plus 10% for activity) was 2.59 MJ/day. These NE requirements assume that the animals have limited exercise. When adding energy for walking, the total NE requirement for maintenance becomes 2.99 MJ/day in protected range, while in the open range it was 3.61 MJ/d. The NEI above maintenance was not affected ($P>0.05$) by protection of range and was 5.11 MJ/d for sheep grazing protected range and 5.48 MJ/d for sheep grazing open range.

Conclusions and Implications

Grazing of open land increased walking distance which would be expected to increase energy requirements. However, failure to detect differences in estimated NE intake above maintenance would suggest no impact of range protection on sheep productivity on a per animal basis. This implies that productivity on a land area basis may differ and be improved by protecting range.

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Role of Area Enclosure as Tool of Woody Species Rehabilitation in a Highland Grazing Lands of Eastern Zone of Tigray, Ethiopia

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Key words: Enclosure, rehabilitation, regeneration, woody

Introduction

The Tigray region is in the northern part of Ethiopia where poverty coupled with population growth and their search for subsistence income has led to deforestation (Nyssen et al., 2009). To restrain the desertification of the region, establishing 'enclosure areas', where grazing and human interference is restricted, has been practiced. Enclosure is an acknowledged tool in creating promising socio-economic and ecological importance (Emiru, 2002). However, woody regeneration status is not studied. Therefore, the study aimed to assess and determine the impact of enclosure duration on woody vegetation cover and regeneration.

Materials and Methods

Description of the study area

The study was conducted in livestock grazing lands of Tigray region, Kilte Awlaelo district, Arbaha Atsbaha sub-district, geographically located at 12°15' to 14°50'N, 36°27' to 39°59'E.

Transect, quadrat sampling technique and woody parameters measuring methods

The study was undertaken from February to September 2006. Transect survey method was used in three land use treatments namely, ten years enclosure called *Arato*, five years enclosure called *Akeb-Tsaeda* and open grazing land called *Hina-Nebri*. Enclosure (in Ethiopian context) is land which is restricted from any human and domestic animal interface for rehabilitation, and open grazing is a land open for grazing without any limit. Five parallel transect lines in each land use were established each 200 m apart from the other; 15 sampling sites were selected within the transects, five site from each land use and three quadrats from each site delineated. A total of 45 quadrats each measuring 20 m x 20 m (400 m^2) were laid out at an interval of 400 m along the transect. In each quadrat, the identity, number, height and diameter at breast height (DBH) of individual stems of woody species were recorded. Height was measured by hypsometer while diameter of small and big trees were measured with the use of a caliper and diameter tape, respectively. The density of woody plants was enumerated in each quadrat. The individual woody canopy diameter was measured. To determine regeneration status through population structures stem diameter were also measured. All data was collected in parallel at the same time for all the three land uses.

Data analysis

One-way analysis of variance (ANOVA) and Duncan multiple range tests (DMRT) with P<0.05 was employed. Indices based on species number and numbers of individuals for species richness (1), diversity (2) and evenness (3) were computed using the following formulas;

Margalefs (Dmg) index (Magurran, 1996); $D = (s - 1) / \ln N$ ……………………. (1)

Shannon diversity index (Magurran, 1996); $H = \Sigma pi \ln pi$ ……………………….. (2)

Where p_i is the proportional abundance of the i^{th} species = $N/\Sigma N$.

Shannon evenness (Hill, 1973); $E = H / \ln s$ ……………………………………. (3)

Where, S: is the total number of species   N: the total number of individuals of all species

Results and Discussion

Species composition, density and crown cover of trees and shrubs

There was no significant difference (P>0.05) in floristic composition and crown coverage of the woody species among the three land uses. However, the enclosures had the highest density of trees and shrubs (Table 1). This proved that some plants were regenerating in the enclosures, which also reflected the enclosures were in early succession. On the contrary it endorsed there was misuse of wood in the open grazing as was reported by Mulbrhan et al. (2006).

Table 1. Tree and shrub composition, density and crown coverage of the land use types

Land use type	Tree and shrub Composition/400 m^2	Density of tree/400 m^2	Crown coverage (m^2)
Ten years enclosure	$6.53 \pm .29^a$	29.20 ± 1.45^b	79.85 ± 7.68^a
Five years enclosure	$6.46 \pm .62^a$	22.60 ± 1.72^a	62.73 ± 5.66^a
Open grazing land	$6.16 \pm .61^a$	18.50 ± 7.87^a	72.09 ± 5.85^a
P value	NS	(0.007)**	NS

^{abcd} Means within a row with different superscript/* are significantly different at P ≤ 0.05 NS=none significant

Woody species abundance, frequency, richness, diversity, and evenness

Species abundance and richness showed that there was significant differences among land uses (P<0.05) (Table 2). The highest abundance and richness were recorded in the ten year enclosure followed by five year enclosure, whereas the least woody richness index was scored in the open grazing land use. Diversity index and species evenness were significantly differ (P<0.05) among the land uses. The highest woody species diversity index and evenness were scored in ten year enclosure followed by the five years enclosure and the least species diversity indexes were scored in the open grazing land use (Table 2), the results were in agreement with Emiru (2002).

Regeneration status of woody species

The majority of individuals in the enclosures were in the short height (< 1.5m) and small diameter (≤ 5cm) class. Whereas the open grazing land use had comparably bigger diameters (≥ 15cm). The higher proportion of small diameter plants in the enclosures indicated that there was active and uniform restoration.

Table 2. Woody species abundance, density, and diversity, evenness and species richness of land uses.

Land use type	Abundance/1200 m^{-2}	Density / ha	Diversity	Evenness	Richness
Ten years enclosure	98.40 ± 9.92^c	1639.98 ± 165.45^b	$2.16 \pm .07^{ab}$	$0.91 \pm .22^c$	$2.49 \pm .24^b$
Five years enclosure	65.00 ± 3.354^b	889.54 ± 201.98^a	$1.94 \pm .06^{ab}$	$0.81 \pm .02^b$	$2.30 \pm .14^{ab}$
Open grazing land	40.08 ± 5.73^a	680.00 ± 95.00^a	$1.41 \pm .12^a$	$0.70 \pm .02^a$	$1.70 \pm .21^a$
P value	(0.004)**	(0.008)**	(0.003)**	(0.002)**	(0.04)*

^{abcd} Means within a row with different superscript are significantly different at P ≤ 0.05 NS = non significant

Conclusions and Implication

The study revealed that the enclosures had significant higher numbers of tree and shrubs, species richness, diversity, and evenness. No significant variation in woody species composition and crown coverage between the land uses. Thus, effective rehabilitation of woody requires a period of enclosure of decades.

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Overgrazing and Stocking of Alpine Meadow in Mongolia

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Key words: biomass, carrying capacity, rangeland management, alpine meadow

Introduction

Rangelands provide feed and is a necessity for food and survival of domestic animals and wildlife. The high grazing pressure has significantly reduced productivity and changed vegetation structure and soil properties. There is a need to create a landscape-based system to optimize management of rangeland utilization. Mongolian rangelands were found to be strongly affected by climate and grazing effects, with the peak of biomass having declined by 20-30 per cent in the past 40 years, decreased spring biomass, earlier emergency of plants, decrease of high nutrient plants (Batima et all, 2009). Grazing effects were determined based on relationships of grazing to biomass production and climate changes. This study describes the results of land use stratification and presents a description of land use of alpine meadow in Mongolia.

Materials and Methods

The vegetation type was identified refering to a vegetation map. Determination of degradation level was used to several indicators. The main indicators were plant species abundance, vegetation coverage, bare ground area and yield. After field work, the data on land use areas under each land use type and the data on biomass yields were analyzed.

Results and Discussion

The area was identified that the largest potential for resource of biomass comes from improving the management of degraded rangelands. In the area, the most degraded rangelands are located in the areas along the river valleys (Figure 1), which are mainly water points in the summer months and very heavily used.

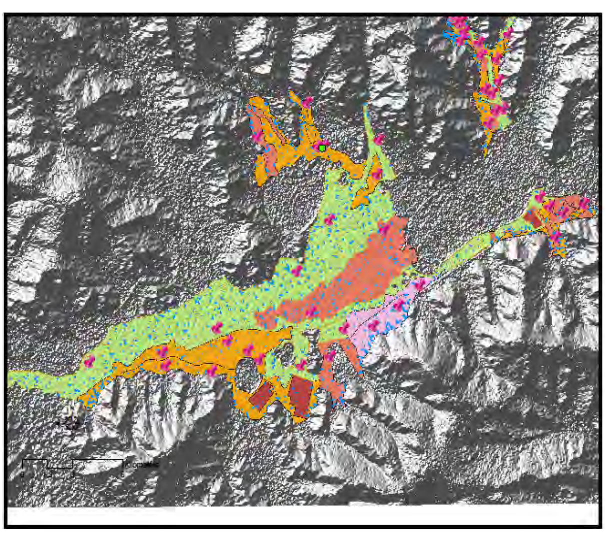

Figure 1.
Based on ecological type and degradation level, a total of three different land use strata were identified. Total of and use nine strata were identified considering the baseline ecological type, degradation level and management practice. These are summarized in Tables 1 and 2.

Table 1. Degradation level by ecological side in study area.

Degradation level	Riparian meadow with marsh	Riparian meadow	Alpine meadow
Lightly	RMM 1	not present	AM 1
Moderately	RMM 2	RM 2	AM 2
Heavily	RMM3	RM 3	AM 3

Table 2. Estimate carrying capacity in study area.

Land use type	Area (ha)	Yield (kg/ha)	Theoretical carrying capacity (SU / ha) in summer period
RMM 1	376	997	1692
RMM 2	2519	600	6822
RMM3	237	541	579
RM 2	53	600	144
RM3	7491	527	17820
AM 1	247	897	1000
AM 2	1326	708	4238
AM 3	2182	536	5279
Total	15301		37574
Current number of SU grazing area			96248

The overgrazing is partly due to mismanagement, but also partly due to the fact that the study area is near the main river and lake. Based on the land use strata identified, the carrying capacity of the area was estimated. This estimate is for 90 days in the summer months only, and assumes that 50% of biomass is utilized, and assuming that one sheep unit (SU) requires 1.6 kg DM per day (Gendaram 2009). The area has an estimated carrying capacity of 37574 SU in the summer months of June July and August. The estimation of the number of animals staying in the study area in the summer months is shown in Fig. 1, Table 2. In total there are about 96 248 SU grazing in the area. This is about 58674 SU more than the 'rule of thumb' sustainable grazing rate that would leave 50% biomass. A grazing density is high, but the biomass production is relatively low.

Figure 2. For riparian meadow with marsh and mountain meadow, the medium degraded yields were 15-19% less than lightly degraded yields; for heavily degraded, the yields were 25% less than lightly degraded. For riparian meadow, there was a little difference in biomass yields.

Livestock numbers should be set on the basis of available forage. Fieldwork identified the average yield of different plots of land in different land use strata. If degraded pastures can be restored to less degraded status, then total biomass yields would increase and the number of animal units that can be sustainably raised on the grassland would increase. Studies on the effects of grazing on biomass of alpine meadow marsh (Shi et al. 2012) in Tibet show that the restricting the season of grazing (winter only compared to all year grazing for 10 years) can result in more than three times higher biomass production per unit area. For alpine meadow, the effects of stocking rate (moderate compared with heavy) can result in a much greater proportion of nutritious forage in plant communities and a 20% increase in the biomass of nutritious forage (Wang et al. 2014). As an initial assumption we take the stocking rates for lands at different degrees of degradation indicated by sustainable stocking level. Furthermore, if the herders can destock the current rate by 60.9%, it is assumed that changes can help to increase biomass yield at all levels of degradation by 20% after five years of proper planning implementation. Therefore, the main activities to decrease degradation level of the study area could be following: continued grazing on summer pastures at lower stocking rates and grazing to move on un-grazed pastures. Our results demonstrate that reduction in grazing intensity may provide a near term solution for alpine meadow that have experienced biomass loss from intensive grazing managements and land degradation will decreased.

Conclusions

A reduction in grazing pressure offers a profitable and sustainable solution to our needs for pairing livestock production with soil organic carbon recovery and decrease global warming through the carbon sequestration.

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Effects of Mob Grazing with Sheep in Winter or Spring on Green-up and Reproductive Effort of *Poa ligularis* in Northern Patagonia

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Key words: Grazing management, phenology, *Poa ligularis*

Introduction

Mob grazing has been recently introduced in semiarid steppes in Northern Patagonia as a management tool promoted by Holistic Resource Management proponents (Savory & Parsons 1980). Information about its effects on local plant communities is still lacking. Given that Patagonian rangelands are susceptible to desertification by overgrazing and since detrimental effects of grazing on plant communities depend on stocking rates and plant phenological stage, we investigated the effects of mob grazing by sheep at heavy stocking rates in either winter or spring on green up and reproductive effort of the key species *Poa ligularis*. Moderate grazing commonly used in semiarid grass-shrub steppes of northwestern Patagonia was used as the control.

Materials and Methods

Our study site is a semiarid grass-shrub steppe with *P. ligularis* and *Mulinum spinosum* with vegetation cover of 50- 60%, where 40% are grasses, representative of the Patagonian Western District (León et al., 1998) in Río Negro province (41º02'14''S, 70º31'23'' W) North Patagonia, Argentina. Extensive sheep ranching has been the dominant land use for over a century. Climate is semiarid, with a mean annual temperature of 7.7°C and a mean annual precipitation of 250 mm, 70% of which occurs in winter between May to September. Summers are temperate and dry. The growing season occurs between October and March, reaching peak standing crop in November-December, coinciding with seed production. The species monitored in this study was *Poa ligularis* Nees ex Steud, the dominant tussock which accounts for 15% of vegetation cover is of high forage value.

In a controlled experiment we applied three grazing treatments: one traditional season-long grazing with moderate stocking rate for 7 months (0.3 sheep ha^{-1}) from October to April (MOD); and two intensive short duration mob grazing treatments with very high stocking rate for 1 month (20 sheep ha^{-1}) designed to use 80% of the forage biomass available. Mob grazing treatments were applied either in winter when plants were dormant (WMG) or spring when plants were actively growing (SMG).

Each grazing treatment was assigned to one paddock in a completely randomized block design with three replicates per treatment. Mob grazing paddocks were 0.25 ha each, while moderate grazing was applied in a 1000 ha paddock which is common in this region. We measured number and length of green leaves per tiller each two months approx. from June 2014 to May 2015 (16 tillers/paddock/date) and number and height of panicles per plant at the time of flowering (20 plants/paddock/date). We used a repeated measures analysis of variance (with an exponential correlation model) to determine the effect of grazing treatment on leaf length and number of green leaves.

To test for grazing effects on number and height of panicles we used generalized linear model adjusting for overdispersion and analysis of variance, respectively, comparing treatment means with Bonferroniadjusted *p*-values when necessary. The analyses were conducted using Infostat (Di Rienzo et al. 2015) and SAS (2002-2010) softwares.

Results and Discussion

Although WMG and SMG reduced the average number of green leaves per tiller immediately after grazing, by the end of the experiment period SMG had a higher number of green leaves per tiller than either WMG or MOD which did not differ from each other (Figure 1).

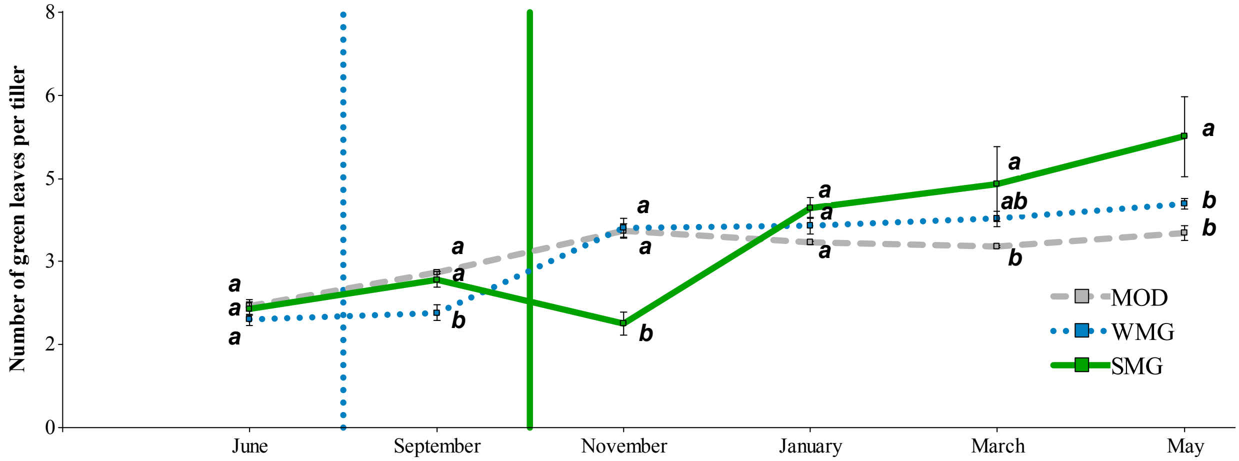

Figure 1. Number of green leaves per tiller of *Poa ligularis* under moderate grazing (MOD), or mob grazing in winter (WMG) or spring (SMG) between June 2014 and May 2015. Symbols correspond to mean values and vertical lines indicate standard errors. Vertical lines in colors indicate moment of grazing (blue: Winter; green: Spring). Different letters indicate significant ($p < 0.05$) differences among treatments at each date.

Average leaf lengths of *P. ligularis* plants in both mob grazing treatments were shorter than those of MOD pastures immediately after intensive grazing was applied. However leaf lengths in WMG and MOD were similar two months later whereas leaf lengths of *P. ligularis* plants in SMG remained significantly shorter throughout the experiment (Figure 2).

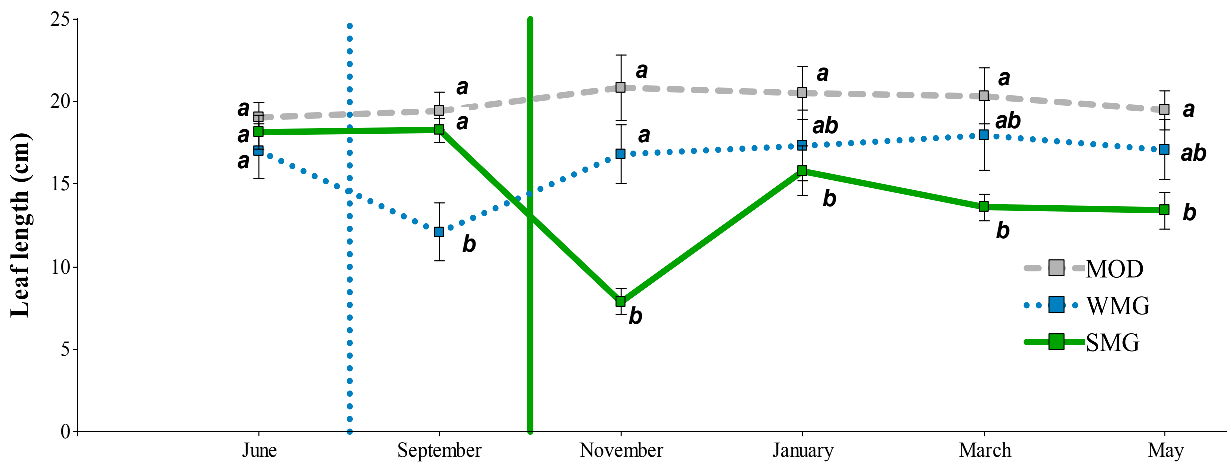

Figure 2: Live leaf length of *Poa ligularis* under moderate grazing (MOD), or mob grazing in winter (WMG) or spring (SMG) between June 2014 and May 2015. Symbols correspond to mean values and

vertical lines indicate standard errors. Vertical lines in colors indicate moment of grazing (blue: Winter; green: Spring). Different letters indicate significant ($p < 0.05$) differences among treatments at each date.

Seed set was also affected by grazing treatments; *P. ligularis* plants in SMG, WMG, and MOD exhibited lowest, intermediate, and highest number of panicles per plant, respectively ($p < 0.05$; Figure 3). Average height of panicles in cm was also significantly ($p < 0.05$) different between SMG and MOD, but not with WMG: 20.69 (a), 29.45 (b) and 26.16 (ab) respectively.

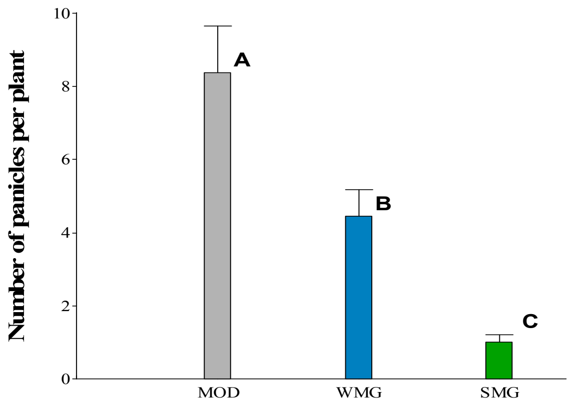

Figure 3. Number of panicles per plant of *Poa ligularis* under MOD, WMG, SMG. Bars correspond to mean values and vertical lines indicate standard errors. Different letters indicate significant ($p < 0.05$) differences among treatments.

Conclusions and Implications

Even though mob grazing in spring produced more green leaves per tiller than the other treatments, leaf length was markedly reduced in SMG producing a strong reduction in forage available. Despite the high stocking rate and forage utilization level in WMG, by the end of the experiment period *Poa ligularis* plants in this treatment and in MOD had similar length and number of green leaves suggesting that plants are less affected by mob grazing during dormancy.

Spring mob grazing, had a strong influence on seed set. This may reduce the ability of *Poa ligularis* to recruit new individuals in the long term if this type of grazing is repeated over time.

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Characteristics and Productivity of Rangelands in Farish District (Uzbekistan)

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Key words: Productivity, fodder plants, degradation, desert, foothill

Introduction

Rangeland degradation caused by excessive and uncontrolled grazing is especially urgent in the Farish district of Dzhizak region of Uzbekistan. Livestock numbers in the given area considerably exceed the carrying capacity of rangelands; therefore, vegetation is subject to serious degradation. A high number of animals are concentrated around settlements in the foothills located between the desert and mountain regions. Animal husbandry is the basic source of livelihood of local people; more than 75% of family income comes directly from livestock, and the efficiency of livestock production is directly dependent on rangeland condition. In this paper I present the results of monitoring and assessment of the current condition of the rangelands of the Farish district, in the case of the Bogdon cooperative state farm, the territory of which covers 53,000 hectares [ha]. Research results will become the basis for developing measures of sustainable management of vegetation resources in this region.

Material and Methods

The territory of the Farish district covers 981,000 ha, of which 384,000 ha are arid and semi arid rangelands. This area receives a relatively low amount of rainfall, which ranges between 250 and 400 mm per year. Elevation of the area changes from 300-400 up to 600-900 m a.s.l. Field investigations were conducted according to widely accepted geobotanical methods (Gaevskaya, 1971). The basic rangeland type of the study area is represented by ephemeral-ephemeroidal and semi shrub-ephemeral vegetation (Mukimov and Beshko, 2011; Beshko et al., 2014).

Results and Discussion

Field surveys showed that rangelands dominated by ephemeral-ephemeroidal species are widely distributed in the study area, and the best fodder plants on these rangelands are *Carex pachystylis*, *Poa bulbosa*. A valuable mix of annual species such as *Leptaleum filifolium*, *Astragalus filicaulis*, and *Bromus tectorum* is found in the plant community. *Eremopyrum orientale*, *Malcolmia africana* are the basic forage during the summer season.

Semi shrub-ephemeral rangelands are distributed on relatively dense soils of desert sierozems, which are quite often salt affected, and are strongly gypsous. Their vegetation consists of two vertical layers: an understory layer usually composed of ephemers and ephemeroids such as *C. pachystylis, P. bulbosa* mixed with annual species; and an upper layer represented by semi shrub xerophytes plants as *Artemisia herba alba*, *A. uzbekistanica, A.santolina*, *Convolvulus fruticosus*, *C. divaricatus. Artemisia*-ephemeral rangelands hold special economic importance.

Overgrazing in rangelands of Uzbekistan is the most important factor in the process of land degradation (CACILM, 2006). Clear examples of rangeland degradation in study area is observed around the watering wells where the species composition of vegetation has deteriorated, with desirable plants being replaced by undesirable ones. The following plants, practically not eaten by animals and widely distributed, occupy about 10-15% of the total ratio of species composition: *Peganum garmala, Ceratocephala falcata, C. testiculata, Psoralea drupacea,* *Hordeum leporinum, Heliotropium dasycarpum, A. scoparia.* The wide distribution of unpalatable and harmful plants is a common problem in desert and foothill rangelands (Gintzburger et al., 2003; Mukimov and Beshko, 2011). One of the main measures to combat the pastoral weeds is yearly cutting of the weed before the reproductive stage.

The measurements of productivity of various types of rangelands during 2010-2014 are presented below in Table 1. The productivity of the rangelands is largely dependent on weather conditions, and varies sharply by year and season (from 50-200 up to 800 kg/ha). The average productivity of mixed ephemeral-ephemeroidal rangelands over five years was 340 kg/ha. Semi shrub-ephemeral rangelands with the mix of *Artemisia* spp. species are a good forage source, with an average productivity of 524 kg/ha over five years.

Table 1. Productivity of various types of rangelands in Farish district (2010-2014).

№	Rangeland types with their dominant plants	Degradation level	Productivity, DM kg/ha					
			2010	2011	2012	2013	2014	average
1	*Artemisia* spp. rangelands	High	510	530	520	610	450	524
2	*Peganum harmala* rangelands	High	180	240	160	200	120	180
3	Rangelands in rainfed areas	High	160	200	210	330	230	226
4	*Poa bulbosa* and *Carex pachystylis* rangelands	High	180	220	240	180	230	210
5	Ephemeral-*Carex pachystylis* rangelands	Moderate	320	320	350	390	320	340
6	*Artemisia* spp. and *Carex pachystylis* rangelands	Low	490	560	550	630	480	542

The rangelands dominated by grazing-caused native invader *P. harmala* is represented by low forage productivity (180 kg/ha). The basic negative tendency of rangeland development is an increased abundance of unpalatable species as *P. harmala* that deteriorates the qualitative condition of rangelands. As a result the amount of best fodder plants has been decreased in the vegetation composition. In some parts of the rangeland, 100% of fodder vegetation is grazed, whereas remote rangeland areas are not used due to a lack of watering points.

Conclusion

The vegetation of the study area has been strongly altered due to the various anthropogenic influences (grazing, cropping, uprooting, haymaking, fires) and inconsistent application of rangeland management. Rangeland territories with high level of vegetation degradation occupy a significant part of the foothills and desert plains. Development of further management strategies of the rangelands under livestock production should be strictly based on the present carrying capacity of rangeland vegetation. Obtained results of the research can lay on the basis of implication practices for sustainable management and restoration of degraded rangelands in study area.

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Involvement of the Population in the Forest-Rangeland Management in Morocco

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Key words: Overgrazing, compensation, association, traditional-institution, sustainable-management,

Introduction

Moroccan forest-rangelands cover 9-M.ha, with high levels of biodiversity. This Kingdom is a water-scarce country, facing rapid population growth and high risk of deforestation and rangeland degradation. Excessive livestock-grazing (30% of sheep, goats, and camels are kept in various mobile systems and graze mainly on forest domain) is the greatest threat to the health and sustainability of Morocco's forest-rangelands. Historically, populations have developed traditional systems in order to regulate natural resource uses between tribes which reconcile social needs and environmental sustainability. In the case of pasture-lands, regulation includes defining the 'right owner', the access modes and common pasture regulation that is imposed by local institutions "Jmaa". This traditional tribal council is also responsible for disciplinary actions to deal with wrong doers. Over the last 50 years, most of these principles have been undermined. A combination of changes in demography, climate, technology, politics, and the economy have intensified practices resulting in a variety of 'natural resource crises' (Bourbouze, 1999) and have lead to open access of that common resource pool. However, unregulated use is causing damage and degradation to common lands. This unsustainable use and lack of cooperation among users is leading to downward trend in rangeland condition, and a hazardous future for forest and pasture resources.

Keeping in mind learned lessons from traditional rules and institutions 'Jmaa' and in order to get viable solutions to overgrazing in forest pastures, the High Commission carried out a program of compensation on forest areas closed to grazing (PCFC). This mechanism aims to involve the local population, organized into associations, in forest conservation and restoration activities. The PCFC was initiated in 2002 and applied for the first time in 2005. According to the legal framework, financial incentives are given to inhabitants near forests that are organized as associations of herders and which agree to respect grazing closure in the reforestation sites. Compensation amounts per ha per year are $35 for argan ecosystem and $25 for the other ecosystems.

Studies focusing on how, if and when a program such PCFC will contribute to reversing the degradation and downward trend are still rare. The aim of this study is to show the importance of this program in the restoration of silvopastoral lands in Morocco and its technical and socio-economic impacts. It also aims to determine the contribution of this program on promoting local development.

Materials and Methods

This study focuses on the implementation of the PCFC on Moroccan forest-rangelands (21°-36°N; 1°-17°W). Data was collected from public reports (HCWFCAD, 2015) to understand the mechanism and to assess its evolution. For this purpose, we combined, in the area being affected with the PCFC, data related to user activities (offense in forest-land) with the technical evaluation of managers activities (restoration success rates). In addition, structured interviews were carried out with forest-managers to assess the general validity of our observations. Also, interviews with key actors from involved associations and a focus group discussion with right holders have been conducted in order to collect data according to the topics: socio-economic characteristics of the respondent and the association, their membership in the association, their viewpoints on the mechanism and the association, their internal evaluations of the instrument, and their suggestions for mechanism improvements. Access rights and local practices for grazing management and control in addition to the use of better incentives were appreciated. Finally, the nature of the relationships between local populations and Forest-managers has been assessed in some key cases.

Results and Discussion

Globally, forest-managers and right holders appreciate the PCFC. Thus, stakeholders have embraced involvement in silvopastoral resource management. Also, the mechanism opened better communication and cooperation between local populations and administration. Populations, through their local associations, have been actively involved in the choice of restoration stands that will be closed for grazing. They also, nominate caretakers who will prevent herd access to those stands.

Since the implementation of the PCFC, grazing association numbers and members have been increasing. Currently, there are more than 165 associations with more than 15,400 members on about 91.000 ha. This trend has been associated, on areas with a high association concentration, with a positive impact on the reduction of the number of offense and on improved reforestation success rates (Fig.1).

Figure 1. Evolution of area compensed, grazing association numbers and members and their impact on offense numbers and restoration success rates

In many cases, associations filled the gap associated with the loss of the "Jmaa's" power as social institutions endorsing regulation. The mechanism enhances solidarity between members, creates a new dialogue space and gives a new perspective on that institutions contribution to the local development. PCFC incentives are generally either: i) distributed equally between members (12%), ii) serve as caretakers payment (32%), iii) invested in small projects and income-generating activities (35%) and iv) used for association's operating costs (12%).

If the PCFC have been described by managers as successful, it faces several difficulties and fragilities. These include mechanism fairness and implementation in addition to user related problems and the future viability of such a structure and mechanism, the legal minimum area and the per ha amount. Also, the administrative process is too long. On the other hand, problems inside association rely on governance-questions, mainly incentives distribution, and problems with the local tribes.

Conclusions

Our results stressed some drivers and constraints regarding the PCFC. Based on our results, the mechanism contributed, in many cases, to find consensus in pasture restoration that will help managers to break the vicious-cycle of overgrazing, and promote a new collective stewardship of the land. If the instrument is helpful, many questions remain open, ranging from the way in which the PCFC is implemented to the viability of the association. Beyond the fact, that PCFC could be analyzed as a "conservation-annuity" and in order to diversify the incentives, the PCFC should be presented as payment for environmental service (the service could be defined as the avoided degradation).

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Animal-to-Land Relationship and Beef Production of Beef Heifers Managed in Natural Grasslands of Pampa Biome: A Meta-Analysis

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Key words: Rangelands, stocking rates, average daily gain, Southern Campos.

Introduction

Overall demand for agricultural products is expected to grow at 1.1 percent per year between 2005-2050 due to increasing population which will require more food production through increased production area, use of nitrogen fertilizer, and increased efficiency (Alexandratos and Bruinsma 2012). In increasing production, agriculture must adopt more efficient and sustainable production methods to adapt to climate change (FAO, 2009).

The use of Pampa Biome natural grasslands to produce food (beef, sheep, and goat) is an important consideration. This ecosystem is one place with high natural biodiversity where it is possible to engage in both food production and environment conservation. This requires animal production to be considered a reward with benefits for the ecosystem (Carvalho & Batello 2009). During the second half of the 20th century, several animal production studies were conducted in these grasslands in regard to stocking capacity and animal gain. The objective of this work was to evaluate, using a meta-analysis, the animal-to-land relationship and beef production of beef heifers managed in natural grasslands of Pampa Biome.

Material and Methods

The dataset consisted of 358 observations from 15 grazing experiments involving beef heifers grazing the natural grasslands of the Pampa Biome between 1998 and 2014. The criteria to include experiments was the use of the variables stocking rates (SR), and presence of average daily gain (ADG) data for beef heifers grazing the natural grasslands of Pampa Biome. The SR adjustments were performed using the criteria of forage allowance in 92% of the observations, and 90% of the experiments were conducted with continuous stocking as the grazing method. Forage mass was evaluated directly in all experiments. The data were summarized MS Excel with the mean of each repetition from each experiment in each climatic season representing one observation.

The SR (kg BW/ha) were calculated from all experiments for each climatic season. The ADG (kg BW/day) was calculated based on fasting initial and final body weights of all animals from each observation. Beef production (BP; kg BW/ha/season) was calculated multiplying the mean ADG by the mean number of beef heifers during each season. The data were separated by season with 102 observations during spring, 102 observations during summer, 87 observations during autumn, and 67 observations during winter. The climate is subtropical humid, with a mean annual temperature of 18.7ºC and mean annual rainfall of 1446.2mm (distributed over seasons); frosts are common during winter season. Data were analyzed by ANOVA with four factors (climatic seasons) and two dependent variables (SR and ADG), with an alpha of 0.05. All statistical analysis were performed using SAS 9.2 (SAS Institute Inc. Cary, NC).

Results and Discussion

There was a climatic season effect on SR, ADG and BP (P<0.05) (Table 1). The SR values were similar between spring, summer and autumn and greater than for winter. The ADG was greatest during spring, intermediate during summer and lowest during autumn and winter. The BP was similar during spring and summer and greater than for autumn and winter.

Table 1. Seasonal effects on pasture productivity (mean ± SE) for beef heifers managed in natural grasslands of Pampa Biome – a meta-analytical approach.

Seasons	Stocking rate (kg BW/ha)	Average Daily Gain (kg BW/ha/day)	Beef Production (kg BW/ha)
Spring	631.6 ± 56[a]	0.424 ± 0.021[a]	95.3 ± 10.4[a]
Summer	667.7 ± 40.4[a]	0.263 ± 0.021[b]	72.4 ± 7.5[a]
Autumn	627.4 ± 34.7[a]	0.068 ± 0.027[c]	10.9 ± 5.1[b]
Winter	416.9 ± 26.9[b]	0.083 ± 0.031[c]	13.4 ± 5.3[b]

[a, b, c] - Means in a column not followed by the same letter differ (SR at P<0.01; ADG at P<0.0001; BP at P=0.02)

The natural grasslands vegetation of the Pampa Biome (Boldrini, 2009) and forage growth during spring and summer provided sufficient forage to support greater SR during spring and summer, and greater ADG during spring than other seasons. Forage growth is not generally not high during the autumn, however, SR were similar between this season and spring/summer. This result was probably due to the growth during the preceding seasons that left biomass with high dry matter content for the autumn. However, this biomass was of lower quality than in the spring resulting in lower ADG. Summer ADG was also lower than spring, despite similar SR. Possible explanations for this result include a reduction in forage quality during periods of low precipitation, and a reduction in animal growth due to thermal stress reducing voluntary intake. Another important result was the positive ADG during winter season (greater than zero; P<0.01), comparable with autumn ADG, although winter SR was lower than other seasons. Generally, during autumn and winter seasons, there is a reduction in forage nutritive value resulting in reduced ADG. It is important to note that winter season data included observations where animals received different types of supplementation. However, only observations where animals received less than 0.5% of BW on a dry matter basis from protein supplements (used to maintain the growing of cellulolytic bacteria) were included. Beef production also clearly reflected the spring-summer pattern of production, where around 87% of the production occurred during these seasons. The annual BP (192 kg BW/ha) is around three times the mean farm production in these grasslands, indicating substantial opportunity to improve food production from the Pampa biome. Furthermore, it is important to note the potential to improve beef production during cool seasons in these grasslands, through use of feed supplements, soil fertilization and/or over-seeding of cool season species (Oliveira et al., 2016).

Conclusions and Implications

The seasonal differences in SR and ADG indicate different management may be required during the different seasons to improve production efficiency. Additionally, these data provide producers with information to support management decisions regarding grazing beef heifers in the Pampa biome.

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The Where and Why of Livestock Movement Patterns: Understanding Herder Decision-Making in an Agropastoral Context

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Key words: Herd movement, agropastoralist, herder decision-making, livestock, livestock movement patterns

Introduction

Free-ranging animal movement (or lack thereof) is one of the key differences between native and domestic ungulate grazing strategies. This is because domestic livestock movements are controlled by a human manager whose decisions are constrained by a host of physical and socio-economic (Baker & Hoffman 2006) constraints, as well as potentially by various perceptions s/he holds regarding aspects of their environment (Baird *et al.* 2009). As grazer movements affect the spatial pattern, and potentially the magnitude, of impacts on a variety of ecosystem properties (Illius & O'Connor 1999), the factors that motivate individual herd movement could play a significant role in herders' ability to sustainably manage livestock and prevent environmental degradation (Baker & Hoffman 2006) and may help explain why wildlife grazing can have positive effects on ecosystem properties while grazing by livestock often does not (McNaughton 1993). This study uses questionnaires (n = 31) to explore the various environmental, socioeconomic and other influences on individual herder movement and management decisions across two communities of agropastoralists surrounding the Serengeti ecosystem of northern Tanzania. We expected that herding strategies would be limited due to a variety of ecological, economic, political, and socio-cultural factors but that a primary factor would be restrictions of herd movement as a result of 1) a limited grazing area and 2) the need to locate grazing movements around the home (Coppolillo 2001).

Materials and Methods

Prior to initiating the study, the proposal was reviewed by Syracuse University's Institutional Review Board (IRB) and found to meet ethical standards. A combination of convenience and random sampling was then used to select a sample of households to be surveyed within each sub-village. Potential respondents were provided information about the study in Kiswahili, the lingua franca of the region, and oral consent was obtained. Participants were 18 years or older and either owned, or belonged to a household that owns, livestock. Only one individual per household was surveyed.

Survey data was analyzed using the Hmisc package of the statistical program R. Summary statistics were used to assess variation in individual responses. Statistical tests included Pearson's correlations (*rcorr* function in R) for quantitative variables and Fisher's exact tests (*fisher.test* in R) for categorical variables.

Results and Discussion

The majority (80%) of participants were agropastoralists while 10% combined that with some external venture and another 10% only kept livestock. Most respondents (74%) kept livestock solely for subsistence while one quarter kept them for commercial purposes as well. Herd sizes varied greatly, ranging from 8 animals to 2,120 animals and averaging 177 animals per herd (SE = 68). The largest share (26%) had a herd size between 21 and 50. Herd size was significantly correlated with family size (n = 31,

r = 0.46, R^2 = 0.208, p = 0.010), with respondents with larger families also having larger herds. The number of herders used also increased with family size (n = 31, r = 0.40, R^2 = 0.162, p = 0.025).

All respondents described the daily movement pattern as moving herds from place to place based on vegetation quantity. Direction and distance of movement varied by season and was driven largely by availability and location of water sources. When asked about factors that restricted movement, 66% cited a nearby protected area. The reported likelihood of grazing in a protected area was positively associated with herd size (n = 31, p = 0.011) and with purpose for keeping livestock, with those whose purpose was also commercial (n = 31, p = 0.011) more likely, and negatively associated with a respondent's perceived risk of doing so (n = 31, p = 0.013). Most respondents (58%) saw livestock population density as high or very high, with older respondents (> 40 years) more likely to think so (n = 31, p = 0.003). As a result, 80% of respondents did not think livestock-keeping would be successful there in the future.

While the search for water and forage resources consistently ranked as the highest concern when making movement decisions, a host of other factors played a role in decisions such as whether to leave the village area or to enter illegally into a protected area for grazing. Variation in the degree of enforcement of protected areas and its effect on the size of the realized risk of illegal grazing may also play a role in the decision to enter these areas. Regional differences in historical context also helped to explain the significance of various factors in explaining movement decisions.

Conclusions and Implications

Understanding how socioeconomic and other factors influence individual herd movement decisions can help to place into context impacts of livestock grazing across the landscape and may be the key to understanding differences in impacts between wildlife and livestock grazing systems (McNaughton 1993). These results illustrate the necessity of considering the socioeconomic and political context in which decisions regarding livestock management and movement are made and in recognizing the larger historical context in which agropastoral communities are set in order to better comprehend the drivers of livestock grazing impacts and their distribution across human-dominated landscapes.

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Grazing and N-Amendment Impacts on Soil Nitrate-N Supply Rate

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Key words: Intensive rotational pasture, nitrate supply, fertilizer-N, grazing impacts

Introduction

Productivity of grasslands in the western Canadian Parkland is limited by N deficiency and is responsive to fertilizer-N application (Kopp et al., 2003). Short-duration intensive rotational grazing with high stocking rates may increase N-cycling and improve excreta distribution so that fertilizer-N application can be reduced or eliminated. Reducing or eliminating fertilizer-N application might be an environmental advantage. However, this has not been demonstrated experimentally.

Our objective was to investigate the impact of rotational grazing meadow bromegrass (*Bromus riparius* Rhem.) on soil mineral-N supply throughout the grazing season, compared to ungrazed hay, grazed-swards with fertilizer-N, organic N-amendments and a grass-alfalfa (*Medicago sativa* L.) mixture.

Materials and Methods

The experiment was conducted from 2003 to 2006 at Lacombe, AB on a black, silt-loam soil with 7-8% organic matter. Treatments established in a randomized block design with three replicates were: 1. Ungrazed – hay (no fertilizer); 2. Grazed (G)-alone; 3. G-Fertilizer; 4. G-Fertilizer+compost; 5. G-Hog manure; 6. G-Grass-alfalfa. The paddocks (9 x 30 m) were mob-grazed with a variable number of yearling beef heifers to an equal residue level in a 3-day grazing period three times per season (Fig.1). Pasture sampling for dry matter (DM) yield and forage quality occurred before and after grazing. Supply rates of NH_4^+ and $N0_3^-$-N were determined using PRS® probes (Western Ag Innovations, Saskatoon, SK), which contain cation and anion exchange resins (Qian and Schoneau, 1995). Probes were place about May 1 each year and were removed, processed and replaced by recharged ones in identical slots at two-week intervals for 22 wk. Soil samples were collected each October from 0-15, 15-30 and 30-60- cm depths and analyzed for NH_4^+ (not shown) and NO_3^--N concentrations. Data were analyzed statistically using a mixed model, parameterized appropriately for years and sampling times treated as repeated measures.

Results and Discussion

Averaged over years, the grazed, fertilized, fertilizer + compost, hog manure and alfalfa-grass treatments produced 1.1, 1.8, 2.0, 1.6 and 1.5 t ha^{-1}, respectively, greater ($P<0.05$) DM yield than the ungrazed. Only fertilizer + compost yielded more DM ($P<0.05$) than grazed-alone.

Both grazing and amendments increased NO_3^-- N supply rate during the grazing season. The supply rates were similar among treatments until grazed and amendments applied (Fig.1). In the first measurement period following grazing, the NO_3^--N supply rates for the treatments without added N increased by an average of 37% while the treatments with amended-N increased by 112%. All treatments then had declining supply rates with succeeding measurements until the second grazing when there was a second spike. On average, unfertilized treatments increased by 245% between before and after grazing while N-added treatments increased 283%. Accumulated supply rates over the 22-wk period showed that grazing increased total NO_3-N supply by 610 ug 10 cm^{-2} above no grazing. Adding fertilizer N (with or without compost) increased the supply by an additional 499 ug 10 cm^{-2}.

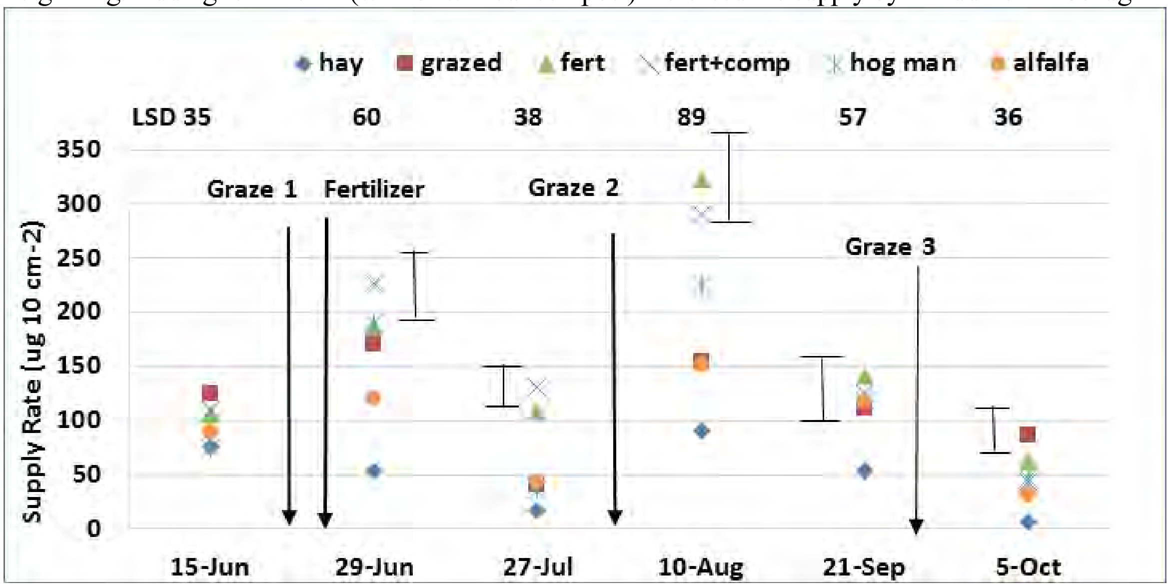

Figure 1. Nitrate-N supply rate at selected dates before and after grazing and application of N amendments (vertical arrows indicate timing of grazing and fertilizer application). LSD $_{0.05}$ is between treatments within dates.

After two years of grazing, soil NO_3^--N concentrations (0-15-cm) were lower ($P<0.05$) for the ungrazed and alfalfa-grass paddocks than the others. Averaged over the experimental period ungrazed, grazed alone and alfalfa-grass had lower NO_3^--N concentrations than fertilizer and fertilizer+compost treatments. The 15-30 and 30-60 cm depths showed similar trends. Production of grazed or hay-harvested perennial grass effectively reduced NO_3^--N concentrations in the soil profile to a depth of 60 cm except when 112 kg N ha^{-1} as commercial fertilizer was broadcast in conjunction with grazing. In spite of the increased supply rate with N fertilization, the total N cycled (consumed and returned urine and feces and sward residue) was similar among grazed treatments (306-350 kg N ha^{-1} annually).

Conclusions and Implications

On a black soil with high N mineralization potential, grazing cycled N to supply sward requirements; no DM yield benefit was evident when fertilizer-N was supplied, alone, or combined with compost or hog manure. This may not occur for sites with low initial N concentration and/or low mineralization potential. Intensive rotational grazing resulted in rapid cycling of N through the system, some mineralized from soil organic matter, a proportion consumed and returned to the soil in fecal and urine forms and some from unconsumed plant residues.

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Physiological Characteristics, Root Mass and Crude Protein of *Brachiaria Brizantha* Cv. Marandu under Inoculation or Nitrogen Fertilization

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Key words: Biological fixation, chlorophyll, grass, nitrate reductase

Introduction

Forage mass production and protein content are products, among others, of assimilated nitrogen (N), climatic conditions, physiological age and management that interfere with the root mass and chlorophyll production. The use of N fertilization increases costs, and therefore, alternatives such as the use of *A. brasilense* which uses nitrogenase complex enzyme to fix nitrogen acting as drought stress indicator has been developed. The objective was to evaluate Marandu grass nitrate reductase enzyme activity, chlorophyll content, crude protein (CP) and root dry mass using three nitrogen doses with or without inoculation.

Material and Methods

The experiment was conducted in Jataí Regional of Federal University of Goiás, Cw climate classification in liming and fertilized Haplortox-LVd soil. The factorial treatments were 0, 50, and 200 kg N/ha as urea and 0 to 200 mL/ha *Azospirillum brasilense* Masterfix Gramíneas® inoculation distributed in four casualized blocks. The evaluation cycle ended when the Marandu grass sward reached 95% Light Interception (LI). Root dry matter (DM) weight was measured in kg/ha in two 3"Ø/60 cm/plot sampled at two depths from 0 to 10 and from 10 to 20 cm, 5 cm away from the clump. The nitrate reductase activity was obtained by the adapted methodology from Meguro and Magalhães (1982). The total chlorophyll content was obtained in 10 leaves/plot in the second completely expanded leaf at the end of the cycle. The crude protein (CP) was determined according to Silva and Queiroz (2002). Analysis of variance was performed using SAS v. 9.3 to 5% probability in a split plot arrangement, with block and dose effect in the plot and inoculant and interaction effect in the split plot. Variables such as chlorophyll and CP were transformed by box-cox.

Results and Discussion

There was no significant effect of the interaction between N doses and inoculation. Despite the grass CP content was 7.69%, this had no response to the inoculant application, however the activity of nitrate reductase (4.96 vs. 3.18 NO2 µmol/h/g GM) and chlorophyll content (32.72 vs. 34.44 SPAD) were changed showing that inoculation interfered with nitrogen use that is a fundamental part of chlorophyll and has its metabolism regulated by nitrate reductase. The inoculation resulted in a significant increase of root DM at the depth of 0 to 10 cm of soil, indicating a surfacial effect of the microorganism. Also regulatory substances like auxins, gibberellins and cytokinins that support vegetable growth can have their production and release increased which assists in N absorption from the biological fixing and obtained by mass flow and other mechanisms of growth promotion. These events are able to increase water absorption capacity of plants and reduce the stress of drought effect resulting in increased activity of nitrate reductase and chlorophyll production (Bazzicalupo and Okon 2000). The nitrate reductase activity did not respond to nitrogen application probably because during the evaluation an extended drought period occurred. In addition, urea undergoes volatilization and reduces NO3-supply speed in the soil. Together, these two factors can promote the N absorption in more readily available forms, reducing the plant energy consumption and causes lower nitrate reductase activity which is a physiological indicative of plants under adverse conditions (Castro et al., 2007). At the same time, the chlorophyll content, CP and roots DM production at the 0-10 cm depth response was quadratic and positive showing that there is increased uptake of soil nutrients for mass synthesis. The increased uptake generates reservations translocation for the production of leaves with a linearly and significant reduction in root mass at the 10 to 20 cm depth, which may lead to a longer forage recovery period after cutting and to a reduction in the resistance to water deficit and nutrient absorption area over the time.

Table 1. Nitrate activity reductase in NO2 µmol/h/g GM (green mass), chlorophyll content in SPAD, crude protein percentage and root dry matter production of depths 0-10 and 10-20 cm in kg/ha in Marandu grasss as a function of inoculation and nitrogen doses

Variable*	*Azospirillum brasilense* mL/ha		Mean±Standard Deviation	P-Value (F Test)
	0	200		
Reductase	3.18 ± 0.43	4.96 ± 0.43	-	0.0185
Chlorophyll	32.72 ± 0.53	34.44 ± 0.53	-	0.0173
Crude protein	7.56	7.81	7.69 ± 0.95	0.2640
Variable (cm)	***Azospirillum brasilense* (mL/ha)**		**Mean±Standard Deviation**	**P-Value (F Test)**
	0	**200**		
Roots from 0 to 10	2970 ± 196	3864 ± 217	-	0.0156
Roots from 10 to 20	593 ± 65	743 ± 65	668 ± 225	0.1372

Variable*	Nitrogen Doses (kg /ha)			Effect**	
	0	50	200	Linear	Quadratic
Redutase	3.74 ± 0.53	3.54 ± 0.53	4.92 ± 0.53	-	-
Clorophyll	27.25	30.82	42.67	<0.0001	0.0263
Crude protein	4.79	5.69	12.57	<0.0001	0.0002
Variable (cm)	**Nitrogen Doses (kg/ha)**			**Effect (P-Value)**	
	0	**50**	**200**	**Linear**	**Quadratic**
Root from 0 to 10	4143 ± 240	2617 ± 240	3491 ± 277	0.2280	0.0241
Root from 10 to 20	897 ± 79	754 ± 79	353 ± 79	0.0027	0.2294

*Redutase: nitrate reductase activity; Chlorophyll: chlorophyll content; ** P-Value

Conclusion

Nitrogen fixation reduces water stress effects by increasing root mass surface, water absorption and nitrogen and chlorophyll synthesis, resulting in faster productive return post-stress, due to the increased assimilates reserve. Fertilization favored forage crude protein content and led the plant to seek more readily available nitrogen forms, while making it better adapted to adverse environmental conditions.

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Morphological Characteristics of *Brachiaria Brizantha* cv. Marandu Inoculated or Nitrogen Fertilized

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Key words: Azospirillum*, Brazilian savanna, forage, light interception, soil colonizing*

Introduction

Biological nitrogen fixation (N), resulting from the association of plants with different organisms, can lead to system sustainability and can impact tropical grasses adapted and/or genetically improved which have high response capacity to nitrogen supply. The N accretion generates forage changes, both in terms of function and in morphological form. Thus, the objective was to evaluate the morphological proportion of Brachiaria brizantha cv. Marandu subjected to nitrogen doses and inoculation with Azospiril lumbrasilense.

Materials and Methods

The experiment was conducted in Jataí Regional of Federal University of Goiás, from January to May 2014, using 24 plots of Brachiaria brizantha cv. Marandú with 16 m^2/plot distributed in four randomized blocks in a factorial arrangement of treatments, 0, 50, and 200 kg N/ha doses of urea and 0 to 200 mL/ha of Azospiril lumbrasilense dose by Masterfix Gramíneas® - Abv5 and Abv6 strains (2.0 x 10^8 CFU/mL). The end of each cycle was determined at 95% light interception monitored by ceptometer (AccuPAR® model LP-80) when two samples were collected of 0.25 m^2/plot, close to the ground and separated in grazing layer (G: 15 cm above the ground) leaf (GLeaf and NGLeaf), stem (GStem and NGStem) and dead material (GDead and NGDead) and no grazing layer (NG: from the ground to 15 cm). Data were analyzed using SAS v. 9.3 at 5% probability in a split plot design, considering block and dose effect of the plot and Azospirillum brasilense inoculation and interaction in the split plot, and the GDead variable was normalized by log transformation (x).

Results and Discussion

GLeaf and GDead fractions (53.70 and 12.30%) and NGLeaf, NGStem and NGDead (7.16, 44.35 and 48.47%), had no significant response to Azospiril lumbrasilense inoculation (Table 1). GStem variable had a negative response ($P < 0.05$) to Azospiril lumbrasilense inoculation, making the pasture structure more appropriate and possibly increasing the forage quality. Oliveira et al. (2007) observed that the treatment without N application and with inoculation produced more forage than control and when N fertilization was accomplished over the grassland there was no effect or the inoculation effect was negative. Guimarães et al. (2011) observed that strains such as AZ09 tended to decrease stem dry mass compared to control, reflecting the larger carbohydrates partition for leaf production.

The morphological fractions GLeaf, GStem and GDead showed a quadratic response, NGLeaf and NGDead variable had a linear response and NGStem variable did not respond to changes in N levels ($P > 0.05$). Increase in the grazing layer leaf proportion was 29 and 95% at 50 and 200 kg N/ha, respectively with 65% stem production reduction as a consequence of the higher growth rate on 200 kg N/ha dose and resulted in a leaf/stem ratio increase from 49 to 84 percent. At the same time, dead material percentage wasbreduced from 19 to 9% with increasing nitrogen doses.

Increase in the no grazing layer leaf percentage as a function of N fertilization favored a faster and vigorous sward regrowth and enabled a greater number of cuts in the grazing season.

Da Silva et al. (2008) commented that defoliation results in growth and mass accumulation limited by photoassimilates and that organic reserves and remaining leaf area index are responsible for the regrowth vigor and for the reduced tiller time dependence of organic reserves. These events allow a faster leaf area recovery as a function of carbohydrate immediate production derived from photosynthesis.

Table 1. Brachiariabrizantha cv. Marandu morphological fractions (leaf, stem and dead material), in function of Azospiril lumbrasilense inoculation and nitrogen fertilization in grazing layer (G) and no grazing (NG)

Variable (%)*	*Azospirillum brasilense* (mL/ha)		Mean ± Standard Deviation	P-Value**
	0	200		
GLeaf	54.25±1.24	56.51±1.24	55.38±4.30	0.2310
GStem	33.39±1.01	29.89±1.01	-	0.0382
GDead	12.35±0.86	13.59±0.86	12.97±3.01	0.3484
NGLeaf	7.27±0.63	7.05±0.63	7.16±2.19	0.8128
NGStem	44.80±1.37	43.91±1.37	44.35±4.75	0.6562
NGDead	47.92±1.32	49.03±1.32	48.47±4.60	0.5674

Variable (%)	Nitrogen Doses (kg/ha)			Effect***	
	0	50	200	Linear	Quadratic
GLeaf	39.19±1.52	50.66±1.52	76.29±1.52	<0.0001	0.0312
GStem	41.43±1.24	39.07±1.24	14.41±1.24	<0.0001	0.0039
GDead	19.36±1.06	10.25±1.06	9.28±1.06	0.0003	0.0325
NGLeaf	3.19±0.77	6.16±0.77	12.13±0.77	0.0009	0.2822
NGStem	40.70±1.68	46.01±1.68	46.35±1.68	-	-
NGDead	56.10±1.62	47.82±1.62	41.50±1.62	0.0126	0.7949

*GLeaf, GStem and GDead: leaf, stem and dead material fraction in grazing layer; NGLeaf, NGStem and NGDead: leaf, stem and dead material fraction in the no grazing layer. ** F Test. ***P Value.

Conclusions and Implications

Azospirillum brasilense inoculation changed *Brachiaria brizantha* cv. Marandu morphological composition as a function of stem fraction reduction making the sward structure more appropriate and nitrogen fertilization generated higher leaf proportion ensuring faster leaf tissue replacement and more cuts throughout the grazing period.

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A Time Series Analysis of Goats' Foraging Behavior in a Semi-Natural Grassland: A Preliminary Report

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Key words: Foraging behavior, goats, heterogeneous pasture, time series analysis

Introduction

Mammalian herbivores select and ingest various types of plant species in heterogeneous plant communities. Their foraging behavior would vary with time, and may have periodic or characteristic patterns, because animals require several energy or protein rich species in some occasions, but seek various types of mineral rich species in other occasions. However, it is not clear yet whether animals show any periodic patterns in their course of foraging behavior. In this pilot study, we tried to explore goats foraging patterns in a heterogeneous plant community, using time series analyses.

Materials and Methods

This study was conducted on a semi-natural grassland (0.8 ha), located in central Japan (35°29' N, 137°1' E; altitude, 130 m). The grassland used to be an abandoned field, but approximately 16 goats grazed the field from early-June to mid- November in the previous year (Doi et al., 2014). The site was dominated by forbs, dwarf bamboos, graminoids, and shrub-like bamboos in the study year. The field was divided into two areas (0.3 and 0.5 ha, respectively), and 9 goats (high stocking rate, 2.25 LU/ha) and 7 goats (low stocking rate, LS: 1.05 LU/ha) were set stocked, respectively, from 9 May to 8 November 2014. In this analysis, goats in LS treatments (BW: 30.4 kg) were used to investigate their foraging patterns. We observed goats foraging behavior on 31 May-1 June (Spring), 1 August-2 August (Summer), and 11 October-12 October 2013 (Autumn). Observers followed two goats for 2 h in the morning and afternoon in each day (total 4 goats in each season), and recorded ingested plant species and number of bites of the plant species, continuously. The number of ingested plant species and bites were arranged every 2 min from the start to the end of observations (basic data) and determined 3-points moving averages (moving average data). Both basic and moving average data of each goat in each season were tested using Phillips-Perron test to know whether the time series data were stationary or non-stationary processes. Then, we performed autocorrelation analysis to explore whether previous foraging behavior affects the subsequent foraging behaviors. Finally, we used spectrum analysis to detect periodic patterns of goat's foraging behavior during the observation time. All statistical procedures were performed using R software (R development Core Team, 2014).

Results and Discussion

Mean plant biomasses were 2.1, 2.3 and 1.2 t DM/ha in Spring, Summer and Autumn, respectively. Goats ate total 43, 40, and 42 plant species and took 3365, 3252, and 3836 bites on average during observation times in Spring, Summer, and Autumn, respectively. As shown in the example of Fig. 1a and b, goats ate approximately 1–5 plant species every 2 min; however, there were no visually-apparent patterns in their choice of plant species. Similarly, changes of the number of bites did not show any apparent patterns (data not shown). Almost all foraging patterns were stationary states, except for 3 cases in moving average data, implying that goat's foraging patterns with time were not random walk processes. Autocorrelation analysis shows that previous foraging behavior, i.e., number of plant species that were ingested by goats or number of bites at a certain time, did not affect the subsequent foraging behavior (Fig. 1c). Spectrum analysis did not find any periodic components in the goat's foraging behavior (Fig. 1d).

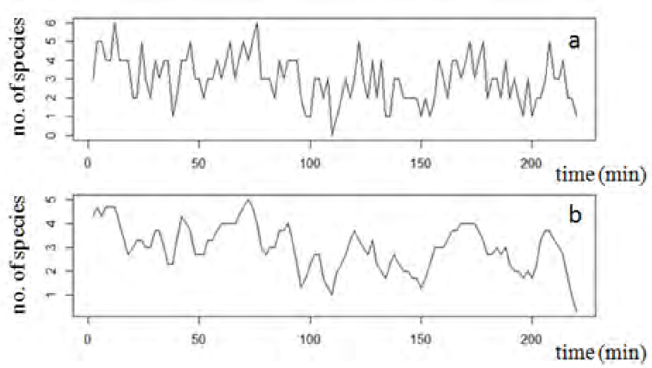
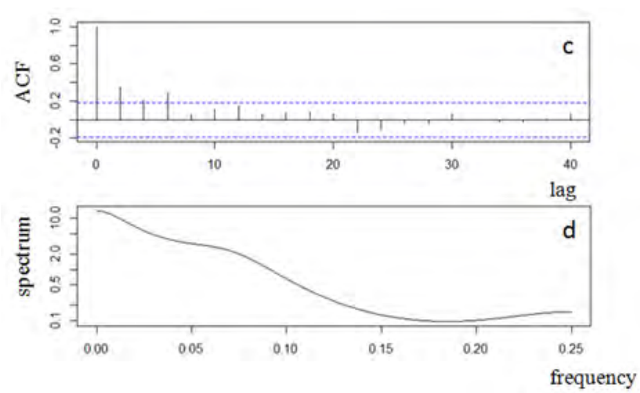


Figure 1. An example of goat foraging behavior with time.

a) number of plant species that were ingested by a goat every 2 min and,
b) that of 3 points moving average;
c) autocorrelation coefficients and,
d) spectrum analysis of the foraging behavior.



Conclusion and Implication

We did not find any periodic or characteristic patterns in goats foraging behavior with time. Probably, spatial distributions of plant species and biomass strongly affect their time-series foraging behavior, suggesting that goats select and bite forages opportunistically rather than autonomously.

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Grazing Management for Tree Recruitment on Pastoral Land

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Key words: Grazing systems, *Eucalyptus,* recruitment, Australia

Introduction

Woodland clearing and replacement of the native grassland with "improved" (new species and fertilizers) pasture is implicated in biodiversity loss and degradation of soil and water (Fischer et al., 2010). Fencing remnant vegetation may increase tree, but not necessarily shrub, recruitment but is expensive and confined to remnant patches (Spooner et al. 2002). Survey of a large portion of pastoral land in SE Australia found that natural recruitment of trees will occur in some paddocks but not all (Dorrough and Moxham, 2005). Tree recruitment is known to be episodic and the effects of rainfall and other factors on reproductive processes, seed germination and seedling establishment are poorly understood (Vesk and Dorrough, 2006). These uncertainties dominate the chances of tree recruitment by grazing management. We used an approach that allowed us to sample and evaluate the effectiveness of different grazing systems for tree recruitment. Grazing systems were compared only when the rainfall sequences had been suitable for successful coupling of the stages of seed production, germination and establishment of trees and when sexually mature trees were present.

Materials and Methods

In the summer of 2001/2002 recruitment of *Eucalyptus* trees in paddocks, roadsides and remnants of native vegetation was determined at 325 sites in an area (149.84 to 148.53^{o}E and 33.10 to 34.83^{o}S) of SE Australia. Sites were found where there had been a recent recruitment event and to these were added one or more sites in adjacent areas which differed in grazing system and in landscape position. At each site the density of adult and recently recruited *Eucalyptus* trees was determined. There were 23 *Eucalyptus* species; 4 were present at more than 50 sites and 12 were present at 10 or fewer sites. At each site, 28 variables describing management, vegetation, landscape and soil properties (micro-topography, pH etc.) were recorded. Examination of relationships between variables reduced the set to 19, some of which were composites of original variables.

Using forward stepwise generalized linear regression modelling, explanatory models were constructed for all species to determine which site variables influenced the presence (binomial errors, logit link) and which influenced the numbers (negative binomial errors, log link) of recently recruited trees. Choice of variables were validated by refitting models to subsets of sites selected randomly without replacement from the total number of sites. This has been described as a 'deleted-jackknife' and is compared to bootstrap methods by Bin et al. (2016). We selected subsets of 75% and 63% of the sites. Validation in this manner was appropriate as it showed that the original study could have been conducted on fewer sites had fewer resources been available.

Results and Discussion

The variables that significantly accounted for deviance in the model for probability of tree recruitment shrub density, grazing system, landscape position and soil electric conductivity (EC) in descending order of importance. . The variables that significantly accounted for deviance in the model for density of tree recruits were grazing system, micro-topography, soil pH and shrub density (in descending order of importance). There were no significant interactions between any of the variables. In Figure 1 (left) the fitted lines indicate that the probability of recruitment is low under sheep grazing, moderate under mixed cattle-sheep grazing and high under ungrazed vegetation such as roadsides, travelling stock reserves and nature reserves. The probability of recruitment was significantly higher where native shrubs were abundant. Shrubs may provide the habitat for germination and establishment of trees or may be associated with but not cause better recruitment. In Figure 1 (right) the fitted lines indicate that where recruitment occurred the density of recruits was higher where sheep grazed. This may be because sheep avoided browsing of *Eucalyptus* seedlings or by trampling increasing the number of sites on the soil surface favourable for germination and establishment of trees.

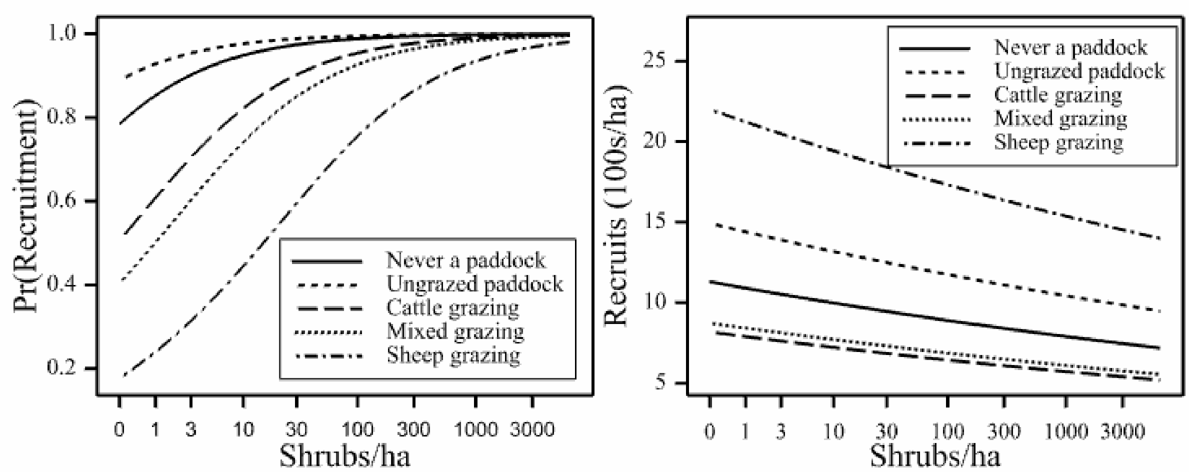

Figure 1. Relationships between probability of recruitment (left) and numbers of *Eucalyptus* juveniles (right) and shrub density for the five grazing systems.

Conclusions and Implications

Cattle and sheep grazing significantly reduced the probability of tree recruitment. However sheep, but not cattle grazing increases the survival and establishment of *Eucalyptus* tree seedlings in the pasture. Increased salt content and lowered pH of surface soil associated with tree clearing, higher positions in the landscape and reduced micro-topography and shrub density also significantly lower the chance of recruitment and establishment processes but their influences were much lower than that of the grazing systems.

Grazing by cattle and sheep does not eliminate recruitment of trees but grazing by these herbivores does reduce the chance of tree regeneration. Changing livestock from sheep to cattle will increase the chance of recruitment and tactical resting from cattle grazing should increase the density of tree recruits but effective resting times would be difficult to predict and manage.

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Range Reference Areas: Monitoring Vegetation in the Presence and Absence of Livestock Grazing

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Key words: Range reference areas, vegetation monitoring

Introduction

Successional changes, particularly positive ones, happen slowly in dry grassland vegetation. Livestock grazing is a major driver of successional change, but other drivers can influence succession, either separately or in combination with grazing. In addition, weather-driven interannual variation of vegetation cover is significant in dry grasslands. For these reasons, long-term vegetation data collection is essential for proper rangeland management (Laycock, 1975, National Academy of Sciences, 1994).

Materials and Methods

In 1995-1998 the BC government funded the construction of some sixty permanent upland range reference area (RRA) sites in representative grazed native grassland locations on Crown lands in the BC interior (MFLNRO, 2016). The typical layout consists of a one hectare fenced grazing exclosure with five permanent 60m vegetation transects inside (Ungrazed Treatment), and five additional transects outside (Grazed Treatment). In a few sites where wild ungulate grazing is significant, an additional hectare was enclosed with wildlife-proof fencing. Monitoring technique was by visual estimation of cover for each plant species, using a Daubenmire frame (Daubenmire, 1959) and estimating to the percent. Ten observations per transect gave a total of 50 observations per treatment. Reference photos were also taken.

Results and Discussion

For 26 RRAs in the Southern Interior (Okanagan, Kettle, Granby, Columbia and Kootenay River valleys), all were monitored the year after construction, during peak phenology (late May to early July). In spite of the program being terminated in 1999, ten RRAs have been subsequently remonitored. Data from five remonitored sites were combined with other longitudinal datasets to demonstrate a decline in diffuse knapweed (*Centaurea diffusa* Lam.) populations due to introduced insect biocontrol agents (Gayton and Miller, 2012). Another one of the ten remonitored sites showed forest ingrowth (as a result of fire suppression) to be a more significant ecological driver than grazing (Gayton, unpublished data). Another site is being currently used to assess the impacts of prescribed burning.

Conclusions and Implications

Rangeland succession typically occurs over decades, not years. Thus the creation, maintenance and re-monitoring of permanent reference areas is fundamental to science-based management, but there are many obstacles. Government-funded reference area programs are subject to budget whims, and a short two or three year lifespan is typical. Data storage is problematic; softwares become obsolete and relevant staff are reassigned or retire. A plethora of different vegetation monitoring methodologies are available, and they too evolve over time.

Several recommendations emerge from the RRA experience. Choose a single monitoring methodology and document it explicitly, including details that may seem self-evident at the time of writing. Assume the individual doing future remonitoring has no prior knowledge of the methodology or of the monitoring site. Store methodology and field data files in both paper and digital versions, in more than one office location. Mark transect start and endpoints with substantial metal markers (heavy enough to be located with a metal detector) buried to slightly above ground level. Document permanent transect start and endpoints with GPS units as well as with physical measurements from permanent markers (rocks, fenceposts, trees). Provide a paper and digital map of transect layout, including all distance measurements.

Build longevity into the range monitoring program by involving multiple stakeholders in its creation and implementation. Different levels of government, universities, producer associations, ENGOS and individual consultants can all play a role to ensure the timely remonitoring, data entry/analysis, data storage and fence maintenance required for an effective, sustainable, long-term rangeland monitoring effort.

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Use of Alternative Pastures on Dry Land Farms in New Zealand to Promote Heifer Growth

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Key words: Heifers, pasture, herb forages, Lucerne, grazing

Introduction

Intensification of the dairy industry in New Zealand has resulted in young dairy heifers being sent to grazing on extensive hill country that has traditionally been used for sheep and beef farming. This has resulted in needing to have sufficient quality and quantity of forage to meet growth rates and hence growth targets as heifers are frequently failing to meet live weight targets (McNaughton & Lopdell 2012).

A particular stage of the year that is challenging is the summer-autumn period (January – May) in New Zealand. The amount and quality of traditional mixed ryegrass and white clover pasture is reduced compared to spring – early summer. As a result of this, there is interest in using alternative forage species such as Lucerne or herb mix (chicory, plantain, red and white clover) forages, which have been demonstrated to have higher dry matter production over the summer period to maintain or increase growth rates. The requirements for plants to be successful in dry areas include: need to be high feed quality, cope with a dry environment, the forage needs to palatable and, consumption of the forage needs to result in high levels of animal performance.

The aim of this experiment was to evaluate using Lucerne and the herb mix to provide quality feed for growing replacement heifers on a non-irrigated farm during summer.

Materials and Methods

This experiment was conducted over a 63 day experimental period. Sixty crossbred heifer calves were allocated to one of three treatments in January: 1) Ryegrass/white clover pasture, 2) the herb mix (chicory, plantain, red and white clover) pasture, and 3) Lucerne pasture. These crops were sown on flat, former river terraces on the farm. The feed allowance offered was calculated to meet the required ADG to meet liveweight targets in May when heifers were 9 months of age. Heifers were strip grazed behind an electric fence in groups of 20.A weekly feed allowance per strip was determined using pre and post cuts and fortnightly weights.

Results and Discussion

Lucerne and the herb mix swards had higher ME, CP % and digestibility, which resulted in greater live weight gains in heifers on those treatments (Lucerne 0.80 ± 0.02^{a} kg/d vs herb mix 0.75 ± 0.02^{a} kg/d vs pasture 0.53 ± 0.02^{b} kg/d; Handcock et al. 2015).

Results presented here focus on changes in botanical composition seen during this time, with changes between 2 time points illustrated in Figure 1. Herb pastures require a slower grazing rotation to ensure the pasture survives, as frequent (every 2 weeks) grazing by dairy cows destroys chicory and red clover pasture within 1 growing season (Navarrete, unpublished data). In our study, a slow grazing rotation (paddocks were grazed every 4-5 weeks) resulted in large botanical changes in the herb mix compared to the Lucerne and pasture swards. The herb mix became reproductive and the proportion of edible chicory leaf decreased from 60 to 30%. In addition, the total proportion of chicory decreased from 89 to 25% of the sward whereas plaintain increased from 6 to 30%. That calves select chicory over plantain is consistent with a subsequent experiment we have conducted (Back, unpublished data). The proportion of edible leaf remained at a similar level in both the Lucerne (70-75%) and pasture (20%) treatments (Figure 1). Calves did not eat the reproductive stem in the herb mix, resulting in a large increase in dead matter but grazed the lucerne stalk to 20 cm, which resulted in only a small increase in dead matter in the Lucerne crop of 9%.

The slow rotation lengths on the 3 treatments resulted in high average pre and post grazing masses, from which apparent intakes were calculated. For Lucerne, pre-post (7833 – 4629 kg DM) resulted in an apparent intake of 13.4 kg/d, whereas the herb mix (6525 – 4517kg DM) resulted in an apparent intake of 9.6 kg DM/d and ryegrass/white clover pasture (9295-8138 kg DM) resulted in an apparent intake of 6.3 kg DM/day. Estimating intake in a pastoral situation is difficult and these apparent intakes in the Lucerne and herb mix compared to ryegrass/white clover pasture highlight how feed allowance can be underestimated.

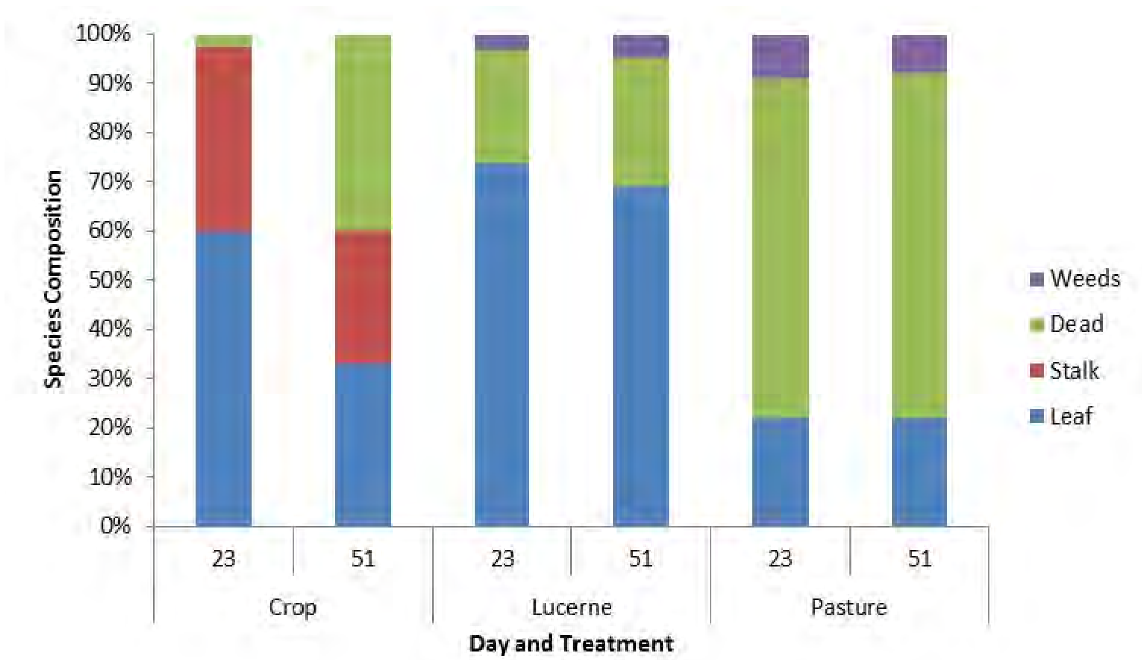

Figure 1. The percentage of weeds, dead matter, stalk and green leaf within each herbage treatment on D23 and D51 of the experiment

Conclusions and Implications

Both the lucerne and herb mix treatments demonstrated the ability of these forages to promote greater heifer growth rates than ryegrass/white clover pasture over the summer period. However the different grazing management required meant it was difficult to keep the herb mix in a vegetative state. The high amount of stem creates the impression of greater availability of feed than is actually available. This also meant the only way of effectively estimating break size was through pre and post cuts which is time consuming and not done on commercial farms.. Therefore, without weighing the heifers regularly it is not possible to effectively monitor live weight gain on these forages.

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Dynamics and Distribution of Grazed Patches under Different Stocking Strategies in Tropical Savanna Rangelands of Australia

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Key words: Ground cover, overgrazing, selective grazing, species composition, landscape function.

Introduction

Rangelands cover much of the earth's land surface, with 30 to 50% defined as rangeland, depending on the definition. Although these lands are often marginal in terms of agricultural production, they nevertheless provide livelihoods and sustenance for millions of people. In Australia, rangelands cover over 80% of the landmass with much of it supporting extensive livestock grazing (Bastin 2008).

With 70% of the country classed as arid or semi-arid, Australia is the driest inhabited continent in the world. Additionally, the extreme variability and unpredictability of the rainfall results in large fluctuations in forage supply, both within and between years. Consequently, overgrazing in dry years frequently occurs, leading to widespread resource degradation and economic loss. Balancing stock numbers with available forage is thus a major challenge for sustainable management. However, rangeland degradation can still occur even where stocking rates are considered to be appropriate due to preferential grazing at patch and landscape scales, which can include grazing by stock and by native animals. While landscape-scale grazing preferences have been fairly extensively studied and can be controlled to some extent, patch grazing has received far less attention and is far more difficult to regulate or mitigate.

Patch grazing typically occurs when animals select patches and then repeatedly graze them while ignoring other non-grazed areas. These patches collapse over time through overgrazing, forcing animals to expand these grazed areas (Mott 1985). These patches then form loci of degradation and over time spread and coalesce, potentially covering the whole paddock. Aside from the loss of more productive species, patch degradation also affects the rangeland ecohydrology through its effects on rainfall infiltration and nutrient cycling. Soil and nutrient loss due to water run-off from overgrazed or patches in poor condition, can have major consequences for the amount and quality of pasture produced, and hence animal production (McKeon & Queensland Department of Natural Resources Mines and Energy 2004). Increased runoff and soil loss are also implicated in major declines in health of downstream ecosystems, such as the Great Barrier Reef lagoon in Australia (Brodie et al. 2012).

While the impacts of patch grazing have been studied previously, nearly all studies have been point based and not considered patch grazing within a landscape context. Moreover, few, if any studies have looked at how patchiness and patch dynamics are affected by grazing management and climate variability over time. There is thus a clear need for further research to improve our understanding of the impacts of patch grazing on vegetation dynamics at the paddock scale under different grazing strategies and how this affects landscape condition and function at the regional or catchment scale.

This study, which forms part of a PhD project, will seek to understand temporal and spatial relationships between patch dynamics, patch distribution, climate variability and grazing management practices at multiple scales. The study will investigate long term changes in patchiness in grazed paddocks, using a combination of ground measurements, remote sensing techniques and historical data.

Materials and Methods

The study will be conducted on a large, long term (>18 year) grazing trial currently being conducted in semi-arid tropical savanna near Charters Towers, North Queensland - Australia. Average annual rainfall is 650 mm, but is highly variable between years. The vegetation consists of a relatively open *Eucalyptus* and *Acacia* woodland underlain by C4 tropical grasses. Soils at the site are relatively infertile. The site includes ten paddocks between 93-117 hectares each with five different stocking strategies replicated twice. Strategies include heavy, moderate and variable stocking as well as a wet season spelling strategy (O'Reagain et al. 2009).

Ground surveys will first be conducted to identify different patch types based on soil surface condition and plant species e.g. perennial grasses, annual grasses, bare ground, ground cover and the shrub *Carissa ovata*. The first ground survey is expected to be conducted in September 2016 and will be repeated twice yearly for a minimum of 3 years. Remote sensing imagery will then be used to identify, map and quantify the spatial arrangement and distribution of patch types in the different stocking strategies. Analysis of a temporal archive of remotely sensed images of the trail site since its inception in 1998 will then be used to quantify how the distribution and arrangement of patches has changed over time in the different stocking strategies. The results from this research will be important in understanding how different grazing strategies affect patchiness and its temporal dynamics as well as its consequences for landscape function and livestock production. The outcome from this project will increase understanding of rangeland dynamics under grazing and inform management guidelines for their sustainability as well as providing adequate evidence to support the use of the present methodology in other rangelands around the world.

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Feeding Behavior of Steers on Natural Grasslands of Southern Brazil

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Key words: Diet selection, forage intake, grazing, movement path

Introduction

Ruminants face challenges in efficiently collecting feed from heterogeneous environments, where forage availability varies in space and time (Ginane et al., 2015). Movement and foraging decisions determine the temporal and spatial patterns of defoliation and impacts on vegetation. Thus, level and sustainability of livestock production depend on spatial-temporal behavior. The objective of this study was to evaluate the feeding behavior of beef cattle grazing native grasslands with varying fertilizer and seed input levels.

Materials and Methods

This study was conducted at EMBRAPA Livestock South, Bagé, Rio Grande do Sul, Brazil, (31°19'51" S, 54°06'25" W and 212 m). Each of three treatments was randomly assigned to three 7-ha paddocks. Treatments were native grassland control (NG), fertilized native grassland (NGF) and natural grassland fertilized and overseeded with annual ryegrass (*Lolium multiflorum*) and red clover (*Trifolium pratense*) (NGFS). Initial seeding in fall 2005 included 8 kg red clover ha^{-1} and 25 kg annual ryegrass ha^{-1}. Fertilized treatments received 50 kg N ha^{-1} as urea in spring (September-December) and 54 kg N and 138 kg P of di-ammonium phosphate in the fall (March-June) of every year. The NGFS paddocks were reseeded with ryegrass in April 2014, and fertilized paddocks received 54 kg N and 138 kg P per ha as di-ammonium phosphate in June 2014. Pastures had been under continuous grazing by yearling Hereford steers with constant intensity of 12 kg forage DM per 100 kg live weight since August 2012. Three "test" animals were in the paddocks for a whole year and grazing intensity was adjusted with other steers. One set of test animals was used in 2013 and a new set entered in July 2014. Measurements were obtained in spring of 2013 (November 5 to 14), fall of 2014 (May 7 to 21) and spring of 2014 (November 4 to 15). Animal coordinates were recorded every 10 min during two days with Garmin™ eTrex® HC series attached to test animals. One observer per paddock recorded animal activity (grazing, rumination and other activities) every 10 min from sunrise to sunset during the same two days. Trajectories and behavior data were processed using the adehabitatLT package (Callenge, 2006) for R (R Core Team 2014). Distance traveled during grazing and proportion of time in each activity were analyzed as a function of treatment, season and their interaction. Treatment and season were analyzed as fixed effects and animal as random effect. It is noteworthy that, prior to statistical analysis, correction to daylight was made of data to different day lengths in order to not interfere with the results.

Results and Discussion

Total forage mass in NG, NGF and NGFS was 2208, 2653 and 2676 kg DM ha^{-1} in spring of 2013, 2712, 3740 and 3024 kg DM ha^{-1} in fall 2014 and 2570, 3130 and 2554 kg DM ha^{-1} in spring 2014. Animals in NG spent more time grazing than in NGF and NGFS (ca. 550 minutes). Grazing time in NGF and NGFS was 63 and 64%, or 490 and 500 minutes. This was probably due to increased time costs of diet selection in NG compared to fertilized treatments. In spring of 2013 animals spent shorter time (62% or 480 minutes) grazing than in fall and spring of 2014 (Table 1). Fertilization probably resulted in easier access to leafy forage, which in turn resulted in shorter grazing time (Gregorini et al., 2009). Thus, better structural characteristics of pasture in the spring of 2013 may have led to shorter grazing by animals at this time, compared to other periods evaluated.

Table 1. Mean and standard error of time spent in grazing, rumination and other activities and daily distance traveled by animals grazing activity in natural grassland (NG), natural grassland improved by fertilization (NGF) and natural grassland improved by fertilization and overseeded of exotic season species (NGFS) and in different periods.

	NG	NGF	NGFS	Spring/13	Fall/14	Spring/14	P_T	P_S	P_{TxS}
Grazing time (%)	70.79a ±1.33	62.72b ±1.50	63.62b ±1.35	62.23a ±1.65	66.95b ±1.74	67.93b ±1.63	0.0340	0.0181	0.4841
Rumination time (%)	17.06 ±1.70	18.68 ±1.73	17.67 ±1.64	18.41 ±1.23	17.39 ±1.30	16.44 ±1.22	0.6735	0.2288	0.2495
Other activities time (%)	12.06 ±3.16	17.67 ±2.91	20.82 ±2.78	19.22 ±2.00	15.44 ±2.05	15.9 ±1.99	0.1412	0.0591	0.1318
Distance (m)	3450 ±255	3322 ±272	3166 ±251	4064a ±215	2036b ±232	3840a ±210	0.4687	<.0001	0.0592

P_T = probability for treatment; P_S = probability for season; P_{TxS} = probability for interaction between treatment and season. Means that are followed by different letters differ (P <0.05) by Tukey test.

Distance traveled while grazing was influenced by season only. Animals walked more during the spring than in fall. This was probably related to the fact that forage mass was highest in fall. Interestingly, time grazing were similar in fall and spring 2014, but distance traveled in fall was just a bit more than half that of spring, which indicates that the grazing speed and pattern of movement were very different in these two seasons. Difference in the size and age of the animals would not be the explanation for this behavior, since the animals had average weight and age of 344 kg and 25 months, 438 kg and 31 months, and 264 kg and 13 months for spring of 2013, fall of 2014 and spring of 2014, respectively.

Conclusions and Implications

Tools such as fertilizing and overseeding of natural grassland reduced the time and presumably the energetic cost of feed acquisition.

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Nutritional Groups of Herbaceous Species from the Pampas Grasslands

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Key words: Crude protein, digestibility, grassland, neutral detergent fiber

Introduction

The Pampa is a major biogeographic unit in South America and one of the world's grasslands richest sources of endemic herbage species, including more than 400 *Poacea* and 150 *Fabeacea* (Boldrini et al., 2010). In Brazil, the Pampa biome represents roughly 2% of national territory and it is the basis for livestock production in the State of Rio Grande do Sul. Because of geographical location and climatic conditions, the Pampa contains a rare combination of C3 and C4 plant species, which makes this biome unique in the world (Boldrini et al., 2010). This study aims at characterizing the nutritional properties of the most important species of the region to help improved nutritional management of herds and to understand the basis for the high meat quality.

Materials and Methods

The experiment was conducted in a native Pampa pasture located near of Bagé, State of Rio Grande do Sul, Brazil, over a three year period (2009, 2011 and 2012). The species evaluated were twenty-one *Poacea: Andropogon selloanus* (Anse), *Axonopus affinis* (Axaf), *Cynodon dactylon* (Cyda), *Dichanthelium sabulorum* (Disa), *Eragrostis cataclasta* (Erca), *Eragrostis plana* (Erpl), *Holcus lanatus* (Hola), *Lolium multiflorum* (Lomu), *Luziola peruviana* (Lupe), *Melica rigida* (Meri), *Mnesithea selloana* (Mnse), *Paspalum nicorae* (Pani), *Paspalum notatum* (Pano), *Paspalum pauciciliatum* (Papa), *Paspalum pumilum* (Papu), *Paspalum urvillei* (Paur), *Piptochaetium montevidense* (Pimo), *Saccharum angustifolium* (Saan), *Schizachyrium tenerum* (Scte), *Setaria parviflora* (Sepa), *Sporobolus indicus* (Spin), and five *Fabeacea:* .: *Desmodium incanum* (Dein), *Lotus corniculatus* (Loco), *Trifolium polymorphum* (Trpo), *Trifolium pretense* (Trpr), and *Trifolium repens* (Trre). Plants were collected at two phenological stages: bloom (F) and vegetative (V). Plants and seeds from each collection were transported to a greenhouse. The plants were analyzed for dry matter (DM), organic matter (OM), crude protein (PC), ash free neutral detergent fiber (aNDF), acid detergent fiber (ADF) and *in vitro* OM digestibility (OMD). Gas production kinetics of each species were estimated at 2, 4, 6, 9, 12, 15, 18, 24, 30, 36, 42, 48, 72 and 96 h (Mould et al., 2005). Data adjustment made by the Gompertz equation (Lavrencic, 1997) generated the variables: coefficients "A" (Acoef, microbial efficiency rate), ""C" (Ccoef; gas production rate), total gas production (TGP). Variables evaluated were: Acoef, Ccoef, TGP, NDF digestibility (NDFdeg), and DM digestibility (DMD). Clusters of species, phenological stages and plant parts were created by K-means clustering with number of cluster ranging from 4 to 8. Clusters were then related to original variables by plotting against the principal components analysis (JMP Pro 12, version 12.0.1).

Results and Discussion

Best clustering results were obtained with 6 groups (Figure 1). The groups were separated mostly by differences in Groups 4 and 6, integrated by species with divergent characteristics represent extreme nutritional sides. Group 4 is composed of species with more structural carbohydrates; *Saccharum angustifolium*, followed by *Paspalum nicorae* scored the highest levels at F and V stage. In group 6 are those species with better chemical composition at both stages of maturation, such as *Lotus corniculatus*, *Trifolium pretense* and *T. repens*, with average CP, NDFdeg and DMdeg of 243, 303 and 748g kg^{-1} of dry matter, respectively. Despite having lower values than group 6, species from group 2 also have high protein and NDF and DM digestibility, with mean values of 181, 630 and 748g kg^{-1} of dry matter, respectively. In this group, C_3 species are predominant.

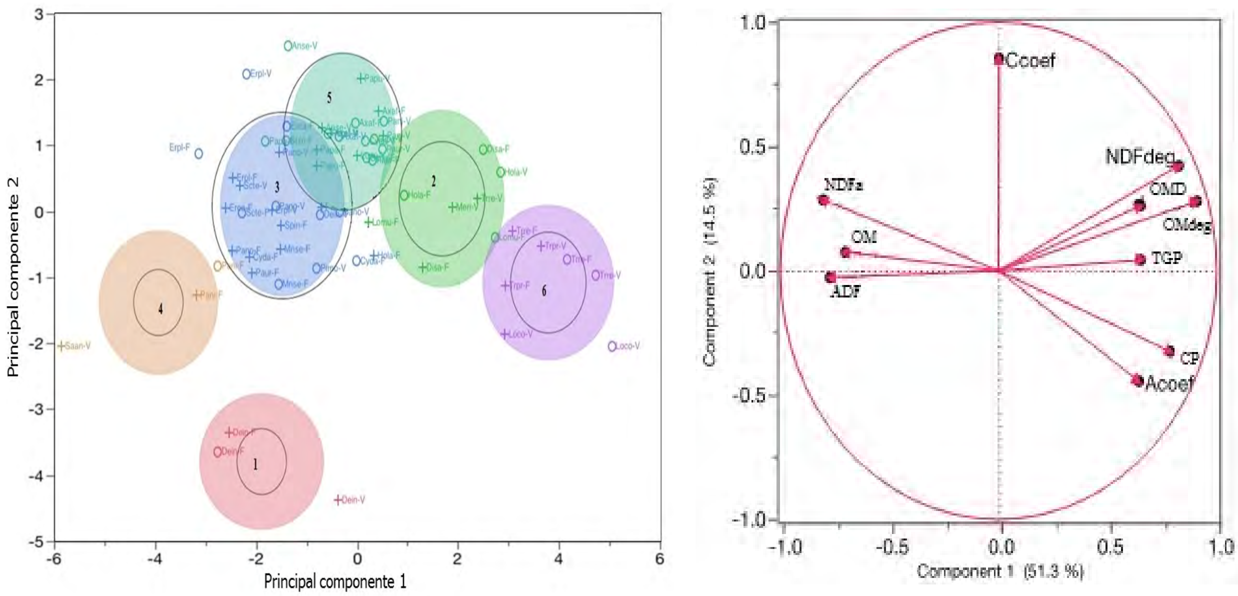

Figure 1. Cluster of Pampa species based on nutritional characteristics. The separation of clusters is explained by a cluster of horizontal variables related to fiber contend and a vertical variable dominated by the Ccoef and Acoef.

In groups 3 and 5 are located species with high content of NDF, but with higher digestibility than those from group 4. Group 1 is integrated only by *Desmodium incanum*, which had different characteristics than others. It is high in CP, low in NDF and ADF, and thus in dry matter and NDF digestibility, suggesting the presence of any plant secondary compound, which in turn could impair degradation by ruminal microbes.

Conclusions and Implications

Chemical composition and digestibility of grass species by multivariate analysis allowed their classification in different nutritional groups, which may be used to improve nutritional management of herds grazing grasslands.

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Effects of Short Duration, High Density Stocking on Soil Properties and Plant Species Composition of a Mesic Grassland in South Africa

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Keywords: Grazing management systems, mesic grassland

Introduction

Short duration, high density grazing (HDG) is currently gaining popularity amongst farmers in South African mesic grassland but little is known about its potential impact on soil properties and plant diversity. The aim of this study was to assess the effect of short duration, high density stocking of cattle on soil physical and chemical properties and plant species composition of mesic grassland. This study was conducted on either side of a fence line between two properties, one of which was a short duration rotational system at a high density (HDG) initiated in 1998, and the other a rotational grazing system at a much lower density (LDG) since 1985. The objectives of the study were to determine the impact of HDG and LDG on:

- soil physical (compaction) and chemical (pH, available phosphorus, total nitrogen and total carbon) properties
- Plant species richness and diversity
- Forb composition defined by functional traits

Materials and Methods

The study area was located in Kokstad, in the KwaZulu-Natal province, South Africa (30^{0}28' S 29^{0}31'E). The area has a mean annual rainfall of 620 mm. Large stock unit (LSU) is defined to be equivalent to a 450 kg cow with or without nursing calf with daily dry matter forage requirements of 10 kg (Meissner, 1982). The stocking density for the HDG system was 20 LSU/ha for 5 – 7 days (max) and for the LDG system was 1.5 LSU/ha for 30 – 40 days. The HDG system has had zero burning for 19 years whereas the LDG system has a burning frequency of 2 – 4 years. The recovery / rest period between HDG and LDG was similar (120 - 150 days).

A total of 20 paired plots of 10 x 10 m were located along the fence between HDG and LDG systems. Soil compaction was measured inside each plot using a dynamic cone. Soil samples were collected at 10 cm depth and were analyzed for the following: soil pH and available phosphorus using the Hunter method; total carbon and total nitrogen by Dumas combustion using a CNS analyser. In each plot a quadrat of 50 x 50 cm was randomly placed 20 times. Each species and its abundance was recorded. Above-ground growth habits of forb species were identified according to competitive ability with a grass sward for light. They were classified into four categories, i.e., cauline erect, cauline prostrate, radical erect, and radical prostrate. This classification was based on the point of leaf emergence (cauline = from stem and radical = at or below ground) and plant orientation (erect or prostrate). A paired t-test on SPSS version 23 was used to analyse the data as well as a partial redundancy analysis (pRDA) using CANOCO 4.5 package on the species data. Partial ordination was used to account for spatial differences along the fence-line.

Results and Discussion

Soil physical and chemical properties

Soils were 44.4% more compacted (p = 0.014) under HDG than LDG, but did not differ in any of their chemical properties (Table 1). This was contrary to the HDG claim that hoof action breaks the soil crusts and that large deposits of dung and urine increase soil nutrients (Savory and Butterfield, 1999).

Table 1: Paired samples Test of soil chemical properties between HDG and LDG.

	HDG Mean± SD	LDG Mean ± SD	t	df	P value
Total nitrogen (%)	0.31 ± 0.042	0.31 ± 0.029	0.39	9	0.708
Total Carbon (%)	4.45 ± 0.478	4.43 ± 0.264	0.13	9	0.902
Total phosphorus (mg/L)	5.9 ± 1.972	5.4 ± 1.020	0.71	9	0.495
Soil pH (KCl)	4.7 ± 0.184	4.6 ± 0.123	0.16	9	0.879

Plant species composition and forbs functional traits

There was a significant species turnover for grasses (Shannon diversity index $t_{(19)}$= 2.954, p = 0.008; evenness $t_{(19)}$=2.520, p = 0.021) but not for forbs (Shannon diversity index $t_{(19)}$= 1.029, p = 0.316; evenness $t_{(19)}$=1.029, p = 0.316) and there was no significant difference in species richness $t_{(19)}$=-0.734, p = 0.472 between HDG and LDG.

Partial redundancy analysis provided an effective description of the compositional variation of grass and forb species due to HDG and LDG systems, with axes one accounting for 29.7 % for grass and 21.4% for forb species variance, (Figure 1 & 2). Monte Carlo permutation showed that HDG and LDG had a significant effect on the species composition variation (F = 5.2, P = 0.0001).

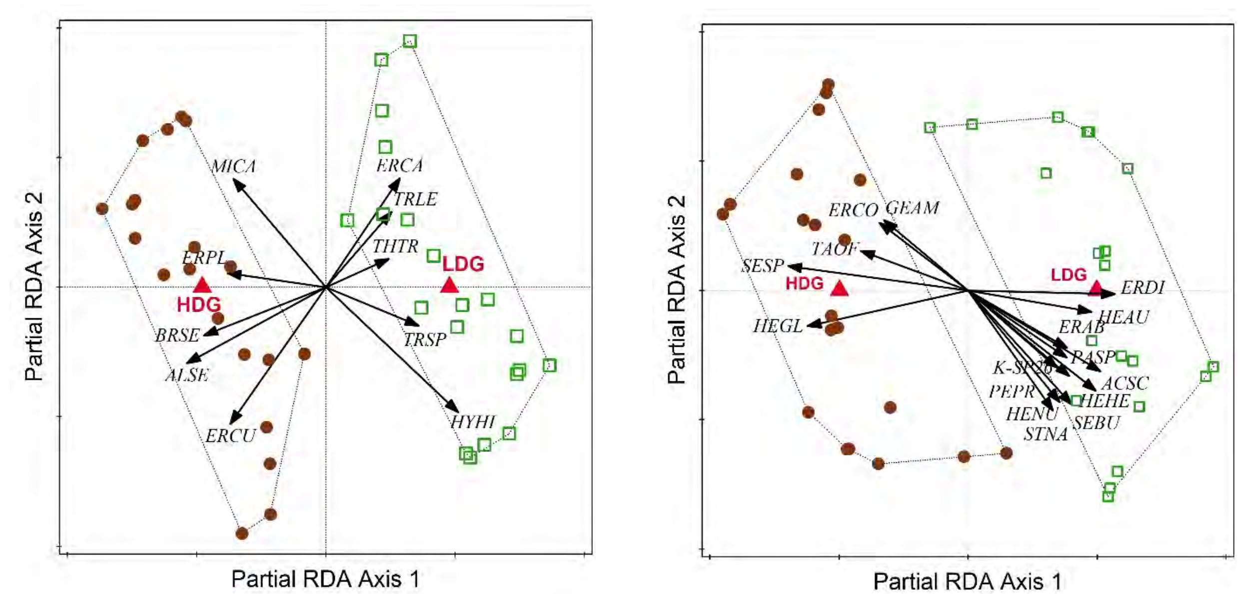

Figure 1 & 2. Biplot of a partial redundancy analysis of grass (on the left) and forb (on the right) species composition (%) for paired plots between high density grazing (HDG) and low density grazing (LDG) systems (*n* = 20) in Kokstad of the KwaZulu-Natal province, South Africa. Species displayed in plots have at least 10 percent of their variation accounted for by the first two axes Triangles represent grazing systems, circles and squares represent species. Key to species: ALSE = *Alloteropsis semialata*; BRSE = *Brachiaria serrata*; ERCA = *Eragrostis capensis*; ERCU = *Eragrostis curvula*; ERPL = *Eragrostis plana*; HYHI = *Hyparrhenia hirta*; MICA = *Microchloa caffra*; THTR = *Themeda triandra*; TRSP = *Trachypogon spicatus*; TRLE = *Tristachya leucothrix*; ACSC = *Acalypha schizii*; ERCO = *Eriosema cordatum*; ERAB = *Eriospermum abyssinicum*; ERDI = *Eriosema distinctum*; GEAM = *Gerbera ambigua*; HEAU =

Helichrysum aureonitens; HEHE = *Helichrysum herbaceum*; HEGL= *Helichrysum glomeratum*; HENU = Helichrysum nudifolium; k-SP26 = Species 26; PASP = Pachycarpus sp; PEPR = Pentanasia pruneloides; SEBU = *Senecio bupleuroides*; SESP = *Senecio speciosa*; STNA = *Stylochiton natalense* and TAOF = *Taraxacum officinale*.

There was a decline of the cauline erect and an increase of the cauline prostrate and radical prostrate above-ground growth habits under HDG compared to LDG (F = 5.3, P = 0.0081). This trend was consistent with other studies that showed that high grazing pressure negatively affects erect plants, because their growing buds and leaf tissues are more exposed to grazing, while prostrate plants respond positively (Diaz et al., 2006).

Conclusions and Implications

Soil compaction resulting from intense trampling under HDG may lead to reduced rainfall infiltration. The palatable, grazing sensitive grass species (e.g. *Themeda trianda*) decreased under HDG and were replaced by the unpalatable species (e.g. *Eragrostis curvula*). The intense grazing and trampling under HDG resulted in the replacement of cauline erect forb growth form by the prostrate growth form. These results indicate that HDG potentially has a negative impact on mesic grassland swards.

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Effect of Rest Period on Herbage Production and Botanic Composition in a Native Pasture

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Key words: Rest period, herbage production, botanic composition, native pasture

Introduction

The grazing system used for decades in Uruguay is a constant stocking rate of sheep, cattle and horses, which generally results in overgrazing of natural pastures. Overgrazing has been identified as a cause of degradation in grasslands (D'Odorico et al. 2013) and a decrease of the productivity of natural pastures.

Our goal was to test four different grazing treatments by adjusting stocking rate and frequency of grazing (Millot, 1991), and their effect of forage production and plant community composition.

Materials and Methods

With the aim of evaluating the performance of a natural field in forage production and the species dynamics on the vegetation mosaic, was studied the effect of the duration of regrowth after grazing (20, 40 , 60 and 80 days of rest period).

The experimental area was a 2.2 hectare site with three distinct topographical zones (hillside high, medium and low). We divided each of the three zones into 4 plots, each plot was randomly assigned one of the four grazing treatments. The experimental period was between April 24 and November 18, 2011, and was carried out at the Facultad de Agronomía, UDELAR.

The production of the native pasture was determined by the application of Haydock & Shaw method (1975) and the contribution of the species were study by Botanal method (Tothill et al., 1978), recording the input of the species present in 30 square frames of 0.1 m^2 for each paddocks, before and after grazing.

Results and Discussion

Available forage increased with an increase in rest period (to increase the days between grazing in all areas; a similar result was obtained for forage use primarily in the area of the hillside high and medium (Figure 1). For forage produced (kg/ha DM), the trend changed between different topographic zones, presenting significant quadratic trend at medium hillside, with maxima production around 60 rest days, not fitted any responses curves at the others sampled sites (Figure 2).

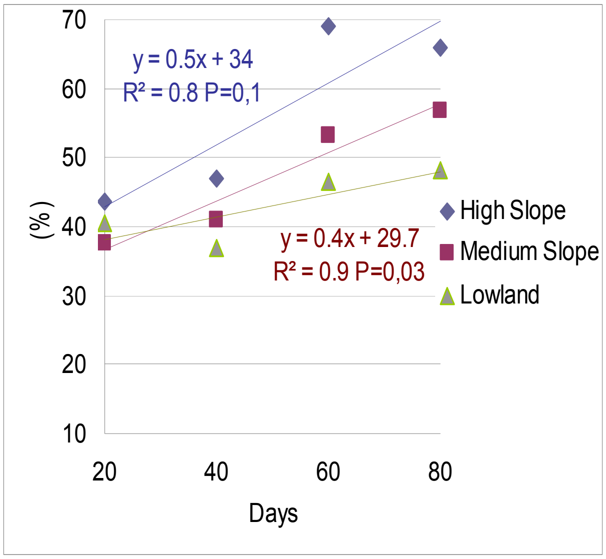

Figure 1. % Utilization of forage according to days between grazing.

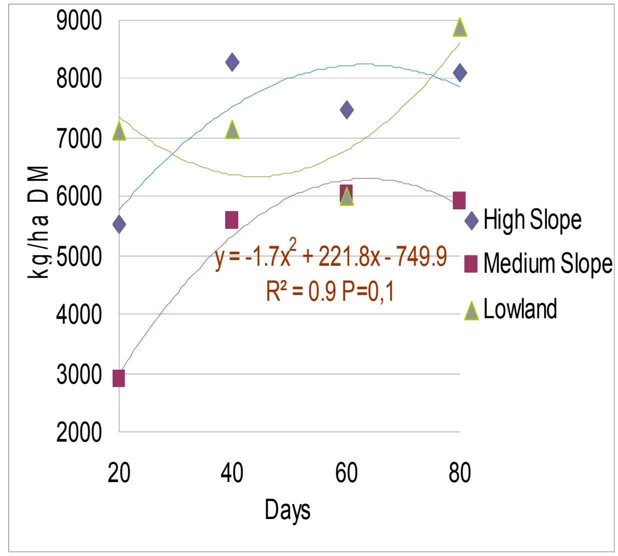

Figure 2. Forage production according to days between grazing.

Species' Composition

Characterization of species' composition at each treatment showed that the proportion of *Festuca arundinacea* was increased with an increase in the period of rest, principally in the lowland zone. A similar situation occurred with *Paspalum quadrifarium,* on lowland, while in the other areas, their behavior was random. *Paspalum urvillei* and *Stipa setigera* had a similar response to this management and *Paspalum notatum* decreased their contribution of forage to decrease rest period.

The pasture quality, measured as the ratio between grass and legume, tended to increase with a decrease in rest period, having a constant value until treatment of 60 rest period, decreasing in the treatment 80. The biomass ratio turfgrass / prostrated had an increase in all the areas as decreased the grazing frequency. Weeds of brush fields presented had increase in the average slope to increase the rest period; showing up at the hillside high a slight inverse trend, but with minor contributions. The litter, increased with increase the days between grazing in the case of the hillside and the average low, while in the average slope there is a trend to keep the levels with high variation between the treatments, although the under which presents the highest values.

Conclusions

The herbage production, forage used and herbage composition was positively associated with rest period. Less frequent grazing increases forage productivity. Thus grazing management is an indispensable tool for conservation and recovery of grassland production.

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Morphogenetic and Structural Characteristics of Marandu Grass Inoculated with *Azospirillum brasilense* or Fertilized with Nitrogen

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Key words: Biological N fixation, leaf elongation, light interception, phyllochron

Introduction

Replacement of nitrogen (N) fertilizer by biological N fixation (BNF) performed by associatives bacteria such as *Azospirillum brasilense* species for tropical grasses, can lead the sustainability in production systems. Tropical grasses highly responsive to fertilization are able to express their adaptive capacity with changes in function and form in this system. Therefore, this study aimed to evaluate the morphogenetic and structural characteristics of *Brachiaria brizantha* cv. Marandu subjected to N fertilization and *Azospirillum brasilense* inoculation.

Material and Methods

The experiment was carried out at Regional Jataí of the Universidade Federal de Goias - Brazil in a tropical savanna climate. Soil was limed and fertilized Haplortox-LVd soil. A 3 x 2 factorial arrangement on randomized complete block design was used (three N doses - 0, 50 and 200 kg/ha of urea and two *Azospirillum brasilense* doses as Masterfix Gramíneas® - 0 to 200 mL/ha - 2.0 x 10^8 CFU/mL). Experiment treatment was replicated four times totaling 24 plots of 16 m^2/plot each. The experimental cycles finished with 95% light interception (LI). Four tillers/plot were used for the morphogenesis evaluation (dynamics of generation and expansion of the plant form in space), the leaf appearance and leaf and stem growth were used to calculate the following rates, morphogenetic characteristics: leaf appearance (LAR), leaf elongation (LER) and leaf widening (LWR); leaf life span (LLS) and stem elongation (SER); structural characteristics: live leaf number/tiller (LLN); leaf final length (LFL); leaf final width (LFW) and phyllochron (PHY). The data were analyzed using SAS v. 9.3 at the 5% significance level.

Results and Discussion

There was not a significant interaction between N doses and *Azospirillum brasilense* inoculation (Table 1). Inoculation did not change the LLN, LLS, LFL and SER, but affected LAR, LFW, LWR and LER with a decreasing effect on PHY. LAR value increased almost 8%, indicating an adequate BNF and/or alteration in mechanisms that increased N absorption (Dobbelaere et al., 2001). LER and LWR increased 22.4 and 20.8%, respectively, thereby raising sward photosynthetically active area. Because SER did not change, there was a leaf/stem ratio increase, which improves forage quality. On the other hand, N elevated forage growth rate, reducing PHY linearly and generating a LAR quadratic response. In the same period, 200 kg N/ha dose provides greater LLN maintaining forage productivity. There was 6.7 live leaf/tiller, making LLN response quadratic which is explained by LLS reduction as a function of high N availability. Initially, greater leaf number generates light competition, increased LER and most LFL, resulting in greater leaf area and lower leaves and basic gems shading (Gastal & Lemaire, 2002). Fertilization increased 136.9% of LER and 103.0% of LWR in response to nutrient deposition in elongation zones and leaf cell division areas that increased new cells production and LFL (Skinner and

Nelson, 1995). Nitrogen doses promoted SER quadratic effect or internodes elongation which pushing new leaf out of the sheath of the preceding leaf and increases LAR (Oliveira et al., 2007).

Table 1. Morphogenetic and structural characteristics of *Brachiaria brizantha* cv. Marandu in function of *Azospirillum brasilense* inoculation and nitrogen doses.

Variable*	*Azospirillum brasilense* (mL/ha)		Average	F-Value
	0	200		
Morphogenetic Characteristics				
LAR	0.1	0.1	-	0.02
Phyllochron	11.3	10.2	-	0.04
LLS	61.3	62.3	61.8	0.5
LWR	0.1	0.1	-	0.003
LER	1.2	1.5	-	0.02
SER	0.2	0.2	0.2	0.4
Structural Characteristics				
LLN	5.6	6.1	5.8	0.2
LFL	17.2	18.5	17.8	0.2
LFW	1.6	1.7	-	0.05

Variable	Nitrogen Doses (kg/ha)			Effect (P-Value)	
	0	50	200	Linear	Quadratic
Morphogenetic Characteristics					
LAR	0.08	0.09	0.01	0.0002	0.03
Phyllochron	13.0	11.6	7.7	0.002	0.2
LLS	82.1	73.6	29.7	< 0.0001	0.004
LWR	0.2	0.1	0.2	< 0.0001	0.005
LER	0.9	1.0	2.1	< 0.0001	0.001
SER	0.2	0.2	0.3	0.001	0.03
Structural Characteristics					
LLN	6.7	6.7	4.0	0.0005	0.009
LFL	15.5	16.9	21.1	< 0.0001	0.03
LFW	1.5	1.6	1.8	0.006	0.2

* LAR: leaf appearance rate (leaf/tiller/day); Phyllochron and LLS: leaf life span (days); LWR and LER: leaf widening and elongation rate and SER: stem elongation rate (cm/tiller/day); LLN: live leaves number/tiller; LFL and LFW: leaf final length and width (cm).

Conclusion

Inoculation changed morphogenetic and structural characteristics of sward by increasing leaf appearance. This probably provides better nutritional value of produced biomass and soil colonization, increasing pasture sustainability and reducing the dependency to N fertilization.

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Tillering of *Brachiaria brizantha* cv. Marandu Inoculated with *Azospirillum brasilense* or Fertilized with Nitrogen

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Key words: *Azospirillum*, Brazilian savannah, light interception, production, soil colonizing

Introduction

Recent evidence of significant biological nitrogen (N) fixation (BNF) in gramineous species has driven research on its potential use for tropical grasses. James (2000) mentioned that results in sugar cane (*Saccharum* sp.), rice (*Oryza sativa*) and forage grasses has (re)generated tremendous interest in N_2 fixation by non-legumes. Therefore, associatiated bacteria such as *Azospirillum brasilense* has been identified as an alternative to lead a sustainable forage production systems. At the same time, in response to N fertilization, forage grasses have shown sward structural and morphogenetic changes, resulting in different type, size, weight and tiller number. The objective of this study was to evaluate the tillering of *Brachiaria brizantha* cv. Marandu subjected to N fertilization or *Azospirillum brasilense* inoculation.

Materials and Methods

The experiment was conducted in Jataí Regional of Universidade Federal de Goiás - Brazil, from January to May 2014 using 24 plots of *Brachiaria brizantha* cv. Marandú with 16 m^2/plot. The experimental design was a four replicated randomized complete block with a factorial arrangement. Treatments included 0, 50, and 200 kg N/ha of urea and 0 to 200 mL/ha of *Azospirillum brasilense* of Masterfix Gramíneas® - Abv5 and Abv6 strains (2.0 x 10^8 CFU/mL). The end of each cycle was determined at 95% light interception monitored by ceptometer (AccuPAR® model LP-80). Tiller dynamic evaluation was made in a 0.070 m^2area by tagging tillers. At the end of the cycle tillers were recounted, the dead tillers were removed and the emerged tillers were marked with different color allowing calculate the tiller appearance (TAR), mortality (TMR) and density rate (TPD). Data were analyzed using SAS v. 9.3 at the 5% significance level using a split plot arrangement, considering block and dose effect in the plot and inoculation and interaction in the split plot.

Results and Discussion

There was no significant interaction effect of nitrogen doses and inoculation (Table 1). Tiller appearance, mortality and population density rates showed no significant response to the *Azospirillum brasilense* application (75.6% and 65.95% and 955.90, respectively), or depending on the N doses. However, *Azospirillum brasilense* inoculation increased tiller appearance, mortality and density rates in 25, 4 and 16%, respectively. At the same time, tiller appearance and mortality were 36 and 16% and 24 and 39% higher, respectively on 50 and 200 kg N/ha doses. A low tiller appearance rate and high tiller mortality rate were observed on 200 N kg/ha dose. Because in this treatment sward spent less time to reach 95% of light interception (34 days) that resulted in a small tillering interval. High N doses promoted high renewal rate (death) of the original population resulting in high tiller density (increase of 4 and 42% for 50 and 200 kg N/ha doses, respectively compared to zero dose). Besides the treatment effect, low night temperature and water deficit during the evaluation period contributed negatively to tillering of grasses. Over the critical sward leaf area index (95% IL), a light quantity and quality restriction within the sward that reduces tillering and increasetiller mortality, in a process described as tiller size/density compensation. The number of dormant buds also increases as a N deficit response (Matthew et al., 1995). Moreira et al. (2009) evaluated *Brachiaria decumbens* tillering and observed a positive linear effect with the increasing N levels from 75 to 300 kg/ha in the tiller number in two years of evaluation and estimated a 47 and 103% live tiller/m² population increase in the first and second year, respectively.

Table 1. Tiller dynamics of *Brachiaria brizantha* cv. Marandu in function of *Azospirillum brasilense* inoculation or nitrogen doses.

Variable*	*Azospirillum brasilense* (mL/ha)		Average ± Standard Deviation	P-Value
	0	200		
Tillering dynamics				
TAR (%)	68.22	85.21	75.55±14.77	0.0505
TMR (%)	64.56	67.15	65.85±13.39	0.6471
TPD	879.76	1,025.39	955.90±237.23	0.2605

Variable¹	Nitrogen Doses (kg/ha)			P-Value
	0	50	200	
Tillering dynamics				
TAR (%)	63.77±6.03	86.99±6.03	79.38±6.03	0.0505
TMR (%)	55.55±4.73	64.49±4.73	77.52±4.73	0.1275
TPD	826.78±83.87	859.52±96.85	1,171.42±83.87	0.2605

*TAR= Tiller appearance rate; TMR= Tiller mortality rate; TPD= Tiller populacional density (tiller/m^2).

Conclusion

Azospirillum brasilense inoculation and N fertilization had similar effect to tillering, both of which resulted in higher tiller turnover rate. This effect can ensure greater soil colonization and promote the sustainabilty of the rangelands, indicating the possibility of N fertilization replacement by the *A. brasilense* inoculation.

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Tradeoffs between Vegetation Management Goals and Livestock Production under Adaptive Grazing Management

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Key words: Shortgrass steppe, grassbanking, forage quality, foraging behavior, spatial distribution

Introduction

Rangeland ecosystems are characterized by substantial temporal variability in weather overlaid on spatial variability associated with topography and soils (Fuhlendorf et al. 2012). Semiarid rangelands in particular are characterized by more extreme intra- and inter-annual variation in precipitation than mesic rangelands (Augustine 2010), and droughts continue to create major financial hardship for livestock producers around the world. Strategies for coping with drought include reducing livestock numbers, leasing forage, temporarily grazing rangeland beyond its capacity, and increasing supplemental feed, but these involve significant economic or ecological costs. Alternative approaches to increase enterprise flexibility in responding to drought are clearly needed (Kachergis et al. 2014). Managing the spatial distribution of livestock with the goal of resting some pastures and "grassbanking" this forage during periods of above-average precipitation could enhance ranch-scale carrying capacity during subsequent droughts, but has not been evaluated at scales relevant to livestock producers.

Materials and Methods

In 2012, we initiated an adaptive grazing management experiment in the shortgrass steppe of Colorado, USA where 11 stakeholders representing ranchers, stand and federal land management agencies, and non-governmental conservation/environmental organizations were assembled to 1) choose and prioritize desired ecosystem services, 2) determine management objectives which include enhancing the abundance of palatable, perennial C3 grasses within this C4-dominated grassland, and enhancing enterprise resilience to drought through grassbanking, 3) determine criteria and/or triggers for movement of livestock among pastures in an adaptive manner to achieve desired services, and 4) select appropriate monitoring approaches to assess management success through attainment of objectives, and inform adaptive management strategies. Pastures managed by the stakeholder group (adaptive grazing management; AGM) are paired with pastures receiving traditional, season-long (mid-May through early October) continuous grazing management (TGM) at the same moderate stocking rate in a replicated experimental design ($N = 10$ pastures per treatment; 130 ha per pasture).

Yearling cattle in the AGM treatment are managed as a single herd that is rotated among pastures during the growing season, with the objective of grazing 8 of 10 pastures (and resting the remaining 2 pastures) given average precipitation, and adjusting this grazing plan in response to intrannual precipitation variability. As a result, stocking density is 10-fold greater in the AGM compared to the TGM treatment (1.7 steers/ha vs. 0.17 steers/ha), and the length of time that high stock densities are maintained in a given AGM pasture depends on growing season conditions. In 2014, cattle were moved among pastures when one of three triggers – residual forage biomass, cattle behavior, or maximum number of grazing days – was achieved in the currently grazed pasture. In 2015, the maximum-days threshold was removed such that moves among pastures were only based on forage biomass and cattle behavior.

Results and Discussion

Due to 2 consecutive years of above-average spring precipitation and forage production rates, the AGM herd grazed 7 of 10 pastures in 2014 and 4 of 10 pastures in 2015. Thus, a substantial portion of the landscape under adaptive grazing management was rested in 2014 and/or 2015. Residual biomass at the end of the grazing season was 54% greater (difference of 149 $\pm$ 56 kg/ha) in rested AGM pastures relative to TGM pastures in 2014. Furthermore, the rate of increase in density of western wheatgrass (*Pascopyrum smithii*) tillers during 2013 – 2015 was marginally greater in pastures rested in 2014 ($\lambda = 0.54$ tillers/m^2) compared to paired TGM pastures ($\lambda = 0.38$; paired $t = 0.53$, $P = 0.098$).

Concurrent with these desired changes in vegetation conditions, cattle weight gains declined by 15% (0.90 vs. 0.77 kg/steer/day) and 16% (0.97 vs 0.82) in the AGM versus the TGM treatment in 2014 and 2015 respectively. Monitoring of cattle foraging behavior with GPS collars revealed a marked shift towards more linear grazing pathways by AGM compared to TGM cattle, indicating reduced selectivity of AGM cattle due to higher stocking density and larger herd size. Consistent with these findings, weekly measurements of forage quality based on fecal analyses documented a significant reduction in digestible organic matter of forage consumed by AGM compared to TGM cattle (Fig. 1).

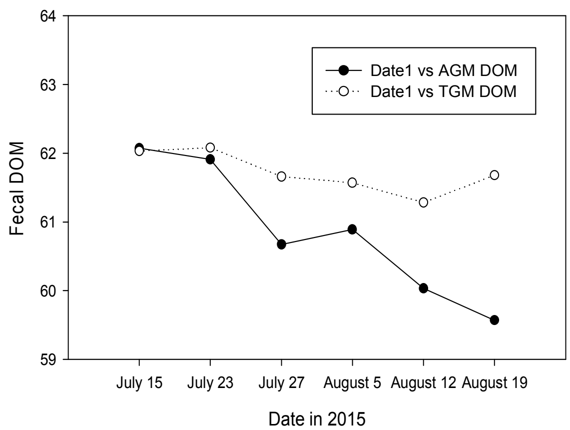

Figure 1. Weekly measurement of forage quality based on fecal analyses.

Conclusion and Implications

After 2 years of adaptive grazing management, we see clear tradeoffs between vegetation objectives achieved and reduced individual livestock performance (i.e., average daily gain) with the adaptive grazing management regime, as implemented under conditions of above-average precipitation. A key unanswered question is whether the vegetation outcomes achieved by AGM during 2014-2015 (both increased residual biomass storage and increase plant production capacity) will translate into increased grazing capacity during future drought(s).

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Monitoring the Grazing Activities of Cattle on Clover-Based Pasture in Northern Japan

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Key words: Bite counter, global positioning system, ingestive behavior, walking activity

Introduction

The Yakumo Experimental Farm of Kitasato University, which is located in northern Japan, has not received any commercial fertilizer or manure from external sources since 2004. The clover-based pasture has been established using a self-sufficient resource-recycling system based on composted manure sourced from cows on the farm. The majority of cattle on the farm are Japanese Shorthorn (JS), a breed that has demonstrated high productivity under managed grazing regimes. A Salers and JS hybrid (SJS) and Japanese black, Hereford, and Charolais cattle have also been bred on the farm. The SJS, a novel cross that was developed on the farm, has strong legs and sturdy feet. However, the grazing behaviors of these animals remain undefined. To better understand these characteristics, information technology was used as a quantitative assessment method for monitoring the spatial and temporal distributions of the study animals while grazing (Agouridis et al., 2004; Kawamura and Akiyama, 2010). The objectives of the present study were to: (1) examine the ingestive behavior of JS and SJS cattle, and (2) evaluate the validity of using walking activity to assess differences in ingestive behavior between JS and SJS cattle.

Materials and Methods

Study area and pasture

We conducted the study during 2014 on a mixed sown pasture (area 2.90 hectare) at the Field Science Centre of the Yakumo Experimental Farm, Kitasato University, Hokkaido, Japan. The global positioning system (GPS) coordinates of the study site were 42°15′N, 140°8′E. The pasture was established by sowing white clover (*Trifolium repens* L.), orchardgrass (*Dactylis glomerata* L.), and Kentucky bluegrass (*Poa pratensis* L.). The experimental protocol was approved by the Kitasato University Animal Care Committee.

The study was conducted over a 4-day period from August 4 13:00, 2014 to August 7 13:00, 2014. Throughout the study period, the pasture was stocked with a herd of 32 cattle (JS, SJS, Hereford, and Charolais; average weight, 620 kg; average age, 26 months).

Monitoring grazing behavior

The study selected six cattle, including three JS (average weight, 562 ± 41 kg; average age, 26 months) and three SJS (average weight, 667 ± 13 kg; average age, 26 months), to be fitted with a 114-g GPS data logger (DG-100, GlobalSat, Taipei) containing a 20-channel SiRF Star III chipset receiver. The GPS positions were recorded at 30-s intervals. Concomitantly, the bite counter values were recorded at 10-min intervals using a 354-g neckband bite counter (Matsushita Electric Works Ltd., Osaka, Japan; Umemura et al., 2009). We examined the eating (investigation, selection, biting, chewing, and deglutition) and non-eating (standing, lying, and walking) habits of grazing cattle with reference to the positioning data. The Hubeny model was used to quantitatively evaluate differences in the walking activity of grazing JS and SJS cattle (Hubeny, 1959).

Results and Discussion

During the study period, grazing occurred from early morning until late at night. However, ingestive behavior was not confirmed during 01:00–04:00 and 07:30–10:00 h on each day of the study period. In addition, ingestive behavior peaked 3–4 times per day. There were no significant differences in ingestive behavior between JS and SJS cattle. After examining the eating positions of each breed, investigators determined that there were no significant differences in selective grazing between JS and SJS cattle. The total distances walked during the study period (calculated using GPS data) differed significantly between the breeds (JS, 15.0 ± 0.36 km; SJS, 16.9 ± 0.08 km; $p < 0.01$). Differences in walking activities were observed until the second day of grazing (first day of grazing, $p < 0.01$; second day of grazing, $p < 0.05$). Study investigators found no significant difference in walk distance between breeds (which ranged from 2.04 to 2.31 km) during the ingestive period. In contrast, there was a significant difference between breeds in walk distance during the non-eating period, which was observed until the second day of grazing (first day of grazing, $p < 0.05$; second day of grazing, $p < 0.1$). Therefore, the results indicate that JS and SJS cattle are characterized by different grazing behaviors during the non-eating period.

Conclusions and Implications

In the present study, investigators evaluated the validity of using walking activity to assess differences in the observed ingestive behavior between JS and SJS cattle. No significant difference was observed in walk distance during the ingestive period; however, the cattle did show significant differences in the total distance walked during the non-eating period. The findings indicate that JS and SJS cattle have distinct grazing behaviors during the non-eating period.

Acknowledgements

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Grazing-Driven Soil Erosion in Sandy Rangelands of Kyzylkum Desert in Uzbekistan

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Keywords: rangeland vegetation, sandy desert, overstocking, degradation

Introduction

Overgrazing-driven soil degradation is a worldwide problem comprising 35% of all factors causing soil erosion. Extent of soil degradation by overgrazing differs by region, being 80,6% in Australia, 49,2% in Africa, 22,7% in Europe (Warren and Khogali, 1992). In Uzbekistan during the last decade grazing-induced soil erosion has reached threatening levels. Yusupov (2003) estimated that of all disturbances, overgrazing of livestock was the most serious, accounting for 44% of the total soil degradation. In Uzbekistan continuous grazing and overstocking around watering points and livestock camps has led to soil degradation being very severe in area adjacent to these focal points. Currently, this process intensifies with unsustainable use of vegetation resources and causes active movement of sandy soils creating serious threats for surrounding native vegetation. However, exact spatial extent of grazing-induced soil degradation is unknown. Thus, the objective of the current study is to make an effort to estimate the spatial extent of soil erosion caused by overgrazing around livestock tributaries (watering wells, camps) on the Karakul farm located in South Kyzylkum desert in Uzbekistan.

Material and Methods

Studying the soil degradation processes caused by intense grazing was carried out at the Karakul *shirkat* farm (Bukhara province) in South Kyzylkum desert during 2013-2015. The farm covers a total area of 420443 ha. The landscape physiognomy of the Karakul shirkat farm is identical to environmental condition of the South-West Kyzylkum desert. Mean monthly temperature is 16,2 °C. The area receives an average of 126 mm of rainfall per year. Elevation of the area ranges from 152 m to 185 m a.s.l. Assessment of degradation extent caused by overgrazing within the farm was based on inventorying of watering points and livestock camps. The spatial scale of degraded areas around watering points was measured with a combination of GPS unit and ArcGIS9.3 software.

Results and Discussion

Altogether 44 points were observed within the farm, including 42 watering wells and two livestock camps. Out of 42 recorded watering wells, 11 are out of operation mostly due to the absence of maintenance and a reduction of the water table. A significant number of watering points are in need of repair. A few operating wells may soon be lost due to very low water capacity. The limited number and unequal distribution of operating watering points doesn't allow for a moderate grazing rate across the entire rangeland of the farm. Accordingly, livestock concentrate around functioning wells and livestock camps. The farm owns about 30,000 head of livestock divided into 24 flocks. On average, each flock has 1200 head of sheep ranging from a minimum of 651 to a maximum of 4081 head per flock. Watering points with such high numbers of livestock cause expansion of soil erosion in the near vicinity of watering points.

Usually hot spots of soil erosion are observed at adjacent areas of the functioning watering wells extending within the average radius from 300-400 m to 1000-2000 m. Severe overgrazing and continuous trampling removed native fodder plant species (e.g. *Artemisia spp., Astragalus villosissimus, Haloxylon persicum*) in a close proximity of functioning watering wells. Almost 50% of the functioning wells in the farm have a degradation radius of more than 1000 m. According to calculation based on ground truth data, severe soil erosion caused by overgrazing and trampling in a vicinity of 44 observed focal points in the farm comprises 7850 hectares (Fig.1). This degraded area consists of a flat surface with compacted soil cover and no vegetation. At a distance away from sacrifice zones around watering points undesired plants such as *Heliotropium micranthum, Eremosparton flaccidum, Peganum harmala, Acanthophyllum pungens Halimocnemis villosa, Salsola praecox* and others were observed. These species have no significance in term of palatability and occurrence of these plants signifies heavily degraded condition of rangeland vegetation.

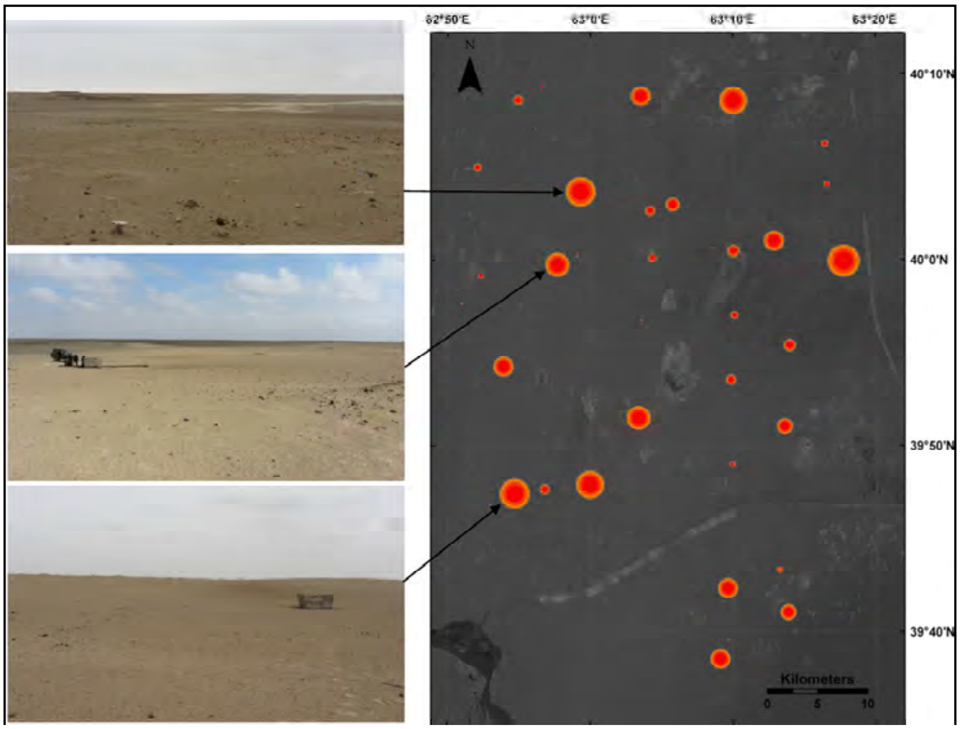

Figure 1. View of severely degraded soils around watering wells (left) and geographical location of area affected by severe soil erosion (right). The size of red cycles on the image (Landsat 7 ETM+ from 2002.06.05) represents actual size of soil erosion extent in field condition.

It was noted that areas adjacent to wells that have been abandoned for 8-12 years show clear signs of self-regeneration of vegetation cover. The radius of bare ground around abandoned wells is considerably smaller (50-100 m) than those currently in use. Appearance of native plant species in previously bare-ground areas improved the physical properties of the topsoil by accumulation of fine soil particles. The long-term vegetation regeneration around abandoned watering points may result in gradual improvement of soil condition.

Conclusion

High numbers of livestock around operating watering points within the farm increases the risk of grazing-driven degradation and expansion of the periphery of degraded rangelands. The negative impacts of this overgrazing can be prevented and/or reversed to some extent by proper rangeland management practices. Having adequate watering points throughout the rangeland of the farm is one of the critical conditions for consistent application of rangeland rotational grazing systems and for prevention of further soil erosion processes caused by overgrazing.

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Effects of Tan Sheep Grazing on Productivity of Typical Steppe on the Loess Plateau

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Key words: Loess plateau, Tan sheep rotational grazing, aboveground biomass, productivity

Introduction

In the Loess Plateau, typical steppe is managed by rotational sheep grazing and its productivity is influenced by stocking rates. Forage biomass and liveweight gain are the two major parts of grassland productivity (Sun, 2015; Li, 2011). To understand the effects of stocking rates on the productivity of the typical steppe under Tan-sheep rational grazing system, a three-year experiment was conducted in the Loess Plateau, China.

Materials & Methods

Experiment was conducted from 2013 to 2015. A flatland area was selected for grazing and it was divided into 9 plots comprising three replicates of three stocking rates: 2.7 sheep/ha (4 sheep), 5.3 sheep/ha (8 sheep), and 8.7 sheep/ha (13 sheep) in a spatial design. Two exclosure plots (0 sheep/ha) were also maintained. The area of each plot was 0.5 ha for the grazing treatments and slightly less than this for the exclosure plots. Grazing duration was 90 days, from early June to early September each year (10 days per replicate, three rotations). Aboveground DM was measured by cutting all vegetation in 1.0-m^2 quadrats (three per plot) before and after plots were grazed every rotation. Samples were dried at 65°C until a constant weight was obtained. Sheep were weighted before and after each rotation.

Results & Discussion

Aboveground biomass decreased as grazing rates increased (Fig. 1). Plots with no grazing pasture had highest aboveground biomass and the aboveground biomass for the stocking rates of 2.7 sheep/ha and 5.3 sheep/ha were significantly higher than that for 8.7 sheep/ha ($P< 0.05$).

The aboveground biomass of the grazing land was highest in 2014 than that in 2013 and 2015 for all the stocking rates (Fig. 1). The aboveground biomass in 2015 was lowest among the three years ($P< 0.05$). Figure 2 shows that the productivity of livestock under different stocking rates of three years (2013-2015), live weight gain per hectare increased as stocking rate increased. Live weight gains per hectare in 2013 and 2014 were significantly higher ($P< 0.05$) than that of 2015. Annual rainfall of 2015 was significantly lower than 2013 and 2014 as rainfall has significant effects on grassland productivity, thus significantly affecting livestock productivity on loess plateau.

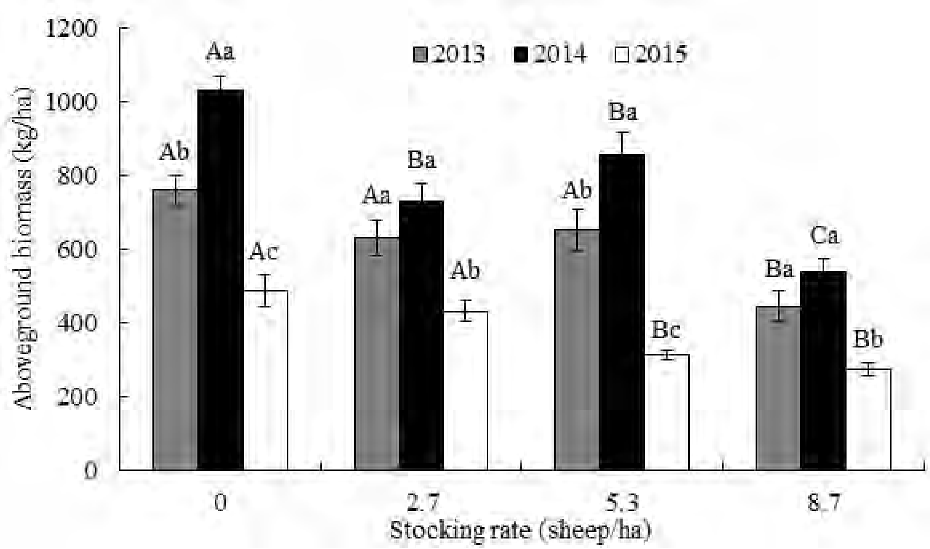

Figure 1. Changes of aboveground biomass for the three stocking rates during the three years. Note: Lowercase letters show significance between different years in the sane stocking rates and uppercase letters show significance between different stocking rates in the same year. Different letters indicate significance at *P*<0.05.

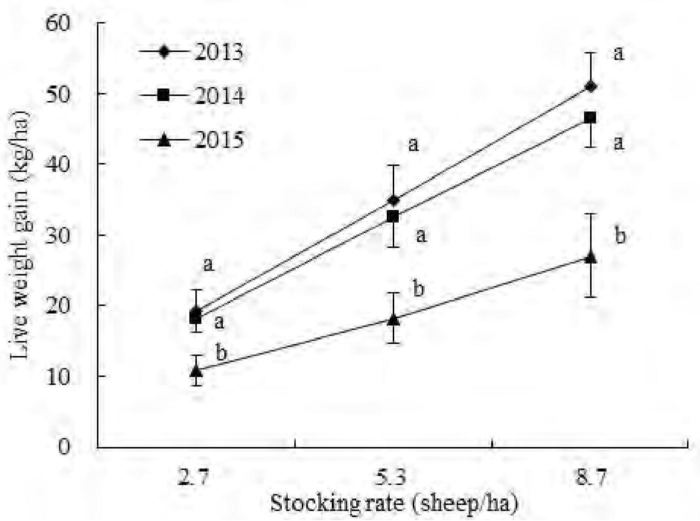

Figure 2. Changes of live weight gain of each hectare for the three stocking rates during three years. Note: Different letters show significant differences of live weight gain for the same stocking rate between different years at *P*<0.05.

Conclusions

Stocking rates influenced the aboveground biomass and live weight gain. Grassland could be used more efficiently to obtain more animal production at stocking rate of 8.7 sheep/ha in the Loess Plateau.

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Response in Structure Vegetation of Campos to Herbage Allowance and Nitrogen Fertilization

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Key words: herbage allowance, nitrogen, diversity, richness, evenness.

Introduction

The increase of herbage production of campos, in response to herbage allowance and nitrogen fertilization could result in the increase of present species productivity or changes in botanical composition. The objective was to verify the effects of herbage allowance and nitrogen fertilization on the richness (number of species), diversity (H) and evenness (E) of a natural pasture located in Rio Grande do Sul.

Materials and Methods

This work was carried out by UFRGS Experimental Station Eldorado do Sul (30º05'52" S, 51º39'08" W), RS, Brazil, within 1996 to 1998. The measurements were taken in a native pasture limed and fertilized in 1996, when 3 t ha^{-1} of dolomitic ground limestone and 500 kg ha^{-1} of 05-20-20 NPK fertilizers were broadcast on top of the soil. In spring of 1998 the paddocks were fertilized with 100 kg/ha of nitrogen as urea. The research was conducted fulfilling the requirements of a Central Composite Rotatable experimental design (Cochran and Cox, 1957), providing for equal precision, with two blocks, encompassing two factors at five levels each, namely: Herbage Allowance (HA) levels of 4.0; 5.5; 9.0, 12.5 and 14.0 kg green dry matter per 100 kg live-weight per day (%LW) and Nitrogen (N) levels of 0; 30, 100; 170 and 200 kg N ha^{-1}, split in two applications as urea. The paddocks were intermittently grazed within a grazing cycle of 30 days allowing three days of grazing. In each paddock botanical composition was measured applying the point quadrat method, listing all species present in each of 150 points that were distributed in three transects. That information was used to calculate the richness of species(S), Shannon diversity index (H´) and Pielou evenness index (E).

Results and Discussion

Richness and Diversity

The species Richness (S) and Shannon Index (H') were fitted to a response surface model (P=0.06; R2=0.75) and (P=0.01; R2=0.86)to each other. Both of them had a significant (P=0.05) linear negative response for Nitrogen and no response (P=0.11) for herbage allowance levels. Then, linear regression equations were fitted (S=41.9 -0.0784x (P=0.042 r^2= 0.61) and H'=2.8-0.0036x ((P=0.056; r^2= 0.55)). The equations show a decrease of richness and diversity when the levels of nitrogen fertilization increases, and that pasture structure trends to be more homogenous.

These responses can be explained by a fasted covering of the canopy promoted by caespitose species, which had more light interception than small-size species, suppressing them and in this way S and H' decreased. The lack of fit between H' and S with herbage allowance effects could be explained for the short term due to treatment application. Carvalho (2003) reports maximum diversity in herbage allowance of 12% LW and decreases at extreme levels on natural pastures in long-term experiment (20 years).

Pielou Evenness Index (E). The E index adjusted a response surface model: E= 0.827 – 0.015 HA – 0.0008 N + 0.00053 HA^2 – $2.1x10^{-7}$ N^2 + 7.1 x 10^{-5}NxHA (P=0.0004; R^2=0.95) where N and N x HA interaction were significant (P< 0.05) (Figure 1).

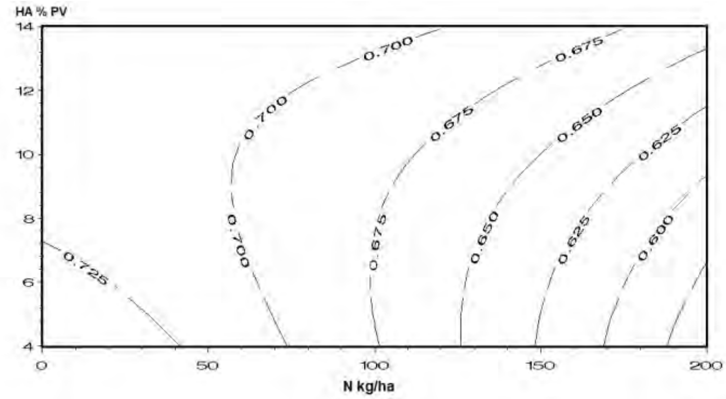

Figure 1. Response surface of evenness index of Pielou (E) through herbage allowance (HA) and nitrogen fertilization (N kg/ha).

Heterogeneity (E) in natural pastures increases with increasing herbage allowances and decreasing N levels, which is a signal that these conditions tend to magnify the complexity of the vegetation structure. The interaction study indicates that E increases when herbage allowance increases at the lowest levels of N application. These conditions allow a greater flora expression. In the conditions when herbage allowance decreases at highest levels of nitrogen, E decreases simplifying the structure of vegetation. In these conditions grasses like *Paspalumnotatum* (Boggiano, 2000) tends to dominate the vegetation cover.

Conclusion

Nitrogen fertilization can simplify the composition of the "campos" natural pasture and the scale of change is dependent of the herbage allowance.

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Cows and Clearcutting: How Can We Manage Both in an Aspen Forest?

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Key Words: aspen, AUM production, cattle collaring

Introduction

The Peace River area of Northeast BC encompasses a unique region with infrequent native grasslands, cleared farmland, and rangeland within a matrix of aspen, mixed wood and coniferous forests (Shorthouse, 2010). The majority of the rangeland is owned by the province and licensed to tenure holders for grazing. At the end of a license term, the province must replace the grazing license for the same number of AUMs as the previous license. It is becoming difficult to replace for the same AUMs, as multiple land uses can conflict with range values. The increasing demand for aspen (*Populus tremuloides* Michx.) products and the subsequent increase in aspen harvesting on range tenures is one such conflicting use. When an aspen stand is cleared, apical dominance is broken, prompting aspen to reproduce vegetatively via suckers. Suckers come in at a high density and prevent access to forage in the understory (Peterson & Peterson, 1995). Because overlap between aspen harvest tenures and range tenures is common, rancher-forester conflict is high. While some studies have shown that high-intensity grazing can reduce aspen regeneration, few studies have looked at the impacts of aspen harvesting on AUM availability. Aspen harvesting results in a net loss of AUMs available for livestock, which can lead to overgrazing on other parts of the range tenure. This study, conducted by the BC South Peace River Stockmen's Association (SPRSA), looks at cattle utilization of aspen cutblocks.

Materials and Methods

Because of the high level of aspen harvesting on range tenures and range-forestry conflict, the SPRSA and the Beef Cattle Industry and Development Fund developed a study of cattle utilization of aspen cutblocks (2009). Two groups of 10 cows were outfitted with GPS collars, and the movements monitored from 2002 until 2006. The cattle grazed in familiar pastures with aspen cut blocks of various ages, and the percentage of time spent in the cutblocks recorded (SPRSA, 2009).

Results and Discussion

In Bear Mountain Community Pasture, with cutblocks harvested the previous winter, the amount of time spent in the cutblocks peaked 3 years after harvest, and dropped off in years 4 and 5 (Figure 1) (SPRSA, 2009). By Year 4 post-harvest, the aspen suckers should be over 2 metres tall (Peterson & Peterson, 1995), tall enough to impede cattle movement into the cutblock (Krzic et al., 2004). While there could be various factors determining cattle utilization patterns, this preliminary data suggests that from 4 years post-harvest onward, cattle utilization of aspen cutblocks is restricted.

The results found by the SPRSA are supported by the findings of Krzic et al. (2004), who found that the density of aspen stems in an aspen cutblock is much higher than that of a mature aspen stand (Krzic et al., 2004). If the density of stems is 16,000-28,000 stems/ha or greater, as it usually is in the Peace area, livestock cannot access the forage in the understory of the stand, and even if this density is not exceeded cattle may still avoid the cutblocks in favor of more open areas (Krzic et al., 2004). Clearcutting mature aspen stands results in a loss of available AUMs, not due to lower production, but due to the inability of cattle to access the forage (Krzic et al., 2004). Krzic et al. (2004) found that moderate grazing intensities had no impact on aspen stem density in cutblocks, and mentioned that the negative impacts on grazing on aspen stand regeneration were the results of studies of high intensity, short duration, late season grazing, which does not describe most Crown grazing systems in the Peace River area.

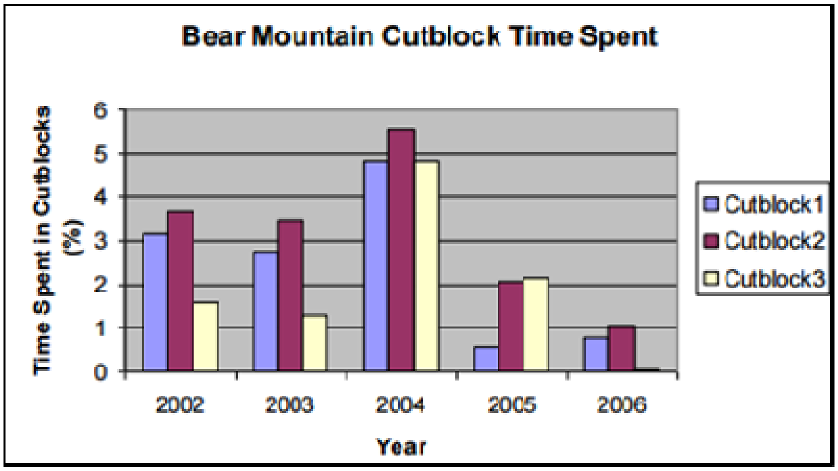

Figure 7. "Percentage of time cattle spent during the grazing season within cutblocks in the Bear Mountain Community Pasture from 2002-2006" © SPRSA, 2009.

Conclusion & Implications

While moderate grazing does not negatively impact aspen regeneration (Krzic et al. 2004), aspen harvesting does reduce utilization of forage within aspen cutblocks (SPRSA, 2009). The Timber and Range Impact Mitigation Committee (TRIMC), with representatives from government, forestry, and range, was formed to identify losses in AUMs due to timber, and brainstorm mitigation strategies. Based on the above results, TRIMC agreed that aspen harvesting reduces grazing opportunities by 90% (Mike McConnell, pers. commun.). While increasing utilization of cutblocks would reduce the amount of AUMs lost, cost effective mitigation is difficult. Peterson and Peterson (1995) suggest removing stumps and slash, and seeding tame forage; however, they admit full use may not be accomplished until trees mature. Mechanical thinning is an effective, but expensive form of mitigation; chemical thinning, however has not been tested in this region. Ideally, aspen harvesting should be directed to areas not currently used for range, or to tenures with excess AUMs. Understanding livestock use of aspen cutblocks ensures that range tenures can be managed to accommodate changes in utilization and forage availability after an aspen harvest.

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The Use of Advanced Remote Sensing to Map Pastureland Change in Mongolia

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Key words: Pastureland, degraded, optical, synthetic aperture radar (SAR), classification

Introduction

Pastureland plays an important role for Mongolian animal husbandry because it provides grazing for 50 million livestock and is used by over 170,000 herding families. Pastureland makes up about 82% of the total land area of the country and represents the largest remaining contiguous area of common pastureland in the world (NSO, 2015). In recent years, the Mongolian pastureland has been seriously deteriorated. Severe droughts and a growing number of livestock have been the main factors for the pastureland degradation in many parts of the country (Amarsaikhan, 2014).

Remote sensing (RS) has provided an important source of information for determination of the pasture condition and its changes. Over the past few years, the integrated features of optical and microwave data sets have been increasingly used for an improved pastureland mapping. A combined use of the optical and SAR images will have a number of advantages because a specific feature, which is not seen on the passive sensor image, may be observable on the microwave image and vice versa because of the complementary information provided by the two sources (Amarsaikhan et al., 2012).

The aim of this research was to map pastureland change over 27 years in Central Mongolia using an advanced RS technique. The advanced method involves a refined maximum likelihood classification (MLC) based on the spectral and spatial properties of the available land cover classes.

Test Site, Data Sources and Method

The test area covers Jargalant, Erdene-Mandal and Tsetserleg sums of Arkhangai Province, Central Mongolia. By the forest-vegetation classification, the area is included in the Khangai region and is dominated by mixed landscapes of forest and steppe. In the test site, it is possible to define such classes as pastureland, degraded pasture, forest, meadow vegetation and water.

As RS data sources, green, red and near infrared channels of Landsat 5 data of 14 September 1987, Landsat 7 data of 18 September 2001, Landsat 8 data of 23 August 2014 as well as ALOS PALSAR L-band HH polarization SAR image of 18 August 2014 have been used. In addition, a topographic map of scale 1:100.000, a pasture map of scale 1:200.000, GPS measurements and ground validation data were available. Fig. 1 shows the test site and Landsat 8 and Palsar images of the study area.

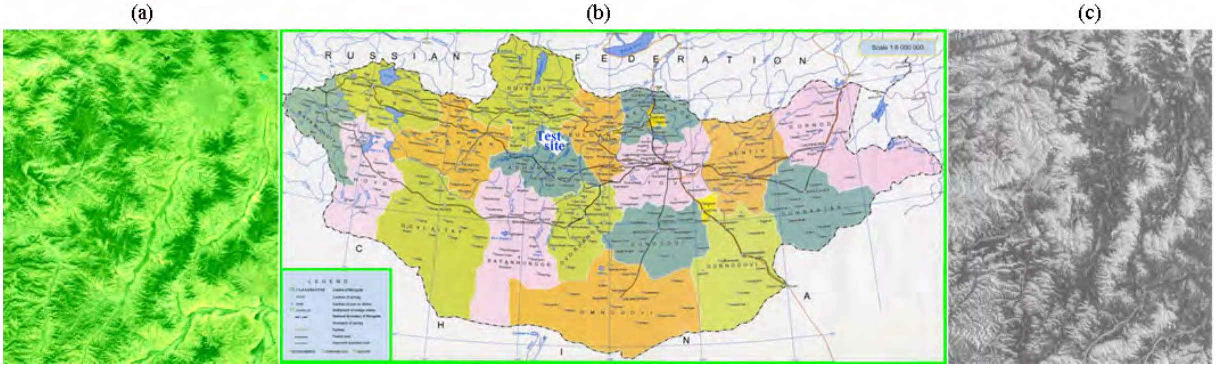

Figure 1. (a) Landsat 8 image of the test area; (b) Map of Mongolia indicating the test site; (c) Alos Palsar image of the study area.

Unlike the traditional MLC, the constructed classification algorithm uses spectral and spatial thresholds defined from the contextual knowledge. The contextual knowledge was defined on the basis of the spectral and textural variations of the land surface features on the colour images. A spectral classifier will be ineffective if applied to the statistically overlapping classes because they have very similar spectral characteristics. For such spectrally mixed classes, classification accuracies should be improved if both spectral and spatial properties could be incorporated into the classification criteria. The spectral thresholds use the upper and lower limits of standard deviations of training samples, while the spatial thresholds use a boundary to separate the overlapping classes. When thresholds apply only the pixels falling within the threshold boundary are used for the classification and the likelihood of the pixels to be correctly classified will significantly increase.

Results and Discussion

Initially, all images were georeferenced to a UTM map projection using a topographic map of the study area. Then, to form the training signatures 2-3 areas of interest (AOI) representing the available classes have been selected through accurate analysis. The separability of the training signatures was evaluated using J-M distance and the samples that demonstrated the greatest separability were chosen. For the actual classification, the refined MLC has been used. For the accuracy assessment, the overall performance was used. It should be noted that application of the optical and SAR images for 2014 produced a better classification result than a single source data. Classification results of the multitemporal RS images are shown in Figure 2.

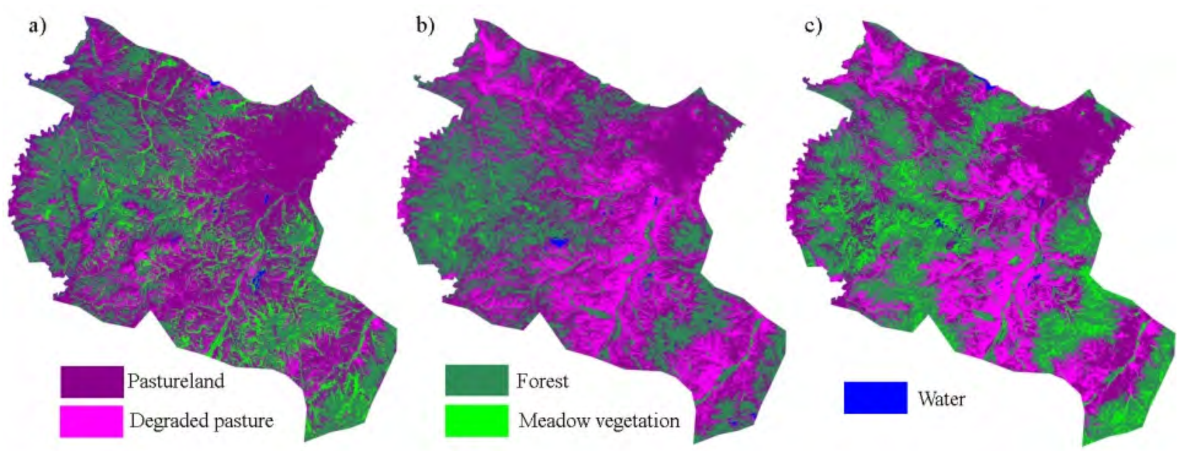

Figure 2. Classification results: (a) Result of 1987, (b) Result of 2001, (c) Result of 2014.

After the classifications, the total areas belonging to the selected classes were calculated. Although we had 5 classes, in the current study, the change analyses of only 2 classes (pastureland and degraded pasture) have been conducted. As can be seen from the classification results, in 1987, the pastureland and degraded pasture occupied 387,633 ha and 85,299 ha, respectively, whereas in 2001 these two classes covered 381,176 ha and 183,756 ha, respectively. As seen, within 14-year period pastureland was decreased by only 1.7%, whereas the degraded pasture was increased more than two-fold. Moreover, it was seen that in between 2001 and 2014, the pastureland had been decreased to 275,639 ha and degraded pasture had been increased to 190,427 ha.

Conclusion

The purpose of the research was to map and study pastureland changes in Central Mongolia using the advanced RS technique. A refined MLC based on the spectral and spatial properties was applied. As seen from the analyses, pastoral resources were significantly degraded in the selected area and RS was a reliable tool for the pastureland change studies.

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Evaluation of Seven Annual Forages for Fall Stockpiled Grazing in Beef Cattle

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Key words: annual forages, beef, stockpile grazing, yield, forage quality

Introduction

Extending the grazing season for beef cattle in western Canada can reduce overwintering costs for beef producers compared with confined feeding (Sheppard et al., 2015). Grazing accumulated forage growth in the fall/winter is referred to as stockpiled grazing. This study evaluates the yield and nutritive value of seven annual forage species for their potential usage for stockpile grazing of beef cows.

Materials and Methods

Experimental sites and treatments

Small-scale plots were seeded at three locations in Manitoba, Canada: Parkland Crop Diversification Foundation, Roblin and Prairies East Sustainable Agriculture Initiative, Arborg in late May/early June in 2014 and 2015 and at the Ian N. Morrison Research Farm, Carman in June 2015. There were thus five site-years. At each site-year seven species were seeded at commercial seeding rates and fertilized according to provincial recommendations in a randomized complete block design (RCBD) with four blocks. The annual forages selected were: Haymaker oat (*Avena sativa*); Hazlet fall rye (*Lolium multiflorum*); Maverick barley (*Hordeum vulgare*); Aubade westerwold ryegrass (*Lolium multiflorum westerwoldicum*); Golden German foxtail millet (*Setaria italica*); Roundup Ready Fusion corn (*Zea mays*); and Mammoth soybean (*Glycine max*). Westerwold ryegrass was harvested once at each site during the growing season.

Data collection

Forage samples were obtained in the 3rd week of October each year. Samples were cut from each plot at each site using a ¼ m² quadrant. Samples were weighed, dried at 60°C for at least 48 hr, weighed and then ground through a 1 mm sieve. Dry matter was calculated to determine plot yield and the samples were analyzed by wet chemistry to determine nutritive value.

Statistical analysis

Data for each site-year were analysed separately using a mixed model which included the random effect of block and fixed effect of treatment (Proc Mixed in SAS). A type I error rate of 0.05 was used for determination of significant differences and Tukey's test was used to compare treatment means within each site-year (Table 1). Due to plot failure, data from soybean plots were not available for Roblin in 2014.

Results and Discussion

Corn was the highest yielding treatment ($p<0.05$) except for Roblin in 2014 where oat and barley were higher. Fall rye and/or soybean had the highest CP ($p<0.05$) for all site-years ranging from 14-23%. Corn had the highest TDN across all sites ($p<0.05$) except Roblin 2014 where fall rye and barley were higher. Corn had the highest RFV at all sites in 2015. Barley and soybean had the highest RFV ($p<0.05$) at Roblin 2014 and at Arborg 2014, respectively. Based on the values from this small plot trial, corn meets or exceeds the yield (15750 kg ha^{-1}) and TDN (69.9) expectations for the 2015 growing season (Seed Manitoba, 2016). Corn TDN and CP values from 2015 would meet the nutritional requirements of a dry beef cow (up to 680 kg) in the middle trimester of pregnancy and potentially a cow in last trimester of pregnancy with some protein supplementation (NRC 2000).

Table 1. Yield and chemical analyses for all 5 site-years. All values are reported on a DM basis.

Measurement	Treatment	2014		2015		
		Roblin	Arborg	Roblin	Arborg	Carman
Yield (kg ha^{-1})	Oats	8267[a]	6887[b]	12 024[bc]	8638[b]	5469[cd]
	Fall rye	2961[b]	1951[c]	5232[d]	4263[b]	2536[d]
	Barley	6964[a]	3833[bc]	10 179[c]	7907[b]	5532[cd]
	Westerwold ryegrass	3705[b]	3115[c]	4416[d]	5595[b]	3421[cd]
	Foxtail millet	2800[b]	2303[c]	14 835[b]	9241[b]	8770[bc]
	Corn	4365[b]	12 594[a]	28 798[a]	27 082[a]	27 199[a]
	Soybeans	n/a	3393[bc]	8360[cd]	6186[b]	13 211[b]
CP (%)	Oats	7[cd]	8[b]	10[b]	11[cd]	10[c]
	Fall rye	15[a]	16[a]	18[a]	22[a]	23[a]
	Barley	9[bc]	7[b]	10[b]	11[c]	10[cd]
	Westerwold ryegrass	7[d]	6[b]	10[b]	12[c]	9[cd]
	Foxtail millet	9[b]	8[b]	8[b]	9[de]	8[cd]
	Corn	8[bcd]	7[b]	7[b]	8[e]	7[d]
	Soybeans	n/a	14[a]	15[a]	19[b]	17[b]
TDN (%)	Oats	65[ab]	59[bc]	66[b]	55[ef]	53[c]
	Fall rye	66[a]	66[ab]	66[b]	65[ab]	68[a]
	Barley	68[a]	55[c]	70[a]	62[bc]	59[b]
	Westerwold ryegrass	62[bc]	63[ab]	65[b]	57[de]	55[bc]
	Foxtail millet	53[d]	59[bc]	57[c]	52[f]	59[b]
	Corn	61[c]	67[a]	71[a]	69[a]	73[a]
	Soybeans	n/a	64[ab]	64[b]	60[cd]	57[bc]
RFV	Oats	114[b]	91[bc]	118[bc]	84[bc]	82[e]
	Fall rye	111[b]	107[bc]	105[c]	111[a]	119[b]
	Barley	128[a]	87[c]	134[a]	112[a]	99[cd]
	Westerwold ryegrass	107[b]	113[b]	112[bc]	91[b]	89[de]
	Foxtail millet	75[d]	88[c]	84[d]	76[c]	103[cd]
	Corn	89[c]	109[bc]	126[ab]	122[a]	157[a]
	Soybeans	n/a	148[a]	127[ab]	113[a]	109[bc]

Conclusions & Implications

Stockpiled annual forages demonstrated good potential for extending the grazing season for beef cows in Manitoba. Corn offers the highest potential based on yield, TDN and RFV; although protein supplementation may be required.

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The Effect of Grazing and Browsing on Aspen Forest Sites in Central British Columbia

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Key words, Aspen Forests, Livestock Grazing, Wildlife Browsing

Introduction

Aspen, *Populus tremuloides,* plant communities have one of the widest distributions in North America (Shepperd et al 2006, McCulloch and Kabzems 2009). These communities provide wildlife habitat, forage for livestock and wildlife, fibre and water as well as aesthetic and First Nations values. Fifty-five mammal species and 135 bird species are associated with aspen forests (McCulloch and Kabzems 2009). In British Columbia, aspen forests have received less attention than coniferous forests in terms of research, monitoring, and protection perhaps due to their classification as seral components of coniferous forests. However, aspen ecosystems are under increasing pressure from resource development, logging, recreation, and livestock and wildlife grazing and browsing. To understand the impacts of livestock and wildlife grazing and browsing on aspen ecosystems we compared plant communities inside and outside two exclosures.

Study Location

The two study sites are on the southern portion of the Fraser plateau of central British Columbia. The Rail Lake site is in the Dry Warm Sub-boreal spruce biogeoclimatic zone (SBS dw) at an elevation of 1130 metres. The Sheridan site is in the Moist Cool Sub-boreal pine spruce zone (SBPS mk) at an elevation of 1130 metres. The mean annual precipitation for the SBS dw and SBPS mk zones are 552 mm and 506 mm, respectively. The exclosures are about a hectare each and were built immediately after the sites were logged, 18-22 years ago, to exclude both livestock and wildlife. No livestock grazing has occurred at the Sheridan site for 19 years.

Materials and Methods

Plants species composition on both sites was determined using the Daubenmire method (Daubenmire 1959) on transects inside and outside of the exclosures. At each exclosure, one transect with 10 Daubenmire plots was sampled, with one paired transect outside of the exclosure. Nine transects were sampled at the Rail Lake site, resulting in nine inside and nine outside transects. At the Sheridan site, eight inside and outside transects were sampled. Shrub cover was determined using the Daubenmire frame if the plants were below the frame. For shrubs higher than the frame, cover was determined using the line intercept method. A non-paired T test was used to compare the species cover inside and outside of the exclosures.

Results

Rail Lake Site

There was a significant difference in species composition inside and outside the Rail Lake exclosure. There was a general shift from tall forbs and native species to non-native and native grasses and medium to low stature forbs. Inside the exclosure *Thalictrum occidentale* (37.22%), *Lathyrus nevadensis* (17.67%), *Aster ciliolatus* (9.25%), *Heracleum maximum* (7.81%), and *Epilobium angustifolium*(7.47%) were the leading understorey species. These plants created an almost continuous canopy cover over lower growing species.

On the grazed plots *Poa pratensis* (25.83%), *Calamagrostis rubescens* (18.33%), *Lathyrus nevadensis* (10.22%), and *Taraxacum officinale* (12.00%). There was a notable, but statistically insignificant, increase in cover of some native grass species and less robust forb species on grazed plots, including *Calamagrostis rubescens*, *Bromus ciliolatus*, and *Geranium richardsonii*. Litter cover was significantly greater on the ungrazed plots.

Sheridan Lake Site

Aspen height and cover were significantly greater inside the exclosure. The difference in aspen height and cover can be attributed to browsing by moose and mule deer as no livestock grazing has occurred at this site for 19 years. While there were no significant differences inside and outside the exclosure in the understorey plant community. There was, however, a greater cover of biological soil crust outside than inside the exclosure.

Management Considerations

Aspen forests provide shade, forage and water for livestock, and may receive relatively more grazing than adjacent coniferous forests. This study confirms what has been observed in other studies in aspen forests; grazing and browsing can alter both species composition and structure of these forests (Shepperd et al 2006). Removal of organic matter and soil compaction may also alter the capacity of aspen to regenerate (Haeussler and Kabzems 2005). This would consequently alter the quantity and quality of forage that is subsequently available to both wildlife and livestock. Encroachment by conifers and invasive plant species has also been attributed to a change in species composition and structure. In British Columbia, the combined effects of livestock and wildlife grazing and browsing, logging and fire management may irrevocably change these communities.

Because of the great diversity of aspen communities, it is important to have site-specific grazing prescriptions and management. An adaptive livestock grazing management regime that considers livestock distribution, level or intensity of grazing, rest, and time and duration grazing would ensure the conservation of aspen forests. However, the cumulative impacts of livestock and wildlife grazing and browsing (Shepperd et al 2006) as well as logging and fire suppression (McCulloch and Kabzems 2009) must be managed and considered in long-term management of aspen forests. This study underscores to the need to further our understanding of the effects or grazing and browsing on aspen forests and to identify indicator species of various aspen forest types that would help identify potentially irrevocable changes in the plant community.

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Compensatory growth of *Leymus chinensis* in response to clipping under saline-alkali addition conditions

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Key words: *Leymus chinensis*, Saline-alkali stress, Grazing, Compensation growth, Photosynthesis.

Introduction

Grazing is a very common phenomenon in grassland system. Leaves can be seriously destroyed by herbivores. The decrease of leaf area can directly influence plant photosynthesis and then the total plant growth. However, some plants can co-evolve with animals and tolerate to grazing through compensatory growth (Belsky, 1986). The degree of compensation depends on the net effect of promotion and inhibition about defoliation, which is closely related to defoliation intensity and resource availability (McNaughton, 1983; Wise and Abrahamson, 2007). At present, there are many studies on plant compensatory growth after clipping or grazing under different nitrogen or phosphorus conditions. Although Songnen plain, a large natural grassland in Northern China, where *Leymus chinensis* is the dominant rhizome grass, is suffering from salinity and alkalinity (Chi and Wang 2010), the study on compensatory growth mechanism under various saline-alkali conditions is currently very deficient. Therefore, the study on compensatory growth under saline-alkali condition is very important to improve and enrich the theory of plant compensation growth.

Materials and Methods

The study was conducted between 2009 and 2010 at the Grassland Ecosystem Field Station of the Northeast Normal University at Songnen Grassland. The experiment was conducted in a completely randomized block design with three replications. Each block included two clipping levels and two saline-alkali levels. Clipping levels included no clipping (C0) and 60% of aboveground biomass removal (C1) twice a year. Saline-alkali levels included no saline-alkali addition (S0) and 559.1 g mixed saline-alkali m^{-2} yr^{-1} addition (S1, NaCl: Na_2CO_3: $NaHCO_3$=1:1:1). The plant samples were harvested in August in each year. The aboveground and belowground biomass, ramet density, photosynthesis and sugar content were measured.

Results and Discussion

Saline-alkali and clipping had significant interactive effects on aboveground and belowground biomass of *L. chinensis*. Saline-alkali significantly increased aboveground biomass under no clipping condition, while no saline-alkali effect was found under the clipping treatment. The significant increase of aboveground biomass under saline-alkali stress was probably due to the integration effect of rhizome, which means the decrease of ramet density was compensated by the increase of individual ramet biomass. The sacrificial ramets could take away part of salt ions from the soil to lower salt concentration, which helped the remaining ramets maintain a higher leaf area index and improve net photosynthesis rate to grow better. Aboveground and belowground biomass of *L. chinensis* decreased after clipping under saline-alkali condition owing to the decrease of rhizome sugar content (Fig. 1). However, under no saline-alkali condition, *L. chinensis* exhibited over-compensatory growth after clipping with increase of aboveground and belowground biomass in 2010. However, the total ramet density was significantly decreased, which means *L. chinensis* might prefer to preserve the growth of existing ramets rather than invest resources in new ramets. The total ramet density decrease could reduce the inter-specific competition, which could improve net photosynthesis rate of the left ramets and maintain a relatively higher root sugar content to promote individual ramet compensatory growth.

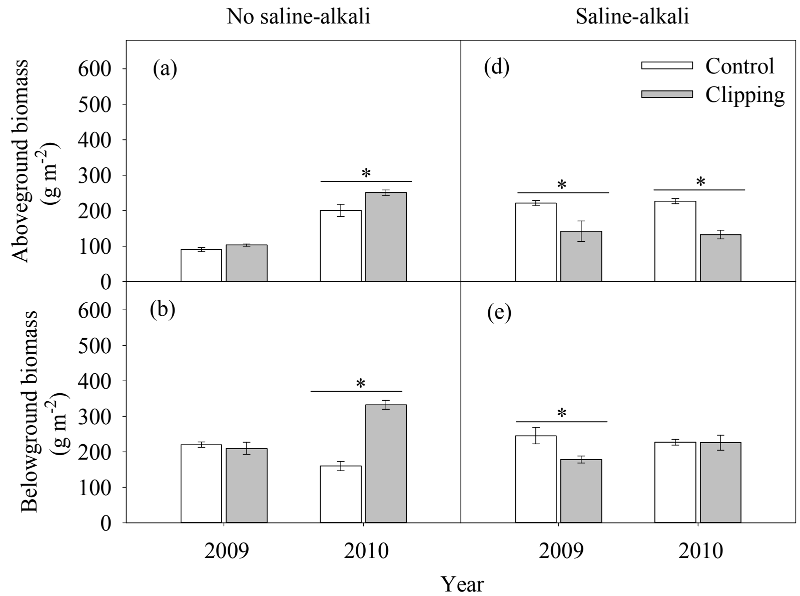

Figure 1. Effects of clipping and saline-alkali on above-ground and below-ground biomass of *L. chinensis* in 2009 and 2010. The asterisk indicates significant difference between clipping levels at $P \leq 0.05$ probability level.

Conclusions and Implications

Compensatory growth of *L. chinensis* was affected not only by clipping intensity, but also saline-alkali condition. Saline-alkali addition changed the positive effect of clipping on compensatory growth of both aboveground biomass and belowground biomass, which exhibited under-compensatory growth under saline-alkali condition. Therefore, it suggests that grazing or clipping are unfeasible for saline-alkalized grassland of *L. chinensis*.

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1.5 GENETIC RESOURCES AND FORAGE DEVELOPMENT

Analysis of Morphological Diversity of Five Native Forage Species, Used in Re-Vegetation Programs in Chihuahua, Mexico

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Key words: Grasslands, genetic variability, forage yield, *ex situ* collections.

Introduction

In arid and semiarid grasslands of northern Mexico, low and erratic precipitation and biodiversity loss of native grasses is a problem. Overgrazing has reduced populations of native species due to their high forage value (Weber et al., 2000). This loss reduces the genetic variability and the functionality of grasslands (Pellant et al., 2005). Thus, there is a need to use high forage yield native species in re-vegetation programs. The potential of such species can be evaluated using *ex situ* collections, where all populations are placed under the same natural conditions (Morales et al., 2009). Thus, it is possible to identify outstanding morphological features in the diversity of native species (Steiner et al., 1998) such as Plains bristlegrass (*Setaria macrostachya*), Green sprangletop (*Leptochloa dubia*), Blue grama (*Bouteloua gracilis*), Arizona cottontop (*Digitaria californica*) and Sideoats grama (*Bouteloua curtipendula*). The aim of this study was to explore and analyze the morphological diversity of five native forage species, used in re-vegetation programs within the Mexican state of Chihuahua. By identifying outstanding ecotypes with a high potential for forage production, soil retention and seed production, breeding programs could be started for these populations and be used in restoration.

Materials and Methods

In 2006, 573 grass ecotypes were collected from ranches located in the state of Chihuahua, Mexico. All the plants were collected with roots and then identified. The ecotypes were as follows: 111 of Plains bristlegrass, 100 of Green sprangletop grass, 136 of Blue grama grass, 91 of Arizona cottontop grass, and 135 of Sideoats grama grass. The ecotypes were transported to 'La Campana' Experimental Station (INIFAP) and then transplanted. This Station has a dry climate, an average annual temperature of 15-18°C, and a yearly average rainfall of 355 mm. Its soils have a sandy loam texture, a pH of 6.5 and support open grassland vegetation. Once established, the ecotypes were grown under natural rainfall. Two years later, measurements of the most important quantitative morphological forage features were evaluated in each ecotype; forage height, plant height, stem density, leaf length, inflorescence length, tuft diameter and forage yield in dry matter. Morphological data were subjected to principal component analysis (PCA) and cluster analysis (CA), using the Ward's method (SAS, 1999).

Results and Discussion

Significant differences ($P<0.05$) between variables were obtained and a high phenotypic diversity among ecotypes of the five species was detected. In Green sprangletop plant height ranged from 56 to 143 cm, stem density in the range of 9-68 and leaf length of 11-34 cm. The length of inflorescence ranged from 10.5 to 28.5 cm. Tuft diameter ranged from 7 to 21 cm and the dry matter values ranged from 6 to 174 g plant^{-1}. In Sideoats grama plant height ranged from 40 to 104 cm, the range of tiller density was 20-352 and leaf length 6.0-25 cm. The length of inflorescence ranged from 12 to 37 cm. Tuft diameter ranged from 4 to 20 cm and dry matter values ranged from 4 to 260 g plant^{-1}. In Plains bristlegrass plant height ranged from 40 to 96 cm, tiller density from 12 to 67 and leaf length from 11.5 to 33 cm. The length of inflorescence ranged from 5 to 20 cm. Tiller diameter ranged from 3 to 12 cm and the dry matter ranged from 24.6 to 187.5 g plant^{-1}. In Arizona cottontop plant height ranged from 9 to 114 cm, tiller density from 2 to 258 and leaf length from 3 to 25 cm. The length of inflorescence ranged from 4 to 19 cm. Tiller diameter ranged from 4 to 35 cm and dry matter ranged from 1 to 200 plant^{-1}. In Blue grama plant height ranged from 17 to 89 cm, tiller density from 3 to 186 and leaf length 4.5 to 30 cm. The length of inflorescence ranged from 2 to 17 cm. Tiller diameter ranged from 2 to 27 cm and dry matter ranged from 0.3 to 48 plant^{-1}.

The principal component analysis showed that the first three components explained 75.3% of the variation in Green sprangletop, 73.8% in Sideoats grama, 73.7% in Plains bristlegrass, 79% in Arizona cottontop and 57.3% in Blue grama. Also, in the diversity of these five species, the variables with the most descriptive value to its principal component were plant height, tiller density and dry matter. Three ecotypes of plains bristlegrass, three ecotypes of Sideoats grama, three ecotypes of Green sprangletop, two ecotypes of Arizona cottontop and one ecotype of blue grama had the highest potential for forage and seed production, as well as erosion control. This survey shows there is a wide morphological diversity of forage variables such as plant height, tiller density, leaf length, length of inflorescence, tuft diameter and dry matter among Green sprangletop, Sideoats grama, Plains bristlegrass, Arizona cottontop and Blue grama populations present in the State of Chihuahua, Mexico.

Conclusions and Implications

Based on the morphological variability of Green sprangletop, Sideoats grama, Plains bristlegrass, Arizona cottontop and Blue grama *ex situ* collection, ecotypes with a high potential for forage production, soil retention and seed production were detected. This represents an opportunity to start plant breeding programs for these populations for their use in rehabilitation programs of rangelands.

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Status, Potential and Strategies for Improving Asian Grazing Lands with Special Reference to India

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Key words: Asian grasslands, potential, status, strategies

Introduction

Rangeland, the dominant ecosystem of the world, occupies more than 50 percent of ice-free land. Livestock, the most ancient source of livelihood are spread throughout these areas in all climates from alpine to temperate and tropical. Productivity of grazingland ranges from abundant to poor with significant areas that are overgrazed. In light of ever increasing global demand for meat and in order to sustain the profitable livestock production, there is a need to view this vast natural resource as a "Global Resource" and to manage it sustainably.

Out of ~5.4 billion ha of global grasslands, the Asia-Pacific region accounts to 1.2 billion ha. This region provides meat, milk and fibre as marketable products and contributes immensely to economic and social wellbeing of millions. Nowhere is the more evident than in India which has 80.51 m ha of grazing lands (768,436 sq km^2 of forest and <5% under forages) but supports 20% of the world's livestock. The very high grazing pressure (3.42 ACU/ha) has severely degraded these Indian rangelands. Nevertheless, these vast lands continue to have tremendous potential as multi-functional grasslands. This paper will discuss strategies for improving Asian grazing lands with special reference to India.

Status of Grassland Resource

India and China (400 m ha) contribute largely to the Asian grazing lands and both have tropical, temperate as well as alpine grasslands. Himalayan grasslands contribute significantly to forage production and environmental protection. For example, the Qinghai-Tibet Plateau is one of the world's major pastoral areas with rich cultural and geographic diversity, high biodiversity. The area currently supports 30 m sheep and 12 m yaks (Wen et al*.,* 2013).

By 2050, the agricultural sector has the huge challenge to produce 60% more food, feed and fibre (8.5 billion t/yr) to sustain a global population of 9.3 billion (FAO, 2014). Income driven dietary changes have been most dramatic in Asia where total protein supplied from livestock products has increased by 140% since 1980 (FAO, 2006). Although, the meat consumed in China and India is substantially low as compared to USA (~117 kg/yr), because of huge population the net requirement will increase significantly.

Indian grasslands are source of subsistence for 550 tribal communities. However, productivity of grasslands in arid and semiarid region is low ranging from 0.5 to 1.0 t/ha. Grassland degradation in these areas not only affects the livelihood of pastoralists, but also those who suffer from changes to soil and water resources; this in turn can result in dust storms, commodity scarcity, and the social consequences of uprooted people (Li et al*.,* 2014).

The vast area under *Sehima- Dichanthium* grass cover is at present yielding only 0.65 t/ha biomass per year due to high grazing pressure. In an estimate, even if 75% of this area under *Sehima- Dichanthium* cover is improved by controlled grazing and reseeding, the biomass yield can be improved to 1.75 t /ha, and thus, the fodder availability will increase from 83 million tons to 224 million tons. Incorporation of trees and shrubs with fodder value has also been found successful for increasing fodder availability. Popularizing such alternate systems such as Horti-pasture, Silvi-pasture and Agro-silvi-pastures systems is also needed although it requires major governmental policy support because these systems can be put in place only on Common Property Land Resources (CPLRs). Forests are also important grazing lands within these areas with 100-250 m people depending on them for sustenance. Hence, policies for CPRLs have to be inclusive of CPLRs (physical, biological, social?) diversity, spatial distribution and changes over time and declining local interest owing to various issues such as ownership, declining community responsibility, shrinking size of CPRLs, lesser interest of youth in agriculture .

Grassland Biodiversity

Grasses have been on this earth and have survived despite various ecological changes over the milenia. The grasses, growing in highly diverse and harsh condition harbour genes for tolerance to many abiotic stresses such as light, heat and salinity/alkalinity. The Indian sub-continent is one of the world's mega centers of crop origins and plant diversity. The area conserves approximately 1,256 species of Gramineae belonging to 245 genera in grasslands. One third of these species have fodder value and many of have medicinal value.

Although the National Bureau of Plant Genetic Resources, India has taken the initiative in conserving germplasm, participatory biodiveristy conservation is an effective alternate to *ex situ* conservation and practiced in several centres of Consultative Group on International Agricultural Research. Additionally, farmer's have been growing wide range of crop varieties and managing grazing lands in varied climatic condition for thousands of years. This allows them to preserve native species that are best adapted to the area. Farmers like Potshangbam Devakanta in India (Manu (2015) and NGOs like *Samvedana* have demonstrated excellent example by maintaining the genetic diversity of the area. Similarly, old grasslands of Banni and Kangayam; backwater lands in Kerala State and Peninsular India are reservoir of vast genetic diversity which are being preserved by farmers at no cost to society. Thus, community based conservation is more cost effective and sustainable than *ex situ* conservation and India protects the Farmer's rights through it unique legal system, i.e., Plant Variety Protection and Farmer's Right Act.

Strategies for Improving Grasslands

Conversion of grasslands to agriculture (or urban areas), marginal habitats (areas with poor soil/undulating topography/poor moisture availability), invasive species, competition for light/water/nutrient (particularly in forest areas and areas with less soil depth) and grazing pressure are threats to grasslands. Several factors pose constraints towards grassland restoration, most important being financial constraint. The social values and peoples participation both in planning and implementation is of great importance. The communities need to feel responsible for restoration. Non availability of seeds is another constraint in implementation of restoration programs. Hence, there is need for mission mode projects, to be implemented on a large area involving large governmental funding with community participation, to revegetate the denuded grazing lands.

In addition, there is need to formulate policy and strategic frameworks for sustained management. These policies must recognize ecosystem services such as carbon sequestration, erosion control, and preservation of genetic diversity. For example, grasslands have potential to sequester 1.5 GT CO_2-eq of carbon annually. Although discrepancies between estimated potential of C-sequestration and field observations need to be resolved first, the Intergovernmental Panel on Climate Change 2007 considered grasslands as the single biggest opportunity for climate mitigation.

Policies and frameworks must also aid in establishing market links and help to develop methodologies and tools for real time assessment of rangeland in order to improve soil and water conservation and overall range health. The policies must encourage a multidisciplinary approach to grassland/rangeland management that demonstrates good practices in grassland/rangeland management using existing regional management networks. They should also encourage documentation of ethnic practices, help improve the value of grasslands and identify key grassland areas as world biosphere reserves.

Conclusion

Severely degraded rangeland of tropical world need to be rejuvenated and suitably managed so as to make them sustainable and productive. Rangeland contribute immensely in protection of environment by protecting soil erosion, water harvesting and biodiversity conservation. The increased production will have positive impact in terms of carbon sequestration, livelihood security and indirectly, through livestock production, to nutritional security. Further, there is need of building technical capacities and formulating policies and measures to create an enabling environment for effective grassland restoration; and exploring opportunities for innovative financing of restoration activities.

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Canadian Milkvetch: A Range Species of Concern and Curiosity

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Key words: Nitropropionic acid, nitropropanol, Canadian milkvetch, ruminal methane, polycross

Introduction

Canadian milkvetch (*Astragalus canadensis* L.) is the most widely distributed *Astragalus* species of North America. It is a perennial legume with forage quality comparable or superior to sainfoin in terms of crude protein and organic matter digestibility (Iwaasa et al., 2014). However, its use as forage is constrained by some toxic compounds known as nitro-toxins that mainly occur as glycosides of 3-nitro-1-propanol (nitropropanol) and glucose esters of 3-nitro-1-propionic acid (nitropropionic acid). The lethal doses of orally administered nitro-propanol in cattle and sheep are 57 and 118 mg kg^{-1} body weight, respectively. Nitropropanol has four-fold greater poisoning potential than nitropropionic acid for ruminants. At a minimum lethal dose of 20 to 60 mg nitropropanol per kg body weight, an intake of 3 to 9 kg fresh plant matter can poison a 500 kg cow (see Anderson et al. 2005, for a review). On the other hand, recent studies have shown that short-chain nitro-compounds such as 2-nitro-1-propanol, 3-nitro-1-propionic acid, 2-nitro-methyl-propionate, nitroethane, 2-nitroethanol and dimethyl-2-nitroglutarate inhibit ruminal methane production (See Leng 2014, for a review). This makes the Canadian milkvetch as a species of bio-prospecting curiosity.

A study was conducted at Swift Current Research and Development Centre of Agriculture and Agri-Food Canada to evaluate the possibility of screening the Canadian milkvetch plants with low level of toxic nitro-compounds. This article highlights the results of selected sample plants of different populations.

Materials and Methods

The study was initiated in 2013 with 27 populations of Canadian milkvetch collected from Canadian prairies. The experiment was laid out in randomized complete block design with three replications. In 2014 growing season, 143 plants were selected from different populations based on growth vigour. Plant samples were taken from the selected plants at blooming stage and analysed through high performance liquid chromatography (HPLC) for nitropropanol and nitropropionic acid contents. In short, the procedure involved sample grinding, extraction in Milli-Q water and centrifugation to get supernatant for HPLC analysis. The data were analysed with GLMMIX procedure using SAS 9.4.

Results and Discussion

The milkvetch populations had no significant difference for biomass productivity per plant (P=0.079). Similarly, the populations did not differ significantly for nitro-propionic acid content (P=0.086). On the other hand, there were significant differences between the populations for nitropropanol content (P<.0001), and the combined amount of both nitro-compounds (P=0.0005). There was a high variation among the sample plants in nitropropanol and nitropropionic acid content both within and between the populations. The nitro-propanol content varied from 0.13 to 6.44 mg g^{-1} of plant dry matter. The range for nitropropionic acid was 2.16 to 19.88 mg g^{-1} of plant dry matter. The combined values of both nitro-compounds of the sample plants ranged from 4.0 to 22.95 mg g^{-1} of plant dry matter (Figure 1).

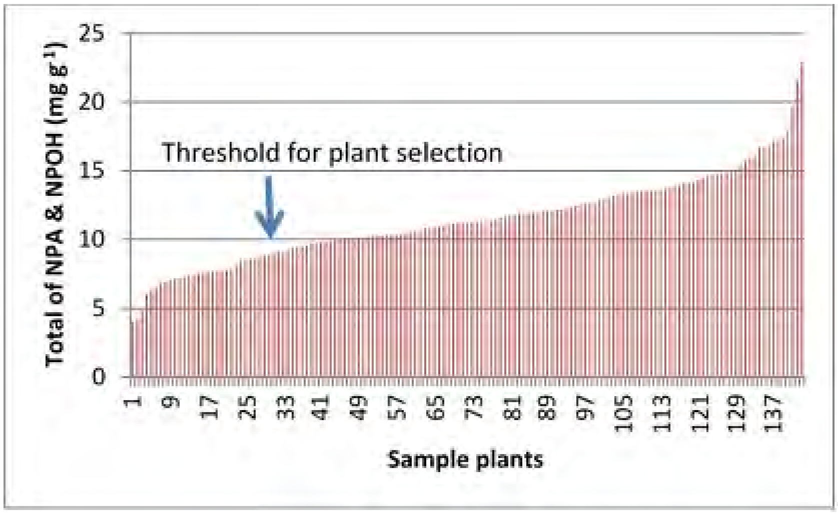

Figure 1. Variation in nitrotoxin content in Canadian milkvetch plants.

In a cross pollinated species like Canadian milkvetch, an individual plant can potentially be a unique genotype giving rise to the variability in the morphological and biochemical parameters of the populations. If the trait governing the nitrotoxin content has good heritability, there is ample opportunity to select plants with low nitro-toxicity from each population. With this premise, a polycross population of low nitro-toxin plants has been established through vegetative propagation. The polycross progenies will be evaluated for their nitro-toxin content. If there is promising result, it is an indication of high heritability of the trait. Further selection on low nitro-toxicity and forage quality will be continued.

Conclusions and Implications

High variability in nitro-compounds content in Canadian milkvetch populations offers opportunities for selection and improvement of the population for low nitro-toxicity. While the toxic principles contained in the Canadian milkvetch have remained a cause of concern, the potential use of these compounds as feed supplements to reduce ruminal methane holds a bioprospecting potential.

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Evaluation of Indigenous *Lotus* Species from the Western USA for Rangeland Revegetation and Restoration

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Key words: Sagebrush steppe, rangeland restoration, condensed tannins, *Lotus*, pollinators

Introduction

Semiarid rangelands in the western USA are facing unprecedented challenges related to past mismanagement, invasive weedy species, wildfires, and climatic change (Pierson et al., 2011). Land managers typically prefer using a diversity of plant species to revegetate and restore these deteriorated rangelands. Leguminous forbs indigenous to the western USA are of particular interest for revegetation/restoration because they provide biologically fixed nitrogen, increase plant production, enhance forage quality, and provide important food sources for grazing animals and pollinators. However, seeds of only a few legume species indigenous to the western USA are currently available commercially for rangelands in the Great Basin and Colorado Plateau. As a result, the number of viable, effective indigenous legumes from the western USA needs to be critically expanded to make them commercially available for use in rangeland revegetation/restoration efforts.

Birdsfoot trefoil (*Lotus corniculatus* L.; abbreviated LC here) is an important forage legume that originates in temperate Eurasia and is used extensively in the Midwest USA and Canada as a pasture species. It readily self-seeds, tolerates grazing, has high nutrient content, and does not cause bloat in grazing animals because of its condensed tannin (CT) content. There are 37 species of *Lotus* indigenous to the USA. *L. utahensis* Ottley (abbreviated LU) and *L. wrightii* (A. Gray) Greene (abbreviated LW) are two species distributed in the Great Basin and Colorado Plateau Regions that may hold promise for rangeland revegetation/restoration.

Materials and Methods

In 2012, wildland seed of LU and LW were collected throughout their distribution in Utah, southern Nevada, and northern Arizona. Seed from each of 19 collections was germinated, and seedlings were grown in a greenhouse during the winter of 2013. 'Norcen' LC was included as a check. The greenhouse-grown plants were transplanted in May 2013 into common-garden plots at Blue Creek, North Park, and Millville in northern Utah. The experimental design at each location was a randomized complete block with six plants from each collection in each plot and five replications. Plants were allowed to establish during the 2013 growing season. Data were collected in 2014 and 2015 for seed pod weight, plant height, dry matter yield, CT, spring emergence date, flowering date, canopy width, number of stems, longest-stem length, neutral detergent fiber (NDF), crude protein, fall regrowth, and plant survival. Data were analyzed with analysis of variance procedures using the MIXED procedure of SAS. Because of space limitations, only selected data from 2014 at the Millville location will be presented here.

Results and Discussion

The three *Lotus* species (LU, LW, and LC) varied significantly ($P \leq 0.001$) for seed pod weight and CT. Collections within species varied significantly ($P \leq 0.001$) for seed pod weight, plant height, dry matter yield, and CT. Seed pod weight (an indication of seed production potential) varied from 1 g $plant^{-1}$ to nearly 6 g plant^{-1} (Fig. 1). Seed production is a key characteristic for making species commercially available at an affordable cost. Collections of LU generally exhibited greater seed pod weights than LW. Collections of LU from the south central Wasatch Mountains of Utah (LU-20, LU-16, and LU-5) were in the top four collections for seed pod weight and dry matter yield. As a result, collections LU-5, LU-16, and LU-20 are being grown for seed increase to allow further testing and evaluation prior to commercial release.

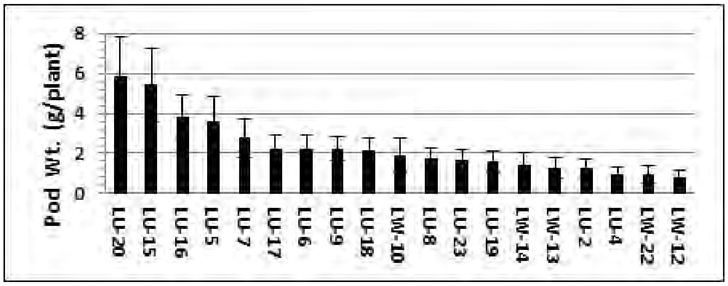

Figure 1. Seed pod weight of indigenous *Lotus* collections.

Some *Lotus* species are known to contain CT, which are a class of polymeric flavanoids that can reduce the risk of bloat in grazing animals and lead to more efficient use of forage protein by grazing animals and subsequently less N runoff and reduced losses of carbon dioxide and methane (known greenhouse gases) to the atmosphere (Mueller-Harvey, 2006). Condensed tannins in LC also have been shown to suppress internal parasites in grazing animals (Hoste et al., 2006). Concentrations of CT varied significantly ($P \leq 0.001$) between species and among collections within species with values ranging from about 14 to 18 % dry matter for LU and LW compared to less than 3 % for LC (Fig. 2).

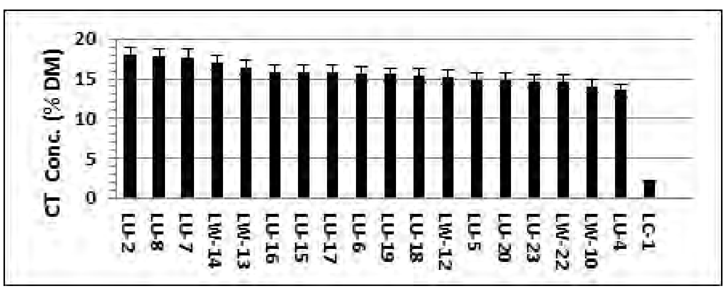

Figure 2. Condensed tannin (CT) concentration in *Lotus* collections.

Conclusions and Implications

A total of 19 seed collections of LU and LW were made across Utah, Nevada, and Arizona. Common-garden studies showed that collections LU-5, LU-16, and LU-20 were unique and hold promise for rangeland revegetation/restoration in the western USA. Data from these common-garden studies will be combined with results from DNA fingerprinting studies to determine the optimum strategies for releasing these indigenous *Lotus* species to the commercial seed trade.

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Evaluation of a Bermudagrass Core Collection

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Key words: Phenotype, cold tolerance, shade tolerance, nitrogen efficiency, fiber quality

Introduction

Bermudagrass (*Cynodon* sp.) has been a valuable forage and hay crop in many parts of the world (Taliaferro et al., 2004). Highly productive hybrid bermudagrass cultivars have been developed and are now grown as improved pasture on an estimated 2-3 million hectares in southern United States. Since the 1930s, breeders have attempted to distinguish genetic traits in bermudagrass important to ruminant nutrition and weight gain, and then select for superior genes in breeding programs. Bermudagrass hybrids with greater yields, better quality for ruminant digestion, greater disease tolerance, and higher cold tolerance have been accomplished through breeding efforts exploiting the great genetic diversity of the bermudagrass collection maintained at Tifton, Georgia (Hanna and Anderson, 2008).

For further improvements, breeders require information on genetic and phenotypic diversity for the selection of diverse parents that will maximize genetic gains for desirable traits. A plant introduction nursery of approximately 600 forage bermudagrass accessions is maintained at Tifton, GA. The ploidy levels of these accessions range from 2n=2x=18 to 2n=6x=54. This nursery was assessed for plant growth habit, leaf, stem and flower heading characteristics and a core collection was formed by measuring relatedness through CLUSTER analysis of fourteen phenotypic traits taken in the summers of 2003 and 2004 along with stand purity and ploidy level (Anderson, 2005). The core collection was then measured and analyzed for the genetic relatedness among accessions using plant phenotypic characteristics and molecular marker data (Anderson et al. 2009). Further information on important traits is needed from this core collection for identification of parents in a breeding program.

Methods and Materials

The 175 entry core collection was replicated and evaluated in test plots at different locations and using the following techniques:

Cold tolerance

Three replications were randomized in the field in one meter square plots in the mountains of North Georgia at Blairsville, GA, (34.84 Lat., -83.93 Long., 590 m Elev.) with average minimal temperatures of -3.9 ^{o}C). Material was established from plugs in 8 cm pots and transplanted into the field May 2007. Emergence, plant height, and leaf coarseness were rated in 2008 and 2009. One square foot plots were harvested, dried and weighed in June of each year. *In vitro* dry matter digestibility (IVDMD) and fiber components were determined for materials harvested in 2008.

Shade tolerance

Two randomized replications were established during the spring of 2008 in 30 cm diameter and 30 cm deep corrugated tubing under 50% shading in Tifton GA (31.48 Lat., -83.53 Long., 108 m Elev.). Plant height and stolon growth was recorded during the establishment year. Plants were harvested in approximately one month intervals in 2008 and 2009 from each plot (0.71 m^2). Dry weights were recorded, material was ground and evaluated for fiber and IVDMD.

Nitrogen use efficiency

Fifty forage bermudagrass genotypes were selected from a bermudagrass core collection. Tests were conducted by establishing plugs in 30 cm diameter and 30 cm deep corrugated tubing in Tifton, GA in 2010. Each genotype was given either 50 kg ha^{-1} equivalent N or 200 kg ha^{-1} equivalent N plus 40 kg ha^{-1} P and 100 kg ha^{-1} K in each year and replicated 4 times. Plots were harvested five times in year one (2011) and four times in years two and three (2012-13). Dry matter yield and fiber quality were measured for each plot (0.71 m^2).

Results and Discussion

Cold tolerance

Due to the cold winters of 2008 and 2009, 31 entries did not survive. Of the remaining 142 entries 20 accessions had a higher average yield than Tifton 44. A few exhibited greater IVDMD than Tifton 44 including PI 290660. Among the coldest tolerant lines from Blairsville, PI 225809 and PI 291724 might be used in breeding to improve seed set, germination and cold tolerance (Table 1).

Shade tolerance

All genotypes declined in yield during the second year of shade. Thicker stem genotypes Florakirk, African Star and breeding lines averaged over 80 g/m total for the second year, which is equivalent to 8 Mg/ha (Table 1).

Nitrogen use efficiency

Significant yield reduction in the lower N rate was observed starting at the third harvest in year one. Total average yield reductions in year one was 35%, and in years two and three, 78% and 73% reductions, respectively. PI 288217, PI 290660, and experimental cross 77-59 were the most N-use efficient though CC II was not significantly lower (Table 1). Nitrogen content averaged 2.4% lower for the 50 kg ha^{-1} N (9.8% vs. 7.4%) with differences among entries.

Table 1. Entries that exhibit the greatest tolerance or NUE among bermudagrass core collection.

Entry	Trait of importance	Stem/leaf characteristics	Plant height (cm)
PI 289917	***Cold tolerance***	Medium/moderate	30
PI 290660	***Cold tolerance/NUE***	Fine/moderate	33
PI 291724	***Cold tolerance***	Fine/long	47
Florakirk	***Shade tolerance***	Coarse/long	74
African Star	***Shade tolerance***	Fine/short	34
Cross D8	***Shade tolerance***	Fine/moderate	28
PI 288217	***Nitrogen use efficiency***	Fine/long	46
Cross 77-59	***Nitrogen use efficiency***	Coarse/long	58

Conclusions and Implications

The bermudagrass core collection screening has identified germplasm with many useful traits that can be used by bermudagrass breeders in the United States. The core collection is currently being evaluated across many locations of southern United States.

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Evaluation and Utilization of *Leymus chinensis* Germplasm Resources

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Key words: *Leymus chinensis*, germplasm, new variety, gene resources

Introduction

Leymus chinensis (Trin.) Tzvel (also known as sheepgrass) is a native, perennial forage grass, with high forage yield and quality, strong resistance to abiotic stress, and grazing. Though this specie is important, the collection and systematic study of its germplasm lacked for a long time. Studies on the germplasm collection, evaluation, and utilization are important for re-establishment and improvement of degraded grassland, and for the development of forage industry and animal husbandry. In recent years, we established a research system, "from the steppes to laboratory, and then from the lab to prairie". We have collected and evaluated thousands of wild sheepgrass germplasm, and cultivated new varieties such as Zhongke No. 1, 2 and 3. A transcriptome-based database was established and a number of novel genes were cloned and identified (Chen et al., 2013; Li et al., 2013; Gao et al., 2015). In this paper, we gave a detailed review of the origin, distribution, germplasm evaluation, propagation, utilization and new variety development of sheepgrass. We also discussed the self-incompatibility (SI) mechanism of sheepgrass, which is the existed in all out-crossing grasses.

Origin and Distribution of Sheepgrass

Sheepgrass belongs to the BEP branch (Bambusoideae, Ehrhartoideae, and Pooideae), and has a higher genetic relationship with barley (*Hordeum vulgare* L) and wheat (*Triticum aestivum* L). The genomic formula of *Leymus* was $N_sN_sX_mX_m$. We found the ployploid *Leymus* has close phylogentic relationships with *Psathyrostachys* species and maternal donor of all the *Leymus* species with a natural distribution in Eurasia were N_s genome (Liu et al., 2008). Sheepgrass is a dominant species in the steppes of east Eurasia and China, and it widely distributed in Russia, Mongolia, Kazakhstan, Japan, and Korea. It also has a widely distributed in Northeast China, Inner Mongolia, Hebei, Shanxi, Shaanxi, Xinjiang of China.

Evaluation of Sheepgrass Germplasm Resources

Sheepgrass grows naturally on dry, saline and alkaline-sodic soils, and plays an important role in soil stabilization. It tolerates high levels of salt (600mM NaCl) and drought stress and has an aggressive and vigorous 'cross-walk' rhizome system that facilitates the absorption of moisture under high salt stress and drought conditions. The genome size of sheepgrass is approximately 10G. We had identified many genes via transcriptome sequencing technique, and established the first genome resource database of sheepgrass (Chen et al., 2013). We also cloned a number of novel genes from sheepgrass and our results confirmed those novel genes can enhanced the various stress-tolerances of transgenic plants (Li et al., 2013; Gao et al., 2015). Therefore, sheepgrass can be considered to be the source of an excellent candidate gene pool, which could potentially provide stress tolerance genes to wheat and barley through traditional recombination breeding and genetic engineering.

Propagation, Utilization, and New Varieties development of Sheepgrass

Low seed setting rate (25%), low heading rate (7.9%), and low seed germination rate (10-20%) were three main factors restricting production and utilization of sheepgrass. We found the sheepgrass have is SI, but the seed setting rate can reach 90% by hybridization. We first investigated the gene expression in the stigmas of sheepgrass using high-throughput next generation sequencing technology and uncovered many notable genes that are potentially involved in SI mechanisms, including genes encoding receptor-like protein kinases (RLK), CBL (calcineurin B-like proteins) interacting protein kinases, calcium-dependent protein kinase, expansins, pectinesterase, peroxidases and various transcription factors (Zhou et al., 2014). The crude protein content of sheepgrass is more than 11% of dry matter in the heading stage and can be up 18.5% in the tillering stage. Through 16 year's research, we developed sheepgrass 'ZhongKe 1, 2, and 3' new varieties. The hay yield of 'ZhongKe 1' is 6000-9000 kg per hectare and seed yield is 450-600 kg per hectare (Fig. 1).

Figure 1. Re-established grassland of 'ZhongKe' varieties.

Conclusions and Implications

In summary, great achievements were made in sheepgrass germplasm evaluation and utilization. More than 1100 germplasm resources were collected, and 128 excellent germplasm resources were evaluated, and developed 3 new varieties. Furthermore, we established a genome resource database, and identify a number of novel genes. However, future research studies are needed, such as new variety breeding, seed production, and commercialization. We proposed the future research emphasis of sheepgrass is new varieties development, and new technologies should be used to speed up the varieties development and utilization.

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Species Resources of Manitoba's Vanished Prairies

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Key Words: Genetic resources, prairies, disturbed, grasses, forbs

Introduction

Agriculture and other human activities are cited as a major factor in the loss of biodiversity. Greater than 99.9% of both tall and mixed prairies in the southern areas of Manitoba have been lost (Samson and Knopf 1984). Areas disturbed for road construction and allowed to recover provide potential reserves for native species. This study looked at three areas in Manitoba that have been disturbed and allowed to recover. Flowering was used to indicate species found and therefore still available for conservation at these sites. Grasslands hold great potential for sequestering carbon and we need to be looking for greater diversity as opposed to simplistic communities (O'Mara 2012).

Methods and Materials

Sites studied included Seton (N49.90192 W99.21633) (mixed grass), Teulon (N50.37380 W97.25218) (tall grass) and Woodlands (50.24050 W97.73531) (tall grass), Manitoba, Canada. These sites were all characterized by being next to roadsides, with a small portion abutting the roads being reseeded to introduce perennial species. Following a transect through each site, flowering was observed on a weekly basis at the three sites in southern Manitoba from 2010 through 2013, from snow melt through early October each year. Flowering was used as an indication of a viable presence of a species. Due to the potential for both itero- and semel-parous species (multiple and single life-history flowering), the first two sites were observed for four growing seasons and the last site for three growing seasons (2011-2013). Once identified, species were then determined as either native or introduced species, and as being annual, biennial or perennial using USDA Plants Database (USDA 2015) as the authority.

Results and Discussion

Not all species were seen flowering each year, with some species only seen in one year. Sites varied from year to year for number and types of species observed (Tables 1-3). Teulon had the fewest species and tended to have similar numbers of introduced and native grasses while the other sites had greater numbers of native grasses. Native legumes were consistently more numerous than introduced legumes at Seton. This could be potentially used as an indicator of loss of plant diversity. No site had evidence of introduced shrubs and some have value as browse species (e.g. *Symphoricarpos occidentalis*) (Lady Bird Johnson Wild Flower Centre, LBJWFC 2015) or nitrogen fixing species (e.g. *Elaeagnus commutata*) (USDA 2015). A number of perennial grasses were found that should be of interest for range use. Grasses such as *Andropogon gerardii*, *Schizochirum scoparium*, *Sorghastrum nutans*, *Bromus ciliatus*, *Koelaria gracilis*, *Hesperostipa comata*, *Panicum virgatum*, *Spartina pectinata* and *Elymus canadensis* were found in the confines of at least one of the sites surveyed with the most common species, *A. gerardii* and *S. scoparium* found at all sites, whereas the introduced (seeded) *Bromus inermis* and *Poa pratensis* were also found at all sites.

Table 1. Number of introduced and native species by plant function type observed for 2010, 2011, 2012 and 2013 at Seton, MB.

	Introduced				**Native**			
	2010	2011	2012	2013	2010	2011	2012	2013
Forbs	8	13	16	12	86	110	113	114
Grasses	8	5	4	5	14	15	17	17
Legumes	3	4	7	6	10	8	8	9
Shrubs	-	-	-	-	7	11	11	11

Conversely, legume and forb species were found across sites, especially the introduced species. Native legume species were least common at Teulon, the most impacted by annual cropping. *Dalea candida* and *Dalea purpurea* were the most abundant of the native legumes, with *Vicea Americana*, although being found at all sites, having only a few individuals at each site. *Oxytropis splendens*, a purportedly poisonous species (LBJWFC 2015) was prominent at the Seton site.

Most species found were perennials. Some biennials were noted, the most common two being the introduced *Melilotus officinalis*, and *Oenothera biennis* which was noted at two sites.

Forbs were the most numerous species found at all sites. Many forbs may be valuable feed species, however, little is known of their palatability. *Solidago canadensis* and *Oligoneuron rigidum*, the two most abundant forbs at all sites, have low browse or graze potential (USDA 2015). Forb species also provide habitat for many pollinators and insect communities.

Annuals were less common, with *Sonchus oleraceus* being the most common introduced annual and *Agalinis aspera* (Friesen and Murray 2011) being the only native annual species noted and was found in all years at the Woodland site.

Table 2. Number of introduced and native species by plant function type observed for 2010, 2011, 2012 and 2013 at Teulon, MB.

	Introduced				Native			
	2010	2011	2012	2013	2010	2011	2012	2013
Forbs	10	10	12	13	45	58	49	45
Grasses	11	8	9	9	8	11	8	14
Legumes	6	8	6	7	4	3	4	4
Shrubs	-	-	-	-	6	10	14	11

Table 3. Number of introduced and native species by plant function type observed for 2011, 2012 and 2013 at Woodlands, MB.

	Introduced			Native		
	2011	2012	2013	2011	2012	2013
Forbs	8	8	13	75	84	74
Grasses	6	4	6	14	15	19
Legumes	5	7	7	7	8	7
Shrubs	-	-	-	10	10	13

Conclusions and Recommendations

Many native plant species that have potential use in range applications are still found throughout the former tall and mixed grass prairie regions of southern Manitoba. Areas where annual cropping is less intense appear to have greater retained plant diversity. However increased pressure on these areas will continue to reduce, if not only the species present, but also the diversity of the populations that still persist. Delay in making a concerted effort to retain the diversity both within communities and species may lead to a loss of the genetic resources of these species and potentially the loss of the ecosystem functions of the communities.

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Lulu Cattle (*Bos taurus* L.): An Unique High Altitude Livestock Breed in Rangelands of Nepal

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Key words: Lulu cattle, high altitude, livestock, livelihood, Nepal

Introduction

Lulu (*Bos taurus*) is the only native, humpless, small-frame cattle breed found in harsh environments of high altitude (2500-3800 masl) of Nepal. Lulu cattle are hardy with emotional sentiments attached among the people of Mustang and Manang of Nepal, the home districts of this breed. The phenotypic measurement and mitochondrial DNA genotypes have already been characterised. Since Lulu cattle are the major source for livelihood and protein supply for Mustang and Manang people, there is an urgent need for the breed's in- and ex-situ conservation as well as for increasing its productivity. Recently, with the initiation of Animal Breeding Division (ABD, 2015), Nepal Agricultural Research Council (NARC), a study has been conducted for production parameters under optimized conditions. Under ex-situ, both in-vivo and in-vitro conservation has been initiated by ABD, NARC. The feeding system at the in-situ conservation location was also explored. In-addition, a recent study showed that the population of Lulu cattle is concentrated in Kagbeni, Jharkot, Tukuche, Marpha, Muktinath and Jhong of Mustang districts. However, the productivity is decreasing because of negative selection, inbreeding and illegal transport of animals to Tibet for slaughter. Moreover, due to haphazard cross-breeding with *Bos indicus* (mountain cattle) and *Bos grunniens* (Yak) cattle, the purebred Lulu population has been declining rapidly. Therefore, a joint coordination among research, education, extension and private stakeholders is utmost importance to save this breed to sustain high elevation people's livelihood and food security.

Materials and Methods

The information and data was collected with the help of a questionnaire either through direct observation and/or recording both in situ and ex-situ conditions. In addition, secondary information was also collected to compare the production in the breed's home district. In the year 2014, ten females and two bulls of Lulu were procured to ABD, Khumaltar for conservation as well as study under optimized management conditions. Among them, five females and one bull was procured from Jharkot, Muktinath VDC and other five lulu females and one bull were procured from Kagbeni Village Development Committee In the following year (2015) again, 10 females and 2 males were procured and transported from respective VDCs to ABD, Khumaltar. In addition, feeding systems on extensive and intensive rearing system was also compared.

Results and Discussion

Production performances of Lulu cattle

Lulu cattle are popular for their peculiarities of small body size (weight range: 68-153 kg; Wither height: < 1m) and their adaptability in dry, cool and harsh environment (ABD, 2004; ABD 2014). The productive performance of Lulu cattle at different conservation modes is presented in Table 1. The age at 1st calving is decreased and the milk production increased from *in-situ* to ex-situ conservation which indicates the scope of production through good management. Moreover, all the Lulu cattle brought at ABD, farm (at 1300masl) were normal for reproductive performances. All eight females brought during 2014 delivered normally and milk production was also higher than that of farmers' condition (mean -2.5 liters/day).

Table 1. Mean Production performance of Lulu cattle at *different modes of* conservation.

Mode of conservation	Age at first calving (months)	Average daily milk yield (L)	Lactation length (days)
***In-situ* (2004)**	50	1.5 (	195
***In-situ* (2012)**	-	1.8	228
***In-situ* (2015)**	-	2.38	180
***Ex-situ* (2015)**	40	2.5	210

Sources: ABD, 2004; Poudel, pers commun. 2012; ABD, 2015

Figure 1. *In-situ* conservation: Lulu cattle at its home tract, Jharkot, Mustang (3200 masl).

Figure 2. *Ex-situ* conservation: Lulu cattle at ABD, Khumaltar, Lalitpur (1300 masl).

Feeding system under in-situ system

Crop residue-based grazing was the predominant feeding system with supplementation of brewers' cot and occasional salt was observed under *in-situ* system at Jharkot and Kagbeni VDC. The rangeland usually comprises of perennial ryegrass (*Lolium perenne*), Kote (*Medicago sativa* spp. *falcata*), White clover (*Trifolium repens*), Dhimchi (*Pennisetum flaccidum*), Furcha (*Elymus nutans*) etc. Other locally available conserved forages such as annual hay (naked barley, buckwheat, maize) and fodder trees (Chestnut, *Alnus nepalensis*, and *Sauraria* sp.) were supplemented as livestock feed.

Conclusions and Implications

- The preliminary results of this study clearly indicate the potentiality of breed improvement by intensive local selection of Lulu cattle.
- Under optimum management, Lulu cattle showed better production (milk yield) than *in-situ* indicated there is a greater scope of expanding the ecological habitat of this breed.

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Goat Raisers' Acceptability and Willingness to Pay for Baled Hay in the Philippines

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Keywords: Baled hay, forage, goat, acceptability, willingness to pay

Introduction

Goats, *Capra hircus* L. or Hircus in Latin, need year-round supply of feeds to meet their nutritional requirement for growth and reproduction. However, in the Philippines where there are two distinct seasons, fresh forages are more than sufficient during wet season but insufficient during dry season (Orden et al 2014). Regardless of the change in nutrient composition after cutting and drying, hay is an important forage for goats in the Philippines when fresh forages are not available. Processing forages is important to make them available to goats year-round. Baling is one way of processing forages through compaction using a baler making them easier to handle, transport and store. However, baling is uncommon in the Philippines especially among backyard farms who constitute 98% of the goat farms in the country (BAS 2012). This paper presents backyard goat raisers' acceptability and willingness to pay for baled hay as basis for its further development and promotion.

Methods

The survey was conducted in Regions 1, 2, 3, 8, 10 and 12, six of the important goat producing regions in the Philippines. A total of 213 backyard goat raisers who were previous partners of the National Science and Technology Program on Slaughter Goat were interviewed using structured questionnaire to determine their acceptability and willingness to pay for baled hay and baler. Most of the respondents were exposed to these products through the Farmers' Livestock School on Goat Enterprise Management (FLS-GEM), a modality to training farmers. Moreover, the farmers were showed with pictures of baled hay and baler before the survey. The survey was done by trained project staff and assisted by the personnel of the Department of Agriculture-Regional Field Offices (DA-RFOs), Local Government Units (LGUs), Provincial Agricultural/Veterinary Offices (PAOs/PVOs), and State Colleges and Universities (SCUs).

The goat raisers' responses were focused on four critical issues such as willingness to feed goats with baled hay, willingness to make or buy baled hay, and willingness to buy a baler. Raisers' willingness on each category used a five point Likert Scale: very unwilling (1), unwilling (2), somewhat willing (3), willing (4), and very willing (5). Data were analyzed on a regional basis then consolidated. Contingent valuation with mixed questioning procedure, i.e., close-ended with follow-up, was used (Lusk and Hudson, 2004).

Results and Discussion

Characteristics of goat raisers and their farms

The goat raisers' age ranged from 18 to 73 years, the majority were male (70%), married (91%), with a mean household size of 4 people. Only 48% were members of goat-related organizations while 80% had attended trainings and seminars on goat production and management. Goat raising was under backyard level with an average of 7 does per farm. In the Philippines, backyard level is characterized as those with <25 does. The does were predominantly of native bloodline and upgraded (Native x Anglo Nubian or Native x Boer). Only 16% of the does were purebred (Anglo Nubian or Boer) and crossbred (Anglo Nubian x Boer).

Most of the raisers were producing goats for slaughter while a few (13%) were into breeders. Majority had their own pasture while some had communal pasture (30%). Unavailability of feeds was a problem among most farmers from Regions 8, 10 and 12 but only a few farmers from Regions 1, 2 and 3. Cut and carry system, tethering, concentrate and legumes supplementation were the common solutions to the problem.

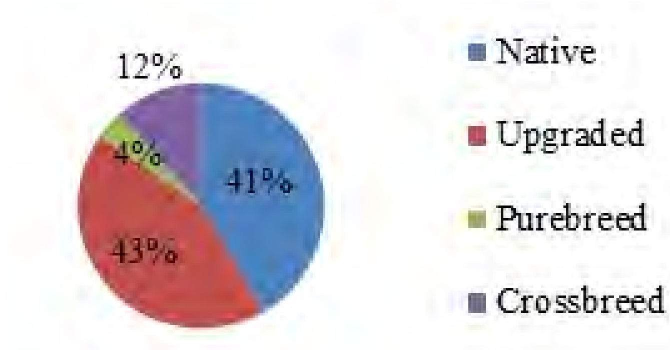

Figure 1. Distribution of does by breed.

Willingness to feed goats, make and pay for baled hay

The goat raisers were willing to feed their goats with baled hay (Table 1) subject to the following factors in order of importance: its palatability to goats, insufficiency of fresh forages, sufficiency of hay, and easiness of feeding. They were also willing to make baled hay from excess feed stuffs to make them available during the dry season. On the contrary, they were unwilling to buy baled hay even if the price is similar with the price of other forages. Moreover, they were very much unwilling to buy it if its price is higher than other forages. Their willingness changed a little positively to somewhat willing if the price is lower. In essence, price factor will not change their behaviour to buying baled hay. On the contrary, some backyard raisers from Nueva Ecija, Philippines were highly price sensitive to buying pellets for goats. Anent, majority of the goat raisers were unwilling to purchase a portable baler even at a price of Php7,000 (US$150) due to lack of financial capability. They would rather make an improvised baler than buy one.

Table 1. Numerical and qualitative response of goat raisers as indicators of their willingness to feed goats and pay for baled hay.

	Numerical Response	Qualitative Response
Willingness to feed baled hay to goats	4	Willing
Willingness to make baled hay	4	Willing
Willingness to buy baled hay	2	Unwilling
Willingness to buy baled hay if price is same as any sold forages in the locality	2	Unwilling
Willingness to buy baled hay if price is lower than any sold forages in the locality	3	Somewhat willing
Willingness to buy baled hay if price is higher than any sold forages in the locality	1	Very unwilling
Willingness to buy portable baler	2	Unwilling

Conclusion and Implication

In the Philippines, backyard raisers are willing to make baled hay and feed them to goats. However, baled hay production may not be a profitable enterprise because of backyard raisers' unwillingness to buy baled hay and portable baler.

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Effect of Seed Size on Sainfoin (*Onobrychis viciifolia* Scop.) Agronomic Performance and Seed Germination

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Key words: Sainfoin, seed size, germination, agronomic performance, dry matter yield

Introduction

Sainfoin (*Onobrychis viciifolia* Scop.) is a non-bloating perennial forage legume that has received renewed interest in western Canada. It has many desirable forage characteristics. Sainfoin is widely distributed in northern temperate regions of the world. Sainfoin has 6-7 times larger seed than alfalfa (*Medicago sativa* L.) which has resulted in high seed cost for sainfoin establishment. Limited information is available on the effect of seed size on sainfoin seed germination. In addition, understanding of agronomic performance of different seed-size classes of sainfoin could serve as a guide for future breeding for reduced seed size cultivars. The objective of this research is to understand the effect of seed size on sainfoin agronomic performance and seed germination.

Materials and Methods

Three sainfoin accessions based on 1000-seed weight were chosen: large (28 g), medium (21 g) and small (12 g). Thirty-two individual plants of each accession were arranged in the field near Saskatoon, SK, Canada (52^o 07' N, 106^o 38' W) in a randomized complete block design (RCBD) with four replications. Spring vigor was scored on the basis of spring growth, plant size, leafiness, disease, and stem density. Number of days from May 1 to emergence of the first flower on each plant was recorded as Days to flower. Number of stems for 12 plants from each accession was counted. The regrowth was scored after 30 days of harvesting. Finally, seed were harvested, and germination test were conducted under day/night (12/12 h) temperature of $20^oC/10^oC$. Fifty seeds were imbibed on top of two layers of filter paper (Whatman 597) in 9 cm sterilized plastic petri dishes moistened by 5 ml distilled water. Germination counts was made daily for 14 days. The germination experiment was repeated twice.

Results and Discussion

Analysis of variance (ANOVA) revealed significant differences among the three different seed-size classes for seed yield (P=0.01), plant spring vigor (P=0.005), growth rate (P=0.004), plant height (P=0.004), dry matter yield (P=0.02) and regrowth (P=0.02) (Table 1). There was no difference among three seed size classes for days to flower (P=0.27) and stem number plant^{-1} (P=0.22) (Table 1). Seed size (P<0.001) had significant effect on final seed germination (Table 1).

Sainfoin accessions with the large and medium size-seed classes had showed similar seed yield, spring vigor, growth rate, plant height, and regrowth, but the dry matter yield was higher in medium size seed class. Sainfoin with small seed sainfoin had poor performance. Seed size class had an effect on early growth and development of plants (Cash and Ditterline 1996), however, no such effect was found in final dry matter yield (Black 1959). The effect of seed class was significantly correlated to seed yield whereas non-significant correlation was found on stem number (Turk and Celik 2006).

Three seed size classes showed significantly different germination performances with the germination highest in the medium size seed, intermediate for large seed, and lowest for the small size seed class.

Table 3. Effect of sainfoin seed size on its agronomic characteristics and seed germination.

Traits	Seed class*			
	large	medium	small	p-value
Thousand seed weight (g plant^{-1})	27.8[a]	22.3[b]	12.1[c]	<0.001
Seed yield (g plant^{-1})	28.2[a]	33.8[a]	4.8[b]	0.01
Days to flower (days)	45.0[a]	41.9[a]	43.5[a]	0.27
Spring vigor**	3.0[a]	3.7[a]	1.9[b]	0.005
Growth rate (cm day^{-1})	1.7[a]	1.9[a]	1.0[b]	0.004
Stem number (number plant^{-1})	26.7[a]	37.6[a]	23.8[a]	0.22
Plant height (cm)	42.7[a]	48.9[a]	25.5[b]	0.004
Dry matter yield (g plant^{-1})	64.0[b]	145.0[a]	21.7[b]	0.02
Re-growth score**	3.4[a]	3.8[a]	1.3[b]	0.02
Final germination (%)	84.4[b]	94.0[a]	3.1[c]	<0.001

* Means with same letters within the row for each traits are not significantly different (*P*>0.05);
** Score 1-5 (1=poor, 5=good)

Seed germinated on the first day for medium and large seed size classes whereas small seed size class showed high degree of physical dormancy (Data not shown) (Fig. 1). Black (1959) reported that the proportion of hard seed increases as seed size decreases, which is the probable reason for low germination of small size seed class.

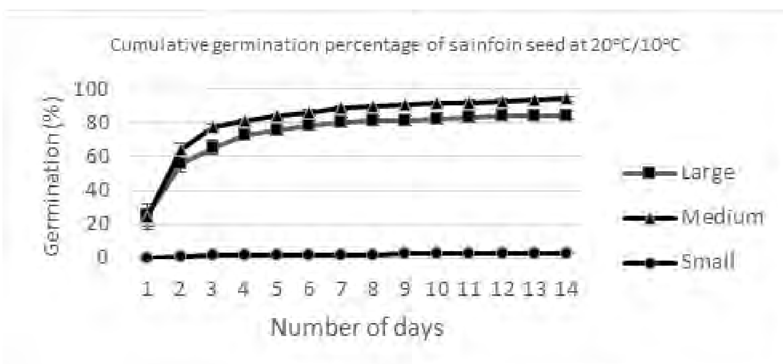

Figure 1. The effect of seed size on cumulative germination (%) of sainfoin seed at 20°C/10°C.
Values are means ± S.E.

Conclusion

New sainfoin cultivars with small seed would reduce the cost of stand establishment, however, our study showed that seed size had negative effect on germination and agronomic performance. Further research is needed to establish critical seed size for agronomic performance.

Acknowledgements
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Nutritive Value and Anthelmintic Properties of Selected Leguminous Shrubs and Trees for Goats

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Key words: Degradability, leguminous, shrubs, tannin, anthelmintics, goats

Introduction

Two related trials were conducted to determine the feeding value and anthelmintic properties of leguminous trees and shrubs such as Acacia *(Samanea saman),*Leucaena *(Leucaena leucocephala),* Gliricidia *(Gliricidia sepium),* Rensonii (*Desmodium cineria),*Desmanthus *(Desmanthus virgatus),* Flemingia *(Flemingia macrophylla),* Grandiflora *(Sesbania grandiflora)* and Sesban (*Sesbania sesban).* These protein-rich forages are important because they improve goat productivity (Orden *et al.,* 2000). However, secondary compounds like tannin have been identified in some species that affect its utilization by the animals. Although tannins exert adverse effects on forage consumption and nutrient degradability, its condensed tannin content, mostly delphinidin, pelargonidin and cyaniding, have been reported to control nematode infection in lambs (Butter et. al. 2000).

Materials and Methods

Samples of Acacia, Desmanthus, Flemingia, Gliricidia, Leucaena, Rensonni, Grandiflora, and Sesban were harvested at about 45-days re-growth from the reservation areas of CLSU, 15^{o}43'N, 120^{o}54'E. Leaves were processed and subjected to chemical analysis and *in-situ* degradation using three male Merino sheep fitted with rumen cannula (Ørskov and McDonald*,* 1977). Residual dry matter (DM) were fitted to the equation, $p = a + b\ (1 - e^{-ct})$. Total extractable phenols (TEPH) were determined using Folin Ciocalteu according to Julkunen-Titto (1985) while the fractionation and total condensed tannins were measured using the method of Porter *et al.,* (1986). Data collected were subjected to ANOVA using General Linear Model of Statistica for Windows™ Released 4.3.

Results and Discussion

Except for Acacia, the legume species contain more than 25% crude protein (CP) and majority of their biomass exceeded 70% degradability after 24hrs post-incubation (Figure 1). Degradability of the tree legume species can be ranked: Grandiflora > Sesban > Gliricidia > Desmanthus > Leucaena > Renzonii > Acacia > Flemingia. Except for Flemingia, other species contain highly soluble and degradable components that can provide immediate supply of N and fermentable matter to meet nutritional needs of goats. Almost 50% of the DM content of Grandiflora is readily soluble, while Rensonii and Desmanthus had more than 42% solubility 4hr-post incubation. Although Leucaena, Gliricidia and Sesban leaves were not as soluble as Grandiflora, Rensonni and Desmanthus, more than 50% of its DM were degraded as incubation time progresses.

More than 65% of total extractable phenols in Flemingia and Leucaena were found to be extractable tannins. Moreover, they contain high condensed tannin (CT) that could potentially reduce gastro-intestinal parasites in goats (Table 1). Other species had minimal or no CT content.

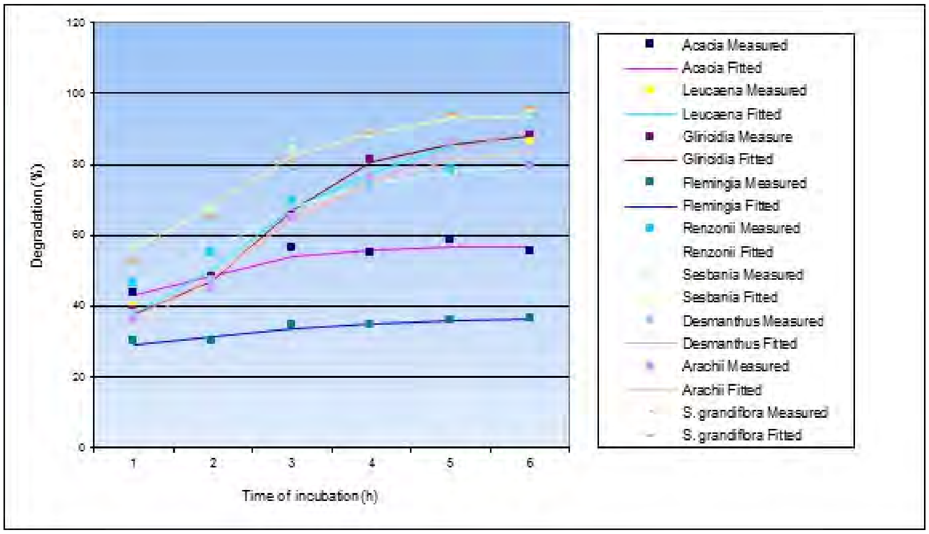

Figure 1. *In- situ* DM degradability of leguminous shrubs and trees at different incubation time.

Table 1. Condensed tannin contents of selected legume species

Legume species	Condensed Tannin Fractions (μg/g DM)			Total CT
	Delphinidin	Cyanidin	Pelargonidin	
Acacia	--	45.33	--	45.33
Desmanthus	1132.21	103.54	--	1,235.75
Gliricidia	98.72	378.09	--	476.81
Flemingia	4,003.08	1,561.37	102.79	5,667.24
Leucaena	1,987.23	1,522.13	288.57	3,797.93
Rensonii	--	--	--	--
S. grandiflora	--	--	--	--
S. sesban	--	--	--	--

-- not detected

Conclusion and Implications

Except for Flemingia and Acacia, leguminous fodders contain high CP, rumen-soluble and degradable organic matter that can provide N and fermentable carbohydrates. Moreover, Flemingia and Leucaena were found with antinutrients in the form of TEPH, total extractable tannin (TET) and total condensed tannin (TCT). However, they are potential and inexpensive sources of anthelmintics against internal parasites for goats.

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Forage Yield of North American and Eurasian Wheatgrass Species in Central Canada

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Key words: Forage yield trend, native grass, tame grass, Canadian prairies

Introduction

The last two decades have seen an interest in native plants of North America for rangeland seeding and restoration, and biomass fuel crop production. In Canada, a native grass species development program was initiated by Ducks Unlimited Canada in 1991, which has released native grass ecological varieties (Coulman et al. 2008). A number of native wheatgrass species have been widely used for reclamation, and for re-seeding rangeland. However, limited data is available on how the native grasses perform under a hay production system. Introduced grasses from Eurasia have been extensively used for hay production as a monoculture or in mixtures with legume in the Northern Great Plains. The objective of this research was to compare forage yield of native and introduced wheatgrass species under hay production systems in the Northern Great Plains.

Materials and Methods

A field trial was established in June 2011 at the Agriculture and Agri-Food Canada Research Farm (52°07'N, 106°38'W) near Saskatoon, Canada. The experimental design was a four replicate, randomized complete block design (RCBD) with each plot consisting of seven, 6 m long rows, spaced 30 cm apart and seeded at a rate of 100 pure live seeds m^{-1}. The soil was a Dark Brown Chernozem (Head 1979). A granular form of inorganic fertilizer was applied in the month of November in each year at rates of 56 kg ha^{-1} P and 112 kg ha^{-1} N, respectively. From 2012-2015, forage dry matter yield was determined in July using a plot harvester. Wheatgrass species included two native wheatgrass of North America: Northern wheatgrass [*Elymus lanceolatus* (Scribn. & Smith) Gould], and slender wheatgrass [*Elymus trachycaulus* (Link) Gould]; and three Eurasian wheatgrass species: crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.], tall wheatgrass [*Thinopyrum ponticum* (Podp.) Z.-W. Liu & R.-C. Wang] and intermediate wheatgrass [*Thinopyrum intermedium* (Host) Barkworth & D.R.Dewey]. Rainfall distribution is shown in Table 1. Data were analyzed as a RCBD with four replicates using SAS.9.4 Proc Mixed model (SAS Institute 2009). When ANOVA indicated significant differences among species ($P \leq 0.05$), the means were separated using the least square means comparison.

Table 1. Monthly rainfall (mm) received during the studies in 2011-2015 in Saskatoon, Canada

	2011	2012	2013	2014	2015
April	1.6	29.3	10.5	74.2	21.1
May	18.1	120.5	15.9	61.1	0.4
June	96.7	123.5	117.7	94.8	13.6
July	69.4	81.9	35.6	44.5	84.3
Total	185.8	355.2	179.7	274.6	119.4

Results and Discussion

Test-Year had a significant effect on forage yield (*P*=0.0021). The amount of April-June rainfall received in 2012 was the highest among the five study years, and this was the year of the greatest forage yield for all species. In 2015, there was almost no rainfall until the end of June (Table 1). Thus, all species produced significantly less forage yield than the other three years. There was a significant (*P*=0.0056) species x year interaction. Therefore, data was analyzed by each year (Table 2). Slender and crested wheatgrass produced similar forage yield under a one-cut system over four years, which was greater than northern wheatgrass. Tall wheatgrass and intermediate wheatgrass produced similar forage yield except tall wheatgrass produced greater yield in 2015. Forage yield was greater for tall wheatgrass than the two native wheatgrass and crested wheatgrass in all four years.

Table 2. Forage dry matter yield (kg ha^{-1}) of native and tame wheatgrass species at Saskatoon, Canada.

Wheatgrass species	Cultivar	Origin	Year				
			2012	2013	2014	2015	4-yr mean
Northern	Polar	North America	8467b*	4724b	3356c	965c	4378d
Slender	Revenue	North America	12886a	5901ab	5527b	724c	6259bc
Crested	AC Goliath	Eurasia	11794a	5135b	5986b	1075c	5997c
Intermediate	Chief	Eurasia	12309a	6723a	7125ab	1629b	6946ab
Tall	Orbit	Eurasia	12517a	6516a	8016a	2481a	7382a
P-value			0.0063	0.0124	0.0022	<.0001	<.0001
SEM**			747	401	691	182	314

*Means within a column with the same lower case letter are not significantly different (*P*>0.05). **SEM, Standard error of the means.

Conclusions

The introduced wheatgrass species, tall and intermediate, generally produced higher forage yields than the native wheatgrass species, slender and northern. Slender wheatgrass produced comparable forage yield in a one-cut hay system to the introduced species crested wheatgrass. Northern wheatgrass produced lower yield than other grasses in the study.

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Effect of Drying Methods on Condensed Tannin Concentration and Nutritive Value of Purple and White Prairie Clovers

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Key words: Purple Prairie Clover, White Prairie Clover, condensed tannins, forage, hay

Introduction

Purple Prairie Clover (*Dalea purpurea* Vent; PPC) and White Prairie Clover (*Dalea candida* Michx. ex Willd; WPC) are legumes that are native to the North American prairie and have excellent forage nutritional properties for ruminants and could be used for restoration and improving rangelands (Iwaasa et al., 2012). They have perennial warm-season growth habits that could be used to extend the grazing season. In a survey of condensed tannin (CT) containing forages across the Canadian prairies, PPC had the highest concentration of CT measured as 68 g kg^{-1} of forage dry matter (DM) (Berard et al., 2011). Furthermore, PPC CT appears to possess unique chemical properties that inhibit *Escherichia coli* O157:H7 activity and under grazing, lower the levels of *E. coli* shed in cattle feces (Wang et al., 2013). Feeding of cattle also includes hay, and it is unclear how PPC and WPC conserved as hay would affect the CT levels. In this study, two different drying methods, freeze-drying (fresh forage) and sun-drying (hay) were used to determine their effect on the condensed tannin concentrations and nutritive values of PPC and WPC.

Materials and Methods

Individual PPC and WPC plants were transplanted from the greenhouse to the field in the summer of 2012 and grown 90 cm apart in rows at Swift Current Research and Development Centre, SK. Forage materials were harvested on August 21, 2013 and August 24, 2014 at full flower/seed set stage. Four individual plants were randomly harvested from eight rows at 5 cm above ground. Each individual plant material was divided into two equal portions with one portion freeze dried in a vacuum freeze drier for four days and the other, sun dried on a rack for about 10 days (in the greenhouse). Dried samples were ground to pass a 1-mm screen in a Wiley mill and analyzed for CP, acid detergent fibre (ADF), neutral detergent fibre (NDF), organic matter (OM), organic matter digestibility (OMD), calcium (Ca), potassium (K), and extractable condensed tannins (ECT) using method described by Terill et al. (1992). Data were analyzed using ANOVA MIXED Procedure of SAS (2005). Fixed effects were species of plants and drying methods, and individual plants were considered as random effect.

Results and Discussion

There were no differences ($P > 0.05$) between the ECT concentrations of freeze-dried and sun-dried samples for both species in the two production years (Table 1). However, there was difference ($P < 0.05$) between species; with PPC containing more ECT than WPC. The results demonstrate that irrespective of whether PPC and WPC are fed as fresh forages or hay, the CT available to feeding animals may not differ. Despite the fact that WPC had higher ($P < 0.05$) CP and OMD than PPC, both species have good nutritional values (Table 2).

Table 1: Extracted condensed tannin concentration (g kg^{-1}) of freeze dried (FD) and sun-dried (SD) Purple Prairie Clover (PPC) and White Prairie Clover (WPC) harvested at full flower/seed set stage in two production years at Swift Current, SK, Canada.

	ECT (g kg^{-1})			
	PPC		WPC	
	FD	SD	FD	SD
2013	89.8b	83.2b	51.4a	51.8a
2014	90.5b	88.1b	62.8a	58.1a

Means in the same column with different letters are significantly different at P < 0.05.

Table 2: Nutritive value (g kg^{-1}) of freeze-dried and sun-dried Purple Prairie Clover (PPC) and White Prairie Clover (WPC) harvested at full flower/seed set stage at Swift Current, SK, Canada.

	PPC		WPC	
	Nutritive value (g kg^{-1})			
	FD	SD	FD	SD
CP	15.0a	14.2a	16.4b	16.9b
ADF	31.0	31.9	30.3	29.4
NDF	40.4	40.7	39.1	38.4
OM	93.5	92.7	93.1	92.5
OMD	54.1b	51.3a	60.2c	58.8c
Ca	1.5	1.6	1.6	1.9
K	1.5	1.6	1.6	1.9

Means in the same column with different letters are significantly different at P < 0.05.

Conclusion and Implications

PPC and WPC could serve as good forage species in native pastures and rangelands by improving the forage nutritional profile. Their unique source of CT that has strong antimicrobial activity against E. coli O157:H7 could lead to improve animal health and alleviate public concern over beef production practices that rely on high grain diets. The CT benefits from feeding PPC or WPC to ruminant animal can occur under grazing or as conserved hay.

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Potential of Stockpiled Perennial Forage Species for Fall and Winter Grazing in the Canadian Great Plains Region

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Key words: Stockpiled forage, perennial forage, winter grazing

Introduction

Stockpiled forage is forage grown and accumulated for use at a later time or during a period of forage deficit. Stockpiling is one of several extended grazing techniques which save certain hay or pasture fields for grazing after forage growth has stopped in the fall. Extending the grazing season into the winter months by using stockpiled forage has been shown to reduce winter feeding costs (Johnson and Wand, 1999; Riesterer et al., 2000). This has led to a growing interest in managing tame pastures for extended grazing and targeted evaluation studies are needed. The objective of this study was to evaluate the production and nutritive value of perennial forage species for stockpiled fall/winter grazing in western Canada.

Materials and Methods

This study was initiated at the Agriculture and Agri-Food research center farm located in Saskatoon, SK, Canada in the spring of 2014. Three legumes (two species) and five grasses (four species) were seeded in pure stands and in two species grass-legume mixtures. The design of the perennial small plot (1.2 X 6.0 m) forage trial was a split-plot randomized complete block with three replicates. The main plots were early (16 July, 2015) and late (10 August, 2015) stockpile initiation. Species/cultivars were Fleet meadow brome (F), Armada meadow brome (AR), Courtenay tall fescue (C), Killarney orchardgrass (K), Success hybrid brome (S), Yellowhead alfalfa (Y), Algonquin alfalfa (A), Oxley cicer milkvetch (O). Stockpiled forage was harvested in mid-October, 2015. Dry matter yields were determined at each stockpiling date by harvesting and weighing green matter from entire plots and drying a sub-sample at 60° C. These yields were added to the stockpiled yields to determine total dry matter (seasonal) dry matter yields. Although nutritive value was also determined, this paper will focus only on yields.

Results and Discussion

Stockpiled Dry Matter Yields (SDM)

SDM was significantly different between stockpile initiation dates and among species/cultivars and mixtures. There was no interaction between these two effects. SDM of the July stockpile treatment was significantly higher (3.3 Mg/ha) than the August treatment (1.4 kg/ha). July stockpiled forage was observed to be taller and contained more reproductive tillers. According to Coleman (1992), it was desirable to produce at least 2.0 Mg/ha of herbage before winter grazing to maintain adequate grazing efficiency. This was obtained for the July stockpile, but not for August. The latter treatment does not have enough time for regrowth to accumulate sufficient biomass. Among pure species, SDM of the meadow bromes, Fleet (F) and Armada (AR), were numerically the highest yielding and F was significantly higher than Killarney orchardgrass (K), Yellowhead alfalfa (Y) and Oxley cicer milkvetch (O). For the grass-legume mixtures, those with F and AR meadow bromegrass tended to have the highest SDM, while mixtures with K and Success hybrid brome (S) were the lowest.

Total Forage Dry Matter Yield (TDM)

TDM was not significantly different between July (7.6 Mg/ha) and August (6.8 Mg/ha) stockpile treatments; however, there were differences among species/cultivars and mixtures (Table 1) with TDM ranging from 2.0 to 10.8 Mg/ha (Table 2). Similar to the SDM, meadow brome (F and AR) generally produced the highest TDM in both pure and mixed stands, while orchardgrass (K) was usually the lowest.

Table 1. Stockpiled dry matter (SDM) and total (seasonal) dry matter (TDM) yields (Mg/h) of pure stands and mixtures in 2015.

	Cultivars and Mixtures								SE
Pure stand	F	C	K	S	AR	Y	A	O	
SDM	3.6 a†	2.3 abcd	1.3 d	1.6 abcd	2.8 abcd	1.3 cd	2.5 abcd	1.1 d	
TDM	10.0 ABC‡	4.7 EFGH	3.5 GH	6.4 CDEFG	10.0 ABC	5.9 DEFG	8.0 ABCDE	2.0 H	
Mixture	F-Y	F-A	F-O	C-Y	C-A	C-O	K-Y	K-A	
SDM	3.3 abc	3.5 ab	2.4 abcd	2.9 abcd	2.8 abcd	3.0 abcd	1.7 abcd	2.5 abcd	
TDM	10.4 AB	10.0 ABC	8.2 ABCDE	6.7 BCDEFG	7.8 ABCDE	5.4 EFGH	5.0 EFGH	7.5 ABCDEF	
Mixture	K-O	S-Y	S-A	S-O	AR-Y	AR-A	AR-O		
SDM	1.6 abcd	1.6 bcd	2.8 abcd	1.6 bcd	2.0 abcd	3.1 abcd	3.3 abc		0.41
TDM	4.0 FGH	6.6 CDEFG	9.1 ABCD	5.9 DEFG	8.2 ABCDE	9.7 ABC	10.8 A		0.77

† Means followed by the same lowercase letter (in SDM rows) are not different at the 0.05 probability level. SE = Standard Error.
‡ Means followed by the same uppercase letter (in TDM rows) are not different at the 0.05 probability level.
F=Fleet meadow brome; AR=Armada meadow brome; K=Killarney orchardgrass; S=Success hybrid bromegrass; C=Courtenay tall fescue; A=Algonquin alfalfa; Y=Yellowhead alfalfa; O=Oxley cicer milkvetch
The

Conclusions

The preliminary data from this first year of a multi-year study showed that stockpiling perennial grass and legume species from July can produce greater than 3.0 Mg/ha of forage by mid-October. Meadow bromegrass produced the highest stockpiled and seasonal yields in both pure stands and mixtures with legumes.

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The Potential of Silver Thicket (*Euphorbia stenoclada* Baill.) as Dry Season Supplement Feed for Pastoral Herds in Southwestern Madagascar

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Key words: Coastal shrubland, resource degradation, ruminants, succulent tree, transhumance.

Introduction

Livestock rearing is very important in the semi-arid southwest of Madagascar, where cattle and small ruminants fulfill multiple economic and socio-cultural functions. Animals are herded on sparsely vegetated sandy soils of the coastal zone and, during rainy season transhumance, on more densely vegetated calcareous plains of the adjacent Mahafaly plateau. *Euphorbia stenoclada* Baill., locally called "samata", is a succulent evergreen spiny tree reaching up to 10 m height. It is endemic to the coastal region and not directly browsed by ruminants. To bridge the often severe dry season forage scarcity, herders cut and chop *Euphorbia* branches, thus providing >80% of the animals' daily feed (Feldt, 2015). This practice threatens growth and regeneration of natural *Euphorbia* stands, from which also seedlings are transferred to plantations near settlements. The present study, conducted near Tsimanampesotsa National Park (24.099°S, 43.832°E), therefore determined natural and planted *Euphorbia* stand density, biomass yield and fodder use as well as the plant's nutritional value.

Materials and Methods

The study covered six villages spreading 50 km from north to south along the coastal strip. The point-centered quarter method (Cottam and Curtis, 1956) served to investigate the distribution of *Euphorbia* along four 1 km transects from each village center. At each sampling point, the following parameters were measured for the four nearest *Euphorbia* trees (>2 m): distance to sampling point, height (total, stem and crown) and crown width. Utilization intensity was scored from 1 to 5 (unused to heavily damaged). Plants <2 m height were not considered as these were not used for fodder. If a 30 m radius around the measurement point contained <4 plants, the spot was considered treeless. The surface of village plantations was mapped with a GPS, and number and average height of trees determined. To quantify fodder biomass, 30 trees of different utilization intensity were selected, 25-50% of their branches cut and dry mass (DM) of the latter determined after chopping and sun drying.

The fodder value of *Euphorbia* was determined in a difference trial with 8 healthy male sheep of 24-32 kg live weight that were kept outdoors in a spacious and shaded enclosure. During the initial 3 weeks they individually received 600 g DM d^{-1} of mature *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult. grass. In weeks 4 and 5, animals received 300 g DM d^{-1} each of *Heteropogon* and locally bought freshly chopped *Euphorbia*. In weeks 3 and 5, feed offered and refused as well as faeces excreted were quantified for each animal, the latter by using faecal collection bags. *Euphorbia* refusals and faeces were weighed fresh and air-dried in the shade. Samples of feed offered, refused and of faeces were analyzed for concentrations of DM, crude protein (CP), phosphorus (P), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) applying standard protocols.

Results and Discussion

Plants in natural stands were 3-4 m high with a crown cover of 3-6 m^2 (Table 1). Stands were very heterogeneous with older and therefore bigger trees, smaller and more intensively used trees, as well as undisturbed individuals, pointing to a healthy population. Goetter et al. (2015) also found a high number of seedlings and plants <2 m in wild stands in the same region, but at the same time reported a high mortality of lopped trees. Small plantations showed the highest *Euphorbia* density, but even in larger plantations tree density was >4 times higher than in the densest natural stands. Low average tree height in plantations pointed to their recent establishment through transplanting of wild seedlings.

Table 1. Characteristics of wild and planted *Euphorbia stenoclada* stands (Mean ±SD).

Village	Efoetse	Ankilibory	Maromitilike	Marofijery	Manasy	Beroka
Wild stands						
Points with trees [a] (%)	32.5	50.0	37.5	57.5	30.0	47.5
Tree density [b] (n ha^{-1})	32	99	40	128	108	177
Tree height [c] (m)	3.7±1.3	3.9±1.3	3.8±1.3	3.9±1.2	4.0±1.3	3.4±1.2
Crown cover (m^2 $tree^{-1}$)	5.5±4.9	3.4±2.6	4.0±3.0	5.8±6.3	6.1±3.4	3.0±2.5
Use intensity (score)	2.1±0.5	3.1±0.9	2.8±1.0	3.0±1.2	2.9±1.1	2.8±0.9
Biomass (kg DM $tree^{-1}$)	27±33	13±24	16±20	31±48	14±19	11±18
Plantations (n)	2	5	4	4	6	2
Area (m^2)	412±163	1283±1607	180±73	2177±3057	636±764	57±6
Tree density (n ha^{-1})	324±352	744±354	2734±1294	935±401	2020±1416	5550±292
Tree height [d] (m)	1.6±0.1	2.6±0.5	2.0±0.5	2.1±0.5	2.1±0.4	1.5±0.2

[a] Total=40 points per village. [b] Across whole village, no SD. [c] Only trees >2 m accounted for. [d] All trees accounted for.

The quality of mature *Heteropogon* was very low (Table 2), and its DM digestibility therefore improved from 36% to 52% when consumed together with fresh *Euphorbia*. The DM digestibility of *Euphorbia* was determined at 61%, whereas its NDF and ADF digestibility averaged both 58% as compared to 48% and 35% in *Heteropogon*.

Table 2. Average* proximate composition of mature *Heteropogon* and *Euphorbia.*

Component	(unit)	*Heteropogon contortus*	*Euphorbia stenoclada*
DM	(g kg^{-1} fresh matter)	936	234
CP	(g kg^{-1} DM)	11	39
NDF	- " -	781	557
ADF	- " -	596	565
ADL	- " -	476	301
P	(mg kg^{-1} DM)	438	900

* No SD given due to low sample number, i.e., two 1-week pool samples for *Euphorbia, and* two 2-week pool samples for *Heteropogon.*

Conclusions and Implications

Euphorbia stenoclada is a quantitatively and qualitatively important dry season ruminant fodder for the livestock-dependent inhabitants of Madagascar's southwestern coastal zone. Offered along with poor quality grasses, it supplies energy, phosphorus and some protein when nearly no other feed is available outside the national park where grazing is prohibited. The plant additionally supplies animals with water in a region where many wells hold brackish water. But intense lopping and transfer of wild seedlings to (private) plantations threaten its future communal usage. Vegetative propagation of *Euphorbia* through cuttings (Goetter et al., 2015) therefore seems to be a promising countermeasure.

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Morpho-Phenological Characterization and Seed Set Enhancement in *Sehima nervosum cv*. Bundel Saen Ghas-1

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Key words: Grass, hormones, seed filling, Sehima

Introduction

India is facing severe fodder shortage with up to 36% deficit in green fodder availability. As per an estimate less than 20 per cent of the required seed of range species is available in India. *Sehima nervosum* (commonly known as Rat's tail grass, white grass in Australia and Saen grass in India) is one of the major grass species particularly in the *Sehima-Dichanthium* grass cover which is distributed all along India. *Sehima nervosum* is an important range species with good fodder potential. With its ability to grow from 100m to 2750m altitude and at 250 to 1375 mm rainfall it is one of suitable range species under rainfed conditions. Seed setting is only 14-17% in *Sehima nervosum* (Bahukhandi et al., 2011). The low seed filling directly effects the establishment of the grass due to poor germination. Enhancement of seed to ovule ratio increases seed quality which may result in increased germination percentage and improved productivity *per se*. Increase in seed setting rate with the application of growth regulators was earlier reported in rice by Pan et al. (2013). Thus, the present study was taken up to enhance the seed quality by increasing the seed filling through exogenous hormonal spray and also to find out the seasonal influence on seed setting in *Sehima nervosum*.

Materials and Methods

The study was conducted at central research farm of ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India (25°31'38"N, 78°32'55"E, 231 m above sea level) during 2012-2014. The released and notified variety of *Sehima nervosum*, Bundel Saen Ghas-1 was taken for morpho-phenological studies and seed setting. The rooted slips were transplanted in 4 m × 2 m plots with 50 cm spacing in three replications in a randomized block design. The treatments contains foliar application of 100 ppm Indole acetic acid, 100 ppm Gibberellic acid (GA_3), 100 ppm Kinetin, 100 ppm 2,3,5-Triiodobenzoic Acid (TIBA) and 200 ppm Cobaltous nitrate ($Co(NO_3)_2$) apart from control. Foliar application of growth regulators/ chemicals was carried out at heading stage. The morpho-phenological characters were studied on ten random plants in each plot for two consecutive years. The pollen viability was studied by counting 1% acetocarmine stained pollen at 100x resolution in ten random fields of observation in three replications each year.

Results and Discussion

The Bundel Saen Ghas-1 cultivar of *Sehima nervosum* has an average height of 103 cm with more than 400 tillers. Out of these tillers, 54% are ear bearing tillers at the time of peak flowering period. Each tiller further possessed more than 4 branches (nodal tillers) and 84% of these nodal tillers possessed racemes (Table 1). The ear in *Sehima* is a raceme with 20 spikelets arranged in 2 parallel columns. Each spikelet consists of two florets of which one is staminate and the other is hermaphrodite. *Sehima* is a protogynous plant with two and half to three week duration from anthesis to maturity. It was observed that the total mean duration of anthesis of hermaphrodite florets is 9 days and during which almost equal number of spikelets opened in each column. The percent spikelets opened decreased with increase in anthesis duration. The availability of pollen is crucial in the first four days of anthesis as more than 80% of anthesis in an ear occurred during this period.

Table 1. Morphological characters of *Sehima nervosum* cv. Bundel Saen Ghas-1.

Crop	Plant height (cm)	Total tillers (No.)	No. of Ear bearing tillers	% Ear bearing tillers	Branc hes/ tiller	No. of ear/ tiller	Tussock diameter (cm)	Tussock perimeter (cm)	Spikelets/ ear
Sehima nervosum	102.06	419.08	217.58	54.55	4.77	4.0	33.35	83.23	20.3
SEM	7.24	62.58	24.59	5.81	0.82	0.73	1.16	4.24	3.03

The morpho-phenological characters showed differences under the influence of seasonal variations. The plant growth characters *viz*., plant height, tussock diameter, tussock perimeter and number of branches per tiller got reduced in the winter season compared to the rainy season. Even though number of spikelets per raceme got reduced, the number of seeds per raceme increased leading to the increase in seed setting per se however, seed yield was more in rainy season compared to winter season. Thus, there is need to improve the seed quality in terms of filled seed mainly in rainy season.

Most of the range grasses are pseudogamous apomictic in nature resulting in the requirement of pollen for the formation of endosperm. In *S. nervosum*, the staminate flowers open later than hermaphrodite florets and act as supplementary pollen source due to non-synchronous anthesis among tillers with in a plant. Thus, pollen availability, a critical resource for seed setting was not limited in *S. nervosum*. Grasses are wind pollinated consequently this grass produces abundant pollen as identified in high proportions in modern pollen assemblages (Vincens et al., 2006). After pollen availability, pollen viability is also equally important for successful seed setting (Kim et al., 2009). The viability of the available pollen in *S. nervosum* is 85%. Thus, after ruling out the pollen availability and pollen viability as reasons for low seed setting, the exogenous application of chemicals was used to enhance the seed to ovule ratio. Application of hormones not only increased the number of flowers but also number of caryopses inside the fluffy seed. Among different hormones/ chemicals tested, 100 ppm TIBA significantly enhanced the number of seeds per raceme as well as seed setting percentage than control (Fig. 1). Triiodobenzoic acid is basically an auxin inhibitor. Exogenous application of TIBA enhances accumulation of endogenous IAA in the ovaries leading to parthenocarpic fruit formation in cucumber (Kim et al., 1992).

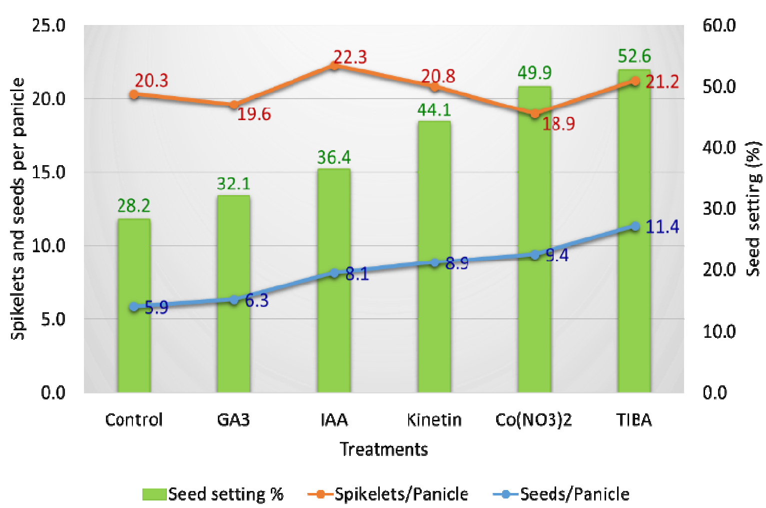

Figure 1. Effect of treatments on flower number and seed filling.

Conclusions and Implications

The present study indicated that, *Sehima nervosum cv* Bundel Saen Ghas-1 is a potential range species with very high tiller number. The pollen availability or its viability is not an issue for seed setting in *S. nervosum*. The seed quality in terms of seed filling can be enhanced through foliar application of 100 ppm TIBA at heading stage. The increase in seed filling influences the possibility of enhanced seed germination and helps in increased per se productivity.

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Zootechnical Value of the Community of Halophytes after Exclusion from Grazing in Flooding Pampa, Argentina

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Key words: Halophytes steppe, exclusion, regeneration, forage value, vegetal cover.

Introduction

The Flooding Pampa (FP) is a 60,000 km^2 region in the central-east area of the Buenos Aires province, Argentina. Mesothermal rangelads is the predominant biome and it is estimated that 10,000 km^2 are halophyte communities. In those environments, overgrazing caused damage to the vegetation (Vecchio, 2014), which is reflected in its zootechnical value (ZV), an appreciation of its forage characteristics (Cauhépé et al, 1985). As recovery strategy of the ZV the replacement by cultivated species has been proposed (Otondo 2012), without having achieved significant results, incurring high economic costs and ecological risks. There is evidence of significant increases in ZV to applying rest periods during grazing (Fernández Grecco e Hidalgo, 1993). Other studies indicate positive effects of exclusion (Cauhépé et al, 1985). However, no studies were found that have evaluated ZV response after grazing exclusion in halophytic communities. The objective was to evaluate changes of ZV after exclusion from grazing.

Materials and Methods

The mean annual precipitation in FP is 1,000 mm. Halophyte communities are found in mosaics interconnected with other grasslands communities, generally more fertile. We took three halophyte communities grown on soil *Natracualf típico*, excluded since 1999, 2004 and 2010. Previously, they were used for continuous grazing by bovine with a livestock density of 0.9 EV/ha, exceeding its livestock carrying capacity. In each exclusion four sampling sites (n=4) were installed. In each site, every year until 2015, the vegetation was surveyed and vegetation cover (VC) was estimated (Braun-Blanquet, 1979). With this data ZV was calculated. In each exclusion ZV and VC were compared statistically throughout the years by means of ANOVA and the measurements comparison, by the Tukey test (α=0.05)

Results and discussion

In all exclosures, VC and ZV increased after grazing exclusion (Figure 1)**.** In the first three years was the most significant increase, the average VC of the three closures increased from 36% to 66.5% since year 0 to 3 after exclusion from grazing, respectively. Only the old exclusion reached 100% VC, in year 13 after exclusion from grazing and then maintained. The ZV average of the three exclusions increased significantly ($p<0.05$) from 13 to 40 since year 0 to 3, respectively (Figure 1). This increase is mainly explained by a change in vegetation structure: in year 3 was registered a significant increase in relative coverage (RC) of species or functional groups with better forage value, among them *Chloris berroi* (Table 1). The RC of weeds increased but this did not affect in ZV of community. In grasslands of region, Cauhépé et al (1985) found a 72% increases in the ZV after three years of exclusion.

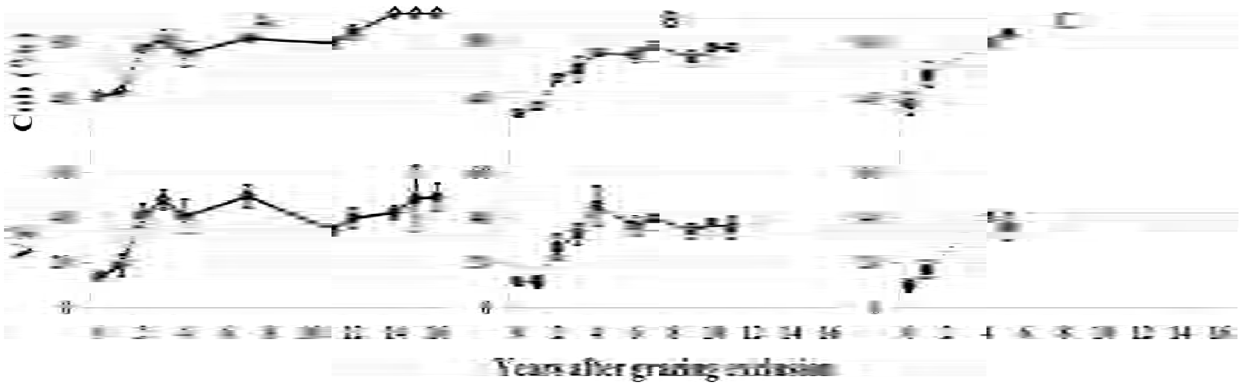

Figure 1. Evolution of vegetation cover (Cov in %) and zootechnical value (ZV in %) in three exclusions halophyte communities: A, B and C that started in 1999, 2004 and 2010, respectively. Zero indicates start time of the exclusions. The vertical segments indicate standard deviation of the mean (n=3) of each year post-exclusion.

Between year 4 and 11 of exclusion there were no significant differences ($p > 0.05$) in the ZV of A and B, having been Chloris berroi, again who more contributed this. ZV post-exclusion of A is higher at year 16 that 11 ($p < 0.05$) and in addition, with species from more fertile ambient how contributor.

Table 1. Relative cover (RC) and zootechnical value input (ZVI, in % of ZV absolute) of species or functional group most important at every time-exclusion (initial, 4, 11 and 16 years post-exclusion), in A, B and C: excluded at 1999, 2004 and 2010, respectively

	0	Cr	AVZ	4	Cr	AVZ	11	Cr	AVZ	16	Cr	AVZ
A	***Sporobolus pyramidatus***	**12**	**36**	***Chloris berroi***	**48**	**71**	***Chloris berroi***	**40**	**69**	***Chloris berroi***	**20**	**25**
	Distichlis sp.	**6**	**7**	***c3 anual Σ1-1***	**10**	**24**	***Eragrostis lugens***	**9**	**10**	***Sporobolus indicus***	**17**	**20**
	Chloris berroi	**3**	**14**	***Paspalum vaginatum***	**4**	**4**	***Sporobolus indicus***	**5**	**9**	***Paspalum dilatatum***	**13**	**21**
										Botriochloa laguroides	**6**	**10**
	Latifoliada Σ1-10	**7**		Latifoliada Σ1-13	**10**		Latifoliada Σ1-16	**14**		Latifoliada Σ1-13	**9**	
B	***Chloris berroi***	**15**	**73**	***Chloris berroi***	**45**	**59**	***Chloris berroi***	**38**	**66**			
	Puccinellia glaucescens	**3**	**8**	***c3 anual Σ1-2***	**17**	**24**	***Lotus tenuis***	**7**	**12**			
	Paspalum vaginatum	**2**	**8**	***Sporobolus indicus***	**1**	**2**	***Sporobolus indicus***	**4**	**7**			
								4	**6**			
	Latifoliada Σ1-9	**7**		Latifoliada Σ1-7	**4**		Latifoliada Σ1-7	**10**				
C	***Distichlis sp.***	**26**	**30**	***Chloris berroi***	**30**	**55**						
	Sporobolus pyramidatus	**5**	**12**	***Distichlis sp.***	**23**	**13**						
	c3 anual Σ1-2	**8**	**29**	***Sporobolus indicus***	**8**	**13**						
	Latifoliada Σ1-7	**7**		Latifoliada Σ1-7	**6**							

Zero is foreclosure beginning. Weeds and annual C_3 Grasses such as functional group indicating total number of species.

Conclusion and Implications

The exclusion showed a strategic way to increase the ZV of the community of halophytes graded by overgrazing. VC and ZV increased significantly in all exclosures in the first three years after exclusion from grazing, keeping the value in later years. The information generated here reveals the potential for self-regeneration of the community of halophytes and the improving of their ZV without the need to incur in the use of inputs or ecological risks.

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Eco-physiological Characteristics of Two Native Forage Species of the Canadian Prairies

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Key words: side-oats gramma, winterfat, Canadian prairie, germplasm, release

Introduction

Evaluation of native and introduced forage species has been an on-going program at Swift Current Research and Development Centre (SCRDC) since its inception. The program objectives included improving biomass production, seed retention and yield, tolerance to biotic and abiotic stresses, improving plant establishment and harvest, and managing competition and complementarity in the tame or managed rangeland environment. Approximately 290 species have been evaluated for their adaptation and possible use as forage crops (Lawrence and Ratzlaff, 1989). Works are underway for improving populations of several native forage species. This paper highlights some eco-physiological characteristics of side-oats grama [*Bouteloua curtipendula* (Michx.) Torr.] and winterfat [*Krascheninnikovia lanata* (Pursh) A. Meeuse & Smit]. Side-oats grama is a deep rooted, drought tolerant warm-season grass with compact rhizomatous crown. It produces palatable, good quality forage throughout summer and fall. Winterfat is a native shrub adapted to semi-arid conditions in the Canadian prairies. It is highly palatable, digestible and nutritious forage for livestock and wildlife. This deep-rooted, long-lived perennial thrives in dry and cold conditions. Winterfat generally retains 8 to 11% protein in the winter months, which offers comparative advantage for off-season grazing in late fall through to early spring.

Materials and Methods

This article integrates the results of various studies conducted at SCRDC along with a review of published literature. The study settings extended from laboratory, growth chambers, and greenhouse to the field conditions. The data were analysed using SAS Proc Mixed.

Results and Discussions

Side-oats grama

Although side-oats grama has diverse populations with promising forage value in Canadian prairies (Schellenberg et al. 2012), there is no released cultivar of this species in Canada. Recently, from 2007 to 2010, nine side-oats grama collections from Saskatchewan and Manitoba, Canada were evaluated for their eco-physiological traits (Schellenberg et al. 2012). In the 4th year of stand establishment (2010), the plant heights of the ecotypes ranged from 32 to 63 cm, with the collections from Sidney and Wolseley, Manitoba having significantly (P<0.05) taller plants (63 cm). While plants in Sidney collection had the highest tiller number (169 plant^{-1}) and basal area plant^{-1}, those in Wolseley had higher tiller density per unit basal area (0.23 vs 0.20 tillers cm^{-2}). With taller plants and greater tiller density, these two collections have greater potential for forage biomass yield. Although plants in the collection from Alexander had 16% lower heights than Sidney and Wolseley, it had the highest tiller density (0.28 tillers cm^{-2}) per unit basal area, thereby having similar biomass yield potential. The product of plant height and tiller density can serve as the proxy measure of biomass yield potential. Those values for Sidney, Wolseley and Alexander were 12.9, 14.4 and 14.8, respectively. Seed yield for the populations ranged from 0.9 to 4.3 g plant^{-1}, with Minto, Wolseley and Alexander having significantly (P<0.05) higher (>4 g) seed yield plant^{-1}. Seed yield of Sidney is nearly half that of three top yielders. However, Minto lagged behind other winners in plant height and tiller numbers. The Sidney, Wolseley and Alexander were about one week earlier in maturity with overall superior traits related to high biomass and seed yield. There is a great opportunity for population improvement through a systematic selection procedure. Three cycles of recurrent phenotypic selection were shown to improve the seedling vigour and success of establishment by 24 and 35%, respectively, in an experiment conducted in USA (Voigt and Brown, 1969). The SCRDC has Selected-class germplasm material of side-oats grama. A breeder's seed plot will be established in SCRDC for the release of the Selected-class pre-variety germplasm of side-oats grama.

Winterfat

Despite its highly nutritive forage value and adaptation to the Canadian prairies, there is no released cultivar of winterfat in Canada. A study was initiated at the SCRDC on winterfat populations from three different locations namely Saskatchewan (Canada), Montana -'Open Range' and New Mexico –purchased from Wind River Seeds of Wyoming (USA), in 2007. The Saskatchewan population exhibited better survival rate over the winters than the populations of southern origin. An earlier study (Thygerson et al., 2002) with seed collections from Saskatchewan, Wyoming, Colorado, and New Mexico showed differential temperature responses for germination and seedling growth. The optimum temperatures for germination and early seedling growth ranged from 5 to 25°C, reflecting the climate at the site of origin (Thygerson et al., 2002). Schellenberg (2003) noted plants of Saskatchewan origin and New Mexico had distinct germination profiles. Seed increase plots of promising Big Muddy, Saskatchewan and common Saskatchewan populations were established in 2013. Seeds were harvested in summer 2014 and 2015. A Selected-class pre-variety germplasm of winterfat will be available in western Canada in the near future.

Conclusions and Implications

The native plant genetic resources offer abundant opportunities to develop functionally diverse and resilient production systems. Side-oats grama and winterfat hold great potential to be functional components of diversified agro-pastoral systems in semi-arid Canadian prairies. Selected-class pre-variety germplasms of these forages will be released in the near future.

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Overexpression of *Medicago sativa TMT* Improves Alfalfa Nutritional Qualities

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Key words: γ-tocopherol methyltransferase, transgenic alfalfa, vitamin E, nutritional quality

Introduction

Alfalfa (*Medicago sativa* L.) is a major perennial, out-crossing autotetraploid leguminous forage crop and possesses a large genome (Armstrong 1954). This complex genetic background has previously limited the discovery and utilization of novel gene resources in alfalfa. Vitamin E is a necessary vitamin for animals, however we can't synthesis it by ourselves and must obtain it from diet. γ-tocopherol methyltransferase (γ-TMT) as the final enzyme in vitamin E biosynthesis, catalyzes the conversion of δ- and γ-tocopherols (or tocotrienols) to β- and α-tocopherols (or tocotrienols), has been shown to determine vitamin E composition in favor of α-tocopherol in many species. Despite the fact that alfalfa is among the main forage crops, this approach has never been attempted in alfalfa. Due to the importance of vitamin E in determining final alfalfa quality, approaches that engineer the production of novel alfalfa varietals with more ideal vitamin E composition could be tremendously valuable as a feedstock for animals.

Materials and Methods

Plant material

Alfalfa (*Medicago sativa* L.) used in this study was Zhongmu No. 1 from Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing, China. Healthy leaves from two month old alfalfa were used for the transformation via *Agrobacterium tumefaciens* with strain EHA105 using the method previously described by Wright et al. (2006).

HPLC analysis of tocopherols, tocotrienols and fiber analyses

Analyses of tocopherols and tocotrienols levels were performed according to a modified procedure described by Zhang et al. (2013). Fiber analyses were performed according to the method described by Printz et al. (2015).

Statistical analysis

These analyses were performed by SAS 9.3, ANOVA followed by a Tukey test was used to identify significant differences. The difference was considered significant at $P < 0.05$.

Results and Discussion

Cloning and expression analysis of MsTMT from Medicago sativa L.

According to the sequence of *MtTMT* from *Medicago truncatula*, *MsTMT* was isolated using homologous cloning. It encodes a protein of 357 amino acids in length that belongs to the AdoMet-dependent methyltransferases superfamily. Multiple sequence alignment and Phylogenetic tree analyses reveal that MsTMT shares high sequence similarity with TMTs from other species and it is closest to MtTMT from *Medicago truncatula*, which suggests that MsTMT is conserved among different species. Expression pattern of *MsTMT* was analyzed using quantitative real time PCR. Results showed that *MsTMT* was constitutively expressed in root, stem, leaf, flower and seed. The transcript levels were most abundant in the leaves and least abundant in the flowers. NaCl, Dark and PEG could all induce the expression of *MsTMT*, suggesting that *MsTMT* might play a role in alfalfa stress response.

Overexpression of MsTMT increased α-tocopherol and α-tocotrienol content in transgenic alfalfa.

To further explore the role of *MsTMT*, it was overexpressed in alfalfa, eleven independent positive lines were obtained. Quantitative real time PCR and GUS histochemical staining analyses confirmed that three transgenic lines of OE5, OE10 and OE 16 had significantly higher transcript levels and protein levels. Tocopherols and tocotrienols were analyzed using leaves. A modest but significant increase of α-tocopherol was observed in OE16 relative to wild type plants (Fig. 1), implying that γ-tocopherol was converted to α-tocopherol, which was in line with the transcriptional levels and GUS staining results. Surprisingly, the content of α-tocotrienol, which is generally accumulated in seeds, was increased 0.6-2.4 fold in transgenic lines relative to wild type plants; however, no significant difference was observed in other tocotrienols as well as total vitamin E content (Fig. 1). Taken together, *MsTMT* may have a preference to redirect the composition of vitamin E, but has no effect on vitamin E content.

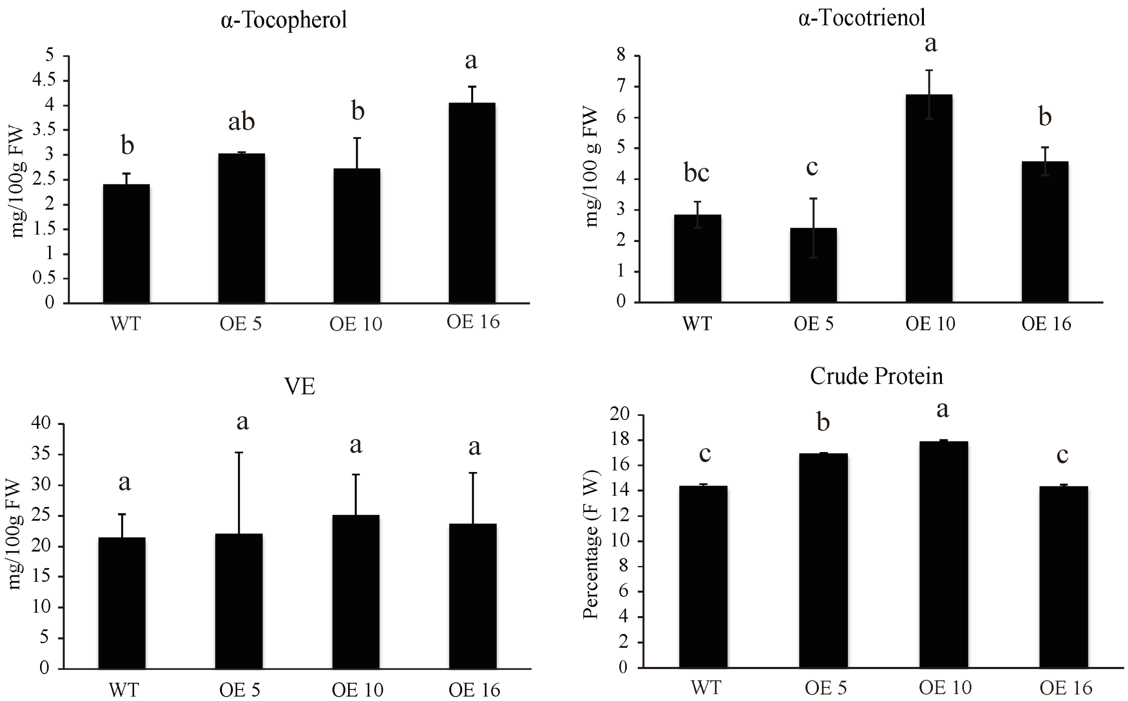

Figure 1. α-Tocopherol, α-Tocotrienol, Total Vitamin E and Crude Protein Levels in Alfalfa *MsTMT* overexpression lines (OE 3, OE 10 and OE 16), Zhongmu No.1 with pBI121 empty vector (WT). Two month old alfalfa leaves were used for the measurement. Data are Mean ± SD. Each was performed with four biological replicates. * P<0.05.

Nutritional qualities of transgenic alfalfa were not compromised

To evaluate the potential application of *MsTMT* overexpression alfalfa, the nutritional qualities of transgenic lines were measured. Nutritional quality analyses revealed that the transgenic lines had increased crude protein content, ranging from 17.7% to 24.1% in OE 5 and OE 10 compared with the control (Fig. 1). Other nutritional quality traits, including the acid detergent fiber and neutral detergent fiber did not show differences between the transgenic and control plants.

Conclusion and Implications

This is the first report on isolation of the gene involved in vitamin E biosynthesis from the forage legume alfalfa. Overexpression of *MsTMT* increased the α-tocopherol (tocotrienol) levels without having obvious negative impacts on other nutritional quality traits in transgenic alfalfa. Altogether, *MsTMT* provides multiple benefits as a tool, which can be utilized in future projects that are focused on the molecular improvement of alfalfa and also other agricultural crops.

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Ratio of Seed Yield to Nitrogen Loss: An Effective Approach for Assessing Nitrogen Benefits and Risks in Perennial Grasses Seed Production in Semi-Arid Regions

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Keywords: lysimeter ^{15}N experiment, N loss, application timing, *Leymus chenisis.*

Introduction

Nitrogen fertilizer application could dramatically facilitate increase seed numbers per unit area, and thousand-seed weight, resulting in an increase in seed productivity in annual cropping plants. However, only a small proportion of nitrogen fertilizer can be taken up by crops and the remainder is lost through ammonia volatilization, denitrification, surface runoff, and leaching in soil system, and finally causing environmental pollution. Therefore, increasing N-use efficiency and reducing N-loss will be the future challenges in agronomic practice.

As dominant species in natural grasslands, perennial grasses have been considered as a proper choice to restore the degraded grassland and establish new grassland in margin region. However, relevant studies of how to improve seed productivity in perennial grassland mainly reference annual crops (Wang et al., 2010), and paid less attention to the relationship of N derived benefits and its potential loss to environment. We conducted a lysimeter ^{15}N experiment in *Leymus chenisis* grassland, aim to: (1) clarify impacts of nitrogen application timing and rate on seed yield and N-recovery/loss rate; and (2) develop a simple method to evaluate seed production and N-loss simultaneously.

Materials and Methods

A split-plot design was arranged in the experiment with nitrogen (^{15}N-labelled urea with 10.15 % atom^{15}N abundance) application timings [fall (August 1, post-fruiting vegetation stage) and spring (May 1, regrowth stage)] as the main plot; and nitrogen application rates [0 kg N ha^{-1} (control), 56 kg N ha^{-1} (low nitrogen) and 112 kg N ha^{-1} (high nitrogen)] as the sub-plot with three replications. The experiment was carried out in a lysimeter facility in the field trench with four replications. Each lysimeter was a cylindrical metal tank, 65 cm deep and 50 cm in diameter, filled with mixed sands and gravel (0.30 cm) in the bottom to prevent soil loss (Cookson et al. 2001). The lysimeters were filled with monoliths (soil with plant cover) of artificial *Leymus chinensis* grassland obtained in spring of 2012. The top edge of each lysimeter was maintained at 35 mm above ground level to avoid surface runoff, and attached with a plastic pipe at the bottom of the lysimeter for leachates collection.

Total N content and ^{15}N abundance in soil and plant samples were determined using an acquired stable isotope ratio mass spectrometer (Isoprime 100, Isoprime UK) coupled with elemental analyzer (Pyrocube, Elementar-Germany). N_2O and NH_3 loss in soil samples were analyzed by gas chromatography (7890A, Agilent) and continuous flow analyzer (Alliance Flow Analyzer, Futura, frépillon, France), respectively.

Results and Discussion

Seed yield

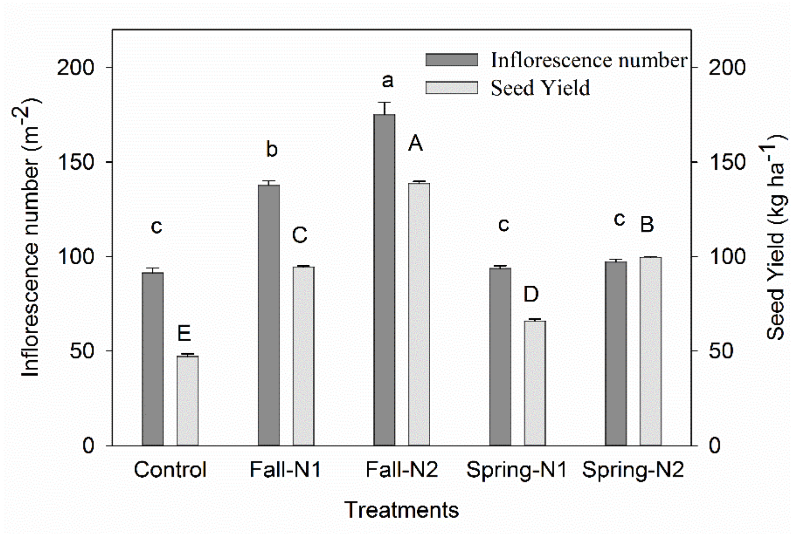

Figure 1. Impacts of nitrogen application timing (fall or spring) and rate (N1, low nitrogen rate with 56 kg ha^{-1}; N2, high nitrogen rate with 112 kg ha^{-1}) on inflorescence number (a) and seed yield (b) in lysimeter experiment.

Seed yield was significantly 40.92% higher with fall nitrogen application than with spring nitrogen application ($P < 0.0001$) (Fig. 1). The maximum seed yield was 138.63kg ha-1 when high N-rate was applied in the fall, which was 294% higher than no nitrogen fertilizer (Fig. 1).

The significantly positive effects of nitrogen fertilizer on seed yield with fall nitrogen application were largely due to the positive effects of nitrogen application on inflorescence number (Fig. 1). We had found that the number of inflorescence is the most important yield component to seed yield (Wang et al., 2010), which formatted at the end of the growing season) and was significantly influenced by fall nitrogen application rate. Fall nitrogen application increased winter tillers and reproduction tillers via increasing the survival rate and reproduction transfer rate in the following year (Wang et al., 2013).

Seed yield: N-loss ratio

Table 1. Effects of nitrogen application timing (N-timing) and nitrogen application rate (N-rate) on N-loss ratio and Seed yield: N-loss ratio.

N-timing	N-rate (kg ha^{-1})	N-loss (%)	Seed yield: N-loss ratio
Fall	56	77.12a ± 0.25	1.09b ± 0.02
	112	63.98b ± 0.44	1.28a ± 0.02
	Mean	70.55 ± 2.00	1.18 ± 0.04
Spring	56	71.76a ± 0.30	0.47d ± 0.03
	112	56.32c ± 0.80	0.84c ± 0.01
	Average	64.04 ± 2.36	0.66 ± 0.09

Notes: Data are expressed as means ± s.e. (n=4). Lowercase letters in the same column indicate Tukey's *post hoc* tests between different treatments.

Seed yield: N-loss ratio was 80.7% higher in fall nitrogen application than in spring nitrogen application (Table 1). With fall nitrogen application the ratio was 16.9% greater in high nitrogen rate than in low nitrogen rate. The overall trend of Seed yield: N-loss ratio was consistent with seed yield value.

Fertilizer nitrogen can be uptake by crops and the remainder was loss through ammonia volatilization, denitrification, surface runoff, and leaching in soil system. In our study, maximum seed yield was gained with fall nitrogen application with high nitrogen rate. Decreased nitrogen loss in spring nitrogen led to less nitrogen pollution, but it decreased seed yield simultaneously. Thus, when we combined considering the seed yield and nitrogen loss, we found the overall trend of Seed yield: N-loss ratio was consistent with seed yield in different nitrogen treatments.

Conclusions

Seed yield of *Leymus chenisis* increased more significantly with fall nitrogen application than with spring nitrogen application. However, fall nitrogen application also leads to a high fertilizer nitrogen loss than spring nitrogen application. In summary, Seed yield: N-loss ratio is an effective approach and can assess the nitrogen benefits and risks in perennial grasses seed production in semi-arid regions. We concluded that, fall nitrogen application with high rate is a proper choice to get higher seed yield with relatively less nitrogen loss to the environment.

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Ecological Goods & Services of Rangelands and Pasturelands

2.1 Nutritional Links from soil to plant to livestock to people

Botanical Composition of the Diet of Camels Grazing at Kalemando District, North Darfur State, Sudan

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Key words: Bite-count, diet selection, nomadic system

Introduction

Diet selection is related to factors that influence foraging behavior. These include factors that affect spatial and forage species choice. Spatial choice is a function of landscape features, plant community characteristics, and grazing patch attributes (Thorne et al., 2007). In Sudan camels are mainly raised under open grazing nomadic system where a wide variety of plant species are on offer. However, very little is known about the diets selected by free grazing camels.This paper aims to investigate the botanical composition of the diet selected by camels.

Materials and Methods

Study area

The study was conducted at Kalemando Locality, North Darfur State, Sudan. The area has an arid and semi-arid climate, with mean minimum and maximum temperatures of 35 ^{0}C and 18 ^{0}C respectively. Annual rainfall ranges from 75 to 287mm. Rainfall fluctuates between and within years leading to vegetation dominated by annual plants and some shrubs and trees.

Range and diet botanical compositions were measured at seed set stage of growth during 2013 and 2014. The loop method (Parker & Harris, 1959) was used to measure range botanical composition in two locations along four transects in each. Camel diet botanical composition was determined using the bite-count technique (Kuria et al., 2005). Five camels were observed for 5 days. Each camel was observed for a total of 60 minutes/day, and the number of bites on various forage species was recorded.

Results and Discussion

The diets selected by camels are presented in Table 1. Browse formed the largest part of the diet (61.03%), followed by forbs (25.33%) and then grasses (13.98%).Trees that constituted the largest part of the diet were *Acacia mellifera* (18.37%), *Acacia nubica* (8.03%), *Acacia tortils* (12.62%) and *Boscia sengalensis* (5.47%). *Acacia nubica and Boscia senegalensis* are not usually considered of forage value for other domestic ruminants such as cattle, sheep and goats. However data obtained through a socioeconomic study, not reported here, supported the finding that these two trees are selected by camels. Two forbs were high in the diet of camels namely *Ipomoea sinesisvar* (7.45%) and *Tephrosia uniflora* (5.41%). The presence of grasses in the diet of camels was low. *Dactyloctenium aegyptium* and *Echinocloa colona* were found in the diet of camels at 5.26% and 2.67% respectively. The finding that camels preferred browse more than herbaceous plants agrees with Kuria et al. (2005) who found that camels selected dwarf shrubs during the wet season, while herbaceous and grass species are selected in the dry season. The present study was conducted during late rainy season (late August) when plants started setting seeds.

Table 1. Botanical composition of the diets of camels grazing at Kalemando Localty at seed set stage (results are the mean of two locations and two years).

No	Latin name	Type	Diet%
1	*Corchorus olitorius*	Forb	1.13
2	*Ipomoea sinesisvar*	Forb	7.45
4	*Oxygonum atriplicifolium*	Forb	1.27
5	*Justicia kotschyi*	Forb	4.20
6	*Tripogon minmus*	Forb	1.20
7	*Tephrosia uniflora*	Forb	5.41
8	*Unidentified*	Forb	1.60
	All other forbs	Forbs	3.07
	Total forbs (%)		**25.33**
1	*Cyperus rotundus*	Grass	2.40
2	*Eragrostis diplachnoides*	Grass	2.31
4	*Dactyloctenium aegyptium*	Grass	5.26
5	*Echinocloa colona*	Grass	2.67
	All other grasses	Grasses	1.34
	Total grasses (%)		**13.98**
1	*Acacia mellifera*	Tree	18.37
2	*Acacia tortils*	Tree	12.62
3	*Acacia nubica*	Tree	8.03
4	*Boscia sengalensis*	Tree	5.47
5	*Permina resinosa*	Tree	5.35
6	*Grewia tanex*	Tree	4.84
7	*Acacia nilotica*	Tree	2.64
	All other trees	Tress	3.71
	Total browse (%)		**61.03**
	Grand total		**100.0**

Conclusion and Implications

Camels selected more browse than forbs and grasses. The study provides an opportunity for range management by using some plants that are desirable for the rehabilitation of degraded lands.

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Effect of Grazing Systems on Volatile Compounds in Subcutaneous Fat of Tan Lamb

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Key words: Grazing system, subcutaneous fat, volatile compounds, Tan lamb

Introduction

Grazing system is regarded as the easiest, most practical and effective method of achieving healthy lamb meat. In the grassland of China, a variety of active plant ingredients of herbage play a role in the rich flavor of grazing lamb meat. It is believed that the outdoor grazing lambs have richer flavor in meat compared with the indoor-fed ones. Our previous study proved that different grazing systems had impact on body fat deposition, fatty acid composition of body fat and meat quality of lambs (Wang et al. 2014, 2015). In this study, GC-MS was used to investigate the effect of different grazing system on volatile compounds in subcutaneous fat of Tan lamb.

Materials and Methods

The present study was carried out in the Yanchi County, Ningxia Hui Autonomous Region, China. The experimental area has the typical temperate continental monsoon climate. The steppe is typified by arid sandy grassland. A total of 52-hectares of pasture was fenced off into 5 equal plots. The fifty 4-month-old male Tan lambs with similar body weights were divided into 5 groups (A, B, C, D, and E). A, B, C and D group of lambs were randomly allocated to one of four restricted grazing time treatments in equal area: Grazing 12h/d (Group A), 8h/d (Group B) 4h/d (Group C), 2h/d (D). Group E lambs had 0 h/d grazing time. Each group with reduced grazing time received the increased amounts of supplementary feed. In former two months, the concentrate supplements was at 0, 150, 150, 300, 300 g/d for Group A, B, C, D and E respectively. For the latter two months, the concentrate supplement was increased to 0, 300, 300, 500, 500 g/d in the same group order. Besides, alfalfa was also supplemented to the group E at 200 g/d for the former two months and 300 g/d for the latter months. After 120 days, all the lambs were slaughtered. The subcutaneous fat samples were collected. The GC-MS (GC-MS-QP 2010 Plus， SHIMADZU Co. LTD, JAPAN) was employed to determine volatile compounds of in subcutaneous fat through automated solid-phase micro-extraction (SPME). The quantification of volatile compounds was integrated by peak area in total ion chromatogram.

Results and discussion

Fig.1 shows total amount of volatile compounds detected in each groups. The sequence of total volatile compound contents from the largest to the smallest was in group A, C, E, B, D, respectively. The volatile compounds in subcutaneous fat decreased with the shorter grazing time coupled with increasing amount of concentrate feeding. The group E had fewer kinds of aldehydes than group A and D, which displayed a high volume in each aldehyde within fewer kinds. The single feed resource led to the lack of variety and resulted in the bad tastes. Meanwhile，the grazing lambs had diverse volatile compounds in greater amount and variety because of the rich kinds of grass and herbage intake during grazing.

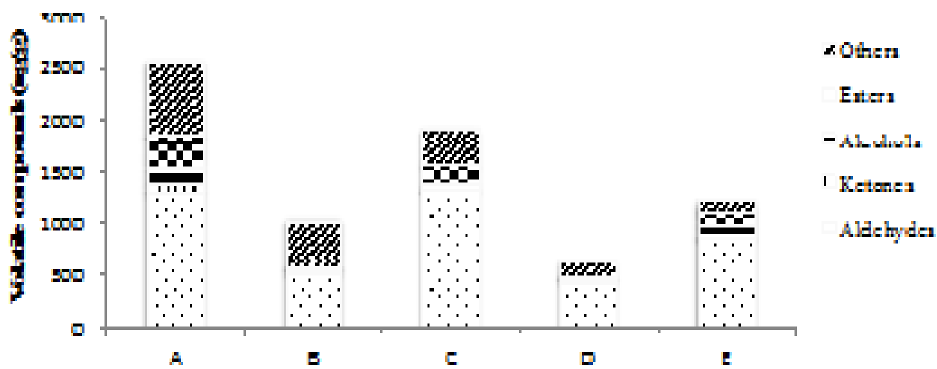

Figure 1. Volatile compounds of subcutaneous fat in Tan lambs.

Conclusion

The accumulation of volatile compounds had a great connection with grazing system. The concentration of volatile compounds increased with the longer grazing time coupled with less concentrate supplementation. The diversity of volatile compounds in the grazing stocks could be attributed to the rich wonderful tastes. However, the higher concentration in aldehydes had no advantage in rich flavors in Group E which were deprived of outdoor grazing. Financial support of the projects of China Agricultural Ministry (CARS-39) was acknowledged.

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Effects of N Addition and Stocking Rate on the Soil Nitrogen Mineralization Rate of Typical Steppe in the Loess Plateau, China

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Keywords: Sheep stocking rate, ammonium nitrate, resin bags

Introduction

The process of soil nitrogen (N) mineralization is very important for grassland N cycling (Zhang et al., 2009), and the soil N mineralization rate has been suggested as an index of the capacity of the soil to supply plant available N (Campbell et al., 1995). The stocking rate also has a great effect on soil N mineralization (Hou et al., 2006). To research the factors influencing soil N mineralization, we studied the interaction of N addition and stocking rate, in order to provide a scientific basis for the protection, restoration and reasonable utilization of grassland resources.

Materials and Methods

The research area was located on grazing land in Tianshui town (37.14°N, 106.84°E), Huanxian county, Gansu province, with an annual average precipitation of 359.3 mm and mean monthly temperature 7.1℃. The stocking rates were 2.7 (LS), 5.3 (MS), and 8.7 (HS). Ammonium nitrate was added as fertilizer, at rates of 0, 5, 10 and 20 $g{\cdot}m^{-2}$. We used the in situ cultivation of resin to cultivate the soil samples. Material included a 7.5 cm diameter PVC tube, a 7 cm diameter resin bags and filter paper. The resin bags were used to absorb the NO_3- from the soil eluviation, and the filter paper was used to separate the resin bag from the soil. Experimental plots were set up on the paddocks with different stocking rates; the size of each plot was 2 m × 7 m. Each plot was divided into 5 equal parts by 4 aisles (0.5 m× 2 m). All the treatments were replicated 3 times. We fertilized 60% in May and the remainder in July.

Results and Discussion

The N mineralization rates for each pasture were similar from July to October (Fig. 1). For grazing plot LS with different N addition treatments, the mineralization rate of 20 $g/m^2{\cdot}a$ was significantly higher than other treatments in August ($p < 0.05$), and the 5 $g/m^2{\cdot}a$ was significantly lower than the other treatments in September ($p < 0.05$) (Fig. 1). The HS and MS reached the minimum in September when the N addition was 20 g/m^2, and were significantly lower than other treatments ($p <0.05$) (Fig. 1). Under the same N addition, the N mineralization rate for the LS was significantly higher than that of MS ($p < 0.05$). There was no significant difference between the rates of the HS and MS. (Fig. 2).

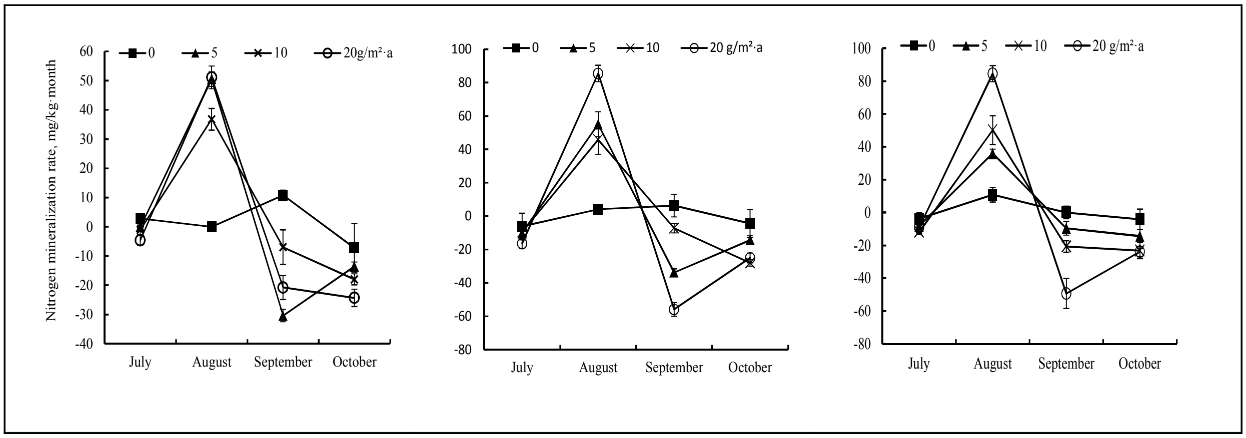

Figure 1. Monthly dynamic nitrogen mineralization rates for LS, MS and HS (from left to right).

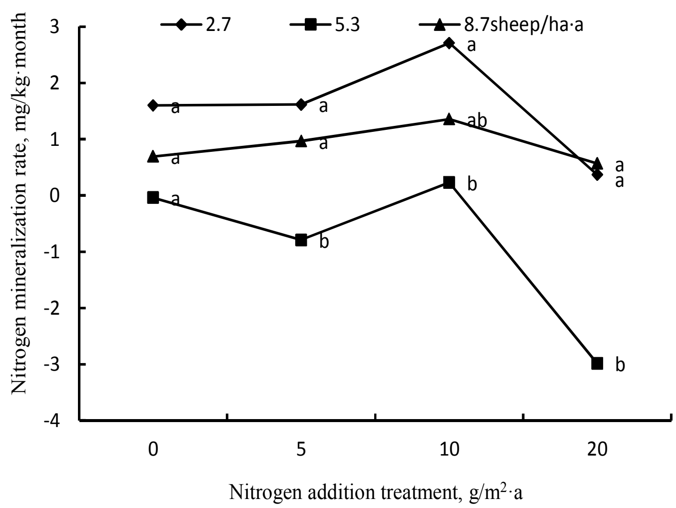

Figure 2. Effect of stocking rates on soil nitrogen mineralization rates.

Conclusions and Implications

The dynamic changes of N mineralization rate in each pasture were similar over time. For the same N addition treatments, the effects of stocking rates on soil mineralization rates were significantly different. In conclusion, stocking rate and N addition have various effects on grasslands and they could diminish the influence of each other. Proper grazing and N addition can promote soil N mineralization.

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Productivity and Quality of Range Grasses and Traditional Forage Crops in *Tarai* Region of Indian Himalaya

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Key words: Katambora, Mulato, productivity, quality, Setaria.

Introduction

The *Tarai* or foot hill region of Indian Himalaya is a belt of marshy grasslands, savannas and forests located south of the outer foothills of the Himalaya, the Siwalik Hills and north of the Indo-Gangetic Plains of India. In northern India, the *Tarai* spreads eastward from the Yamuna river across Indian states like Himachal Pradesh, Haryana, Uttarakhand, Uttar Pradesh and Bihar (Johnsingh et al., 2004). The lowland plains of the *Tarai* lie at an altitude of between 67 and 300 m (220 and 984 ft). North of the *Tarai* rises the Bhabhar, a narrow belt but continuous of forest about 8–12 km wide (Bhuju et al., 2007).

India has only 2.3% of world's geographical area and 16.8% human population but contributes nearly 20% of total world livestock with 16% cattle, 55% buffalo, 20% goat and 5% sheep. India has the highest buffalo, 2nd largest goat and 4th largest sheep population in the world but the country has a shortage of green and dry forage and concentrates by 60, 25 and 64%, respectively. This shortage is due to lack of knowledge within farming communities about green forage cultivation, animal health care and best management practices of rangeland and pasture resources, this in turn leads to poor productivity of livestock. In the Tarai region of the Indian Himalayas, sorghum, maize, cowpea and ricebean in summer and berseem, oat and forage mustard in winter are the major forage crops. Among grasses, Bajra Napier hybrid, *Heteropogon contortus*, *Panicum maxicum*, *Chloris gayana*, Setaria, *Chrysopogon fuluvus*, *Ergrostis curvula* etc. are grown in region.. New varieties of grasses and crops have been introduced to improve both the availability of green fodder and livelihood of the local masses. This research is to evaluate the productivity, profitability and quality of newly introduced varieties of range grasses and forage crops in *Tarai* region of Indian Himalaya.

Materials and Methods

The field experiment was carried out during 2011 to 2013 at G B pant University of Agriculture & Technology, Pantnagar (India) to study the productivity and profitability of range grasses and traditional forage crops in *Tarai region* of Indian Himalaya. The experimental site is situated at 290N latitude 79.29^{0}E longitude and at an altitude of 243.83 m above sea level in the foot hills of Indian Himalaya. The climate of the site is humid subtropical climate with cool winters and hot dry summers. The experiment consisted of 6 treatments i.e., T_1:*Sorghum bicolor* var. *Pant Chari-5*, T_2:*Vigna sinensis* var. *UPC 5286*, T_3:*Setaria anceps* var. *Splenda,* T_4: *Brachiaria* var. *Mulato II*, T_5:*Chloris gayana* var. *Katambora* (Rhode grass)) and T_6: *Vigna sinensis* var. *Ebony* (black seeded), that were planted in second week of June in 2011 under a randomized block design with 5 replications and continued till May 2014.The grasses and forage crops were grown under recommended agronomy practices for the area. All crops were planted at 40 cm row spacing and fertilized with 60 kg N, 40 kg P_20_5 and 30 kg K_20 /ha. The grasses and sorghum were top dressed @ 30 kg N after each cut. The 1st cut was taken after 60 days of sowing and subsequent cutting were taken after 30 days interval.

Results and Discussion

Plant height of forage crops differed significantly and the tallest plant was cowpea variety UPC 5286 that remained statistically at par with sorghum (Table 1). Ebony cowpea had the lowest plant height among fodder crops. Among grasses, Rhode var. Katambora had the tallest plants. The numbers of shoots were also affected significantly with maximum in Rhode var. Katambora that had significantly equal values with Mulato II and setaria var. Splenda. Among the fodder crops, sorghum had the highest shoots and ebony cowpea the lowest. Green and dry forage yield of different crops were found significantly variable with the highest and the lowest values in *Setaria anceps* var. *Splenda* and *Vigna sinensis* var. *Ebony*, respectively. Among the fodder crops, the maximum green and dry forage yield was recorded in *Sorghum bicolor* var. *Pant Chari-5 i.e.* 480 and 78 q/ha, respectively. Among grasses, the green forage and dry matter yield did not differ but the highest values were obtained in *Setaria anceps* var. *Splenda i.e.* 760 and 156 q/ha followed by *Brachiaria* var. *Mulato II i.e.* 647 and 127 q/ha and the lowest in *Chloris gayana* var. *Katambora i.e.* 561 and 120 q/ha, respectively (Table 1).

The crude protein was estimated only in 2013-14. The highest protein content was observed in *Vigna sinensis* var. *UPC 5286,* 17.65%. Mulato grass had higher protein content 10.79% than Splenda Setaria, 9.33% and Katambora Rhode, 8.06% (Table 1). The protein content in green forage on dry matter basis was 9.98% in Sorghum. The higher crude protein production was the result of more dry matter yield and L: S ratio. The L: S ratio was significantly higher in Mulato i.e. 2.13 that remained statistically equal to Cowpea UPC 5286 and Ebony Cowpea. Splenda Setaria had higher L: S ratio than Sorghum and Katambora Rhode grass.

Table 1. Productivity and quality of range grasses and forage crops in *Tarai* region of Indian Himalayas (pooled data of 2011 to 2013).

Treatments	Plant height (cm)	No. of shoots/ m row length	Green forage yield t/ha)	Dry matter yield (t/ha)	L : S ratio	**Crude protein** Content (%)	Yield (q/ha)
Setaria anceps var. Splenda	73	105	7.60	1.56		9	16
Vigna sinensis var. UPC 5286	150	14	2.99	0.41	1.43	18	5
Brachiaria var. Mulato II	50	122	6.47	1.27	1.62	11	12
Chloris gayana var.Katambora	87	137	5.61	1.20	2.13	10	11
Sorghum bicolor var. Pant Chari-5	132	22	4.30	0.78	1.16	10	6
Vigna sinensis var. Ebony	76	10	2.90	0.45	1.20	-	-
SEM±	**15**	**17**	**0.73**	**0.17**	1.86	**-**	**-**
CD at 5%	**48**	**55**	**2.30**	**0.54**	**0.19**	**-**	**-**

Conclusion and Implications

The above results reveal that Setaria var. Splenda and Brachiaria var. Mulato grasses have greater potential in *Tarai r*egion of Indian Himalayas but Mulato particularly provides better option for higher quality production of green fodder round the year in *Tarai* region of Indian Himalayas.

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Preference of Range Plant Species by Sheep as Assessed by Pastoralists' Perception and Actual Empirical Determinations in a Semi-Desert Area in Sudan

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Key words: Enclosure, botanical composition, relative preference index, bite count

Introduction

"Grazing preference" refers to the selective responses made by an animal to consume different plant species or plant parts, and it is essentially behavioral (Valentine, 2001). The preference value of each plant species is dependent on both animal (e.g. type, grazing preferences, age, pregnancy, and hunger) and non-animal (e.g. composition, growth stage, frequency and palatability of companion plants, local and physical plant conditions) parameters. Holecheck et al., (1984) believe that diet selection is not only different between animal types, but it is also dependent on plant phenology, availability and climate conditions. The study aims to provide information that contributes to a better understanding of the sustainability of herbivore populations in the open rangeland of Kordofan area, Sudan using pastoralists' perceptions and empirical methods.

Materials and Methods

This study was conducted at El-Khuwei Locality, Kordofan area, Sudan during the rainy season in August 2010 and 2011. Two range sites were selected: El-Rosa enclosure and a control in the open area nearby. The perceptions of pastoralists were investigated through the collection of data from the livestock raisers, using a questionnaire and five group discussions. Botanical composition of the diet of sheep was determined using the bite count technique. Relative preference index (RPI) was used to classify plants according to their preference. The collected household data were summarized and analyzed using (SPSS).

Results and Discussion

There was reasonable agreement between our experimental findings and pastoralists' perceptions regarding plant preference by sheep. Plants that had high relative preference index (RPI) from the bite count method and were also cited by pastoralists as preferred in the two sites were *Desmodium spp.* (RPI=15.9), *Ipomea eriocapa* (RPI=15.7), *Echniochloa colonum* (RPI=5.1), *Zornia glochidiata* (RPI=3.9), and *Cenchrus biflorus* (RPI=1.68). Findings from pastoralists indicated that 57.5% of those interviewed considered *Zornia glochidiata* as a preferred plant while 70% of respondents reported that *Sida cordifolia* was an undesirable plant. The key important species as preferred plant at flowering stage in protected range were *Merremia spp*. and *Echinocloa colonum*.

Annual forbs that appeared in the diet of sheep as preferred plants at flowering stage were *Zornia spp* (32.2%). *Merremia spp* (6.3%), and *Desmodium ssp* (4.0%). The important grasses that appeared in the diet selected at flowering stage were *Echinocloa colonum* (21.0%), Eragrostis tremula (13.3%) and *Cenchrus biflorus* (10.9%). Two plants accounted for 53.4% of the diet. These were *Zornia spp*. and *Echinocloa colonum.* Some plants that appeared in the diet were not detected in the botanical composition which indicates that they are preferred plants. In the open range these were *Calotropis procera*, *Hymenocardia acida, Mollugo nudicaulis and Cucumis dipsaceus*. One of the shrubs that appeared in the diet selected at flowering stage was *Calotropis procera* (2.4%). It was observed that this shrub was grazed

mainly when the leaves were dry. No grazing was observed on green leaves. This is an area for future research.
Table 1 shows some range plants that surveyed pastoralists ranked as palatable species. The same species appeared in diet selected by grazing sheep as preferred plants which supports the outcome of the study on diet selection.

Table 1. Palatable species according to opinion of surveyed pastoral groups.

Species	Number	Percent
Zornia glochidiata	23	57.5
Cenchrus biflorus	14	35
Blepharis ciliaris	1	2.5
Desmodium spp	3	7.5
Cucumis dipsaceus	2	5
Echinocloa colonum	10	25
Total	**40**	**100.0**

Table 2 shows some plants that recorded high percentage as unpalatable species according to the livestock raisers. These are represented *Sida cordifolia.* About 70% of surveyed pastoralists reported that *Sida cordifolia* is unpalatable. The diet selected by grazing sheep also showed that this plant is unpalatable.

Table 2. Unpalatable species according to opinion of surveyed pastoral groups.

Species	Number	Percent
Sida cordifolia	28.0	70.0
Cassia ssp	4.0	10.0
Svensonia laeta	8.0	20
Total	**40**	**100**

Conclusion and Implications

The study concludes that pastoralists' perceptions give reasonable valuation for plant quality and may be taken as a measure of preference in certain instances. Information from pastoralists' perceptions may assist in making quick management decisions when resources of time and funds are limited and do not allow detailed classical studies. Plant preference studies such as those reported here allow ranking of range plant species with respect to preference, so that plants with high RPI can be used in further studies to assess other quality attributes such as tolerance to water stress, grazing pressure and fire. Plants can then be propagated and used in reseeding of degraded rangelands. This study recommended utilization of a wealth of information on current management systems in the El-khwuei locality of Kordofan, area which will be invaluable in developing sustainable management strategies for use by pastoralists.

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Livestock and Forage Production in Afghanistan

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Key words: agropastoral, *kuchi*, nomadism, rangeland management.

Introduction

Livestock production is an important contributor to livelihoods within rural areas and accounts for close to half of Afghanistan's agricultural GDP. Key constraints to ruminant production are insufficient feed stocks, lack of access to seed of improved forage varieties, poorly developed feed and seed markets, and insufficient knowledge among producers and service providers (GIRoA, 2009). This paper provides brief information on the current state of the livestock and forage production in Afghanistan.

Livestock Production

Nomadic pastoral, sedentary villagers and settled transhumance (Fitzherbert, 2006) are characteristic features of existing livestock production systems. Pastoral nomadism is a dominant feature of livestock production and largely based on sheep, goats and camels. Cattle are still the main source of farm power and provide subsistence for dairy needs in mixed farming. While cattle, sheep and goats continue to be favoured within household production systems, camels, donkeys and horses have specific importance. Number of livestock has changed considerably over the last 25 years (Table 1).

Table 1. Changes in livestock population (million) between 1990 and 2013 in Afghanistan.

Years	Cattle and Buffalo	Sheep	Goats	Horses	Donkeys	Camels	Mules	Poultry
1990	1.600	14.170	3.350	0.362	0.600	0.215	0.026	6.600
2000	2.900	15.000	7.300	0.104	0.920	0.260	0.030	6.856
2013	5.235	13.141	7.037	0.171	1.451	0.170	0.021	12.053

Source: FAOSTAT (2014)

In Afghanistan, more than 70% of the livestock holdings are owned by 1.5 million *Kuchis* or nomadic pastoralists (Time, 2006). Animals and animal products are the main sources of income for *Kuchis* whose livelihoods are entirely dependent on livestock. The pastoral systems have been adaptive to cope with the political turmoil but major challenges have forced *Kuchis* to gradually shift from pastoralism to agro-pastoralism and into mixed farming systems. These factors include changing migration patterns owing to weakening of tribal authority, increasing population pressure and shrinking grazing land and associated grazing rights, limited access to veterinary and other extension services, markets and credit facilities (Azimi and McCauley, 2002).

Mixed farming systems are increasingly being adopted by sedentary farmers who possess small number of cattle, sheep and goats within a cereal/horticultural crop production system. Settled farmers are seldom involved in livestock trade, and usually keep livestock for regular source of staple food and income including animal products processing and trade. Traditionally, flocks reach the highland pastures at the start of summer and come back to lowlands at the beginning of autumn. In winter, small ruminants are kept inside the houses during the night and bad weather. Concentrates and roughages such as hay, straw and leaves are provided as supplementary feed during this period (Fitzherbert, 2006).

Rangelands and cultivated forages as main source of animal feed

Rangelands are defined as uncultivated lands that supply a grazing or browsing resource to domestic and wild animals, and are the major land type in Afghanistan covering 45% of the area of the country (Figure 1). They provide about 70-80% of the total animal feed available, for the majority of sheep, goats, and camels and a large proportion for cattle and donkeys. Overgrazing and overexploitation of rangeland resources, rights to rangelands or land tenure issues, conversion of rangelands into rainfed cropping systems, and climate change including drought and land degradation are key factors largely responsible for rangeland degradation. Rangeland degradation adversely affects productivity as well as biodiversity of the land, and causes for the spread of invasive species of non-palatable and non-native weeds.

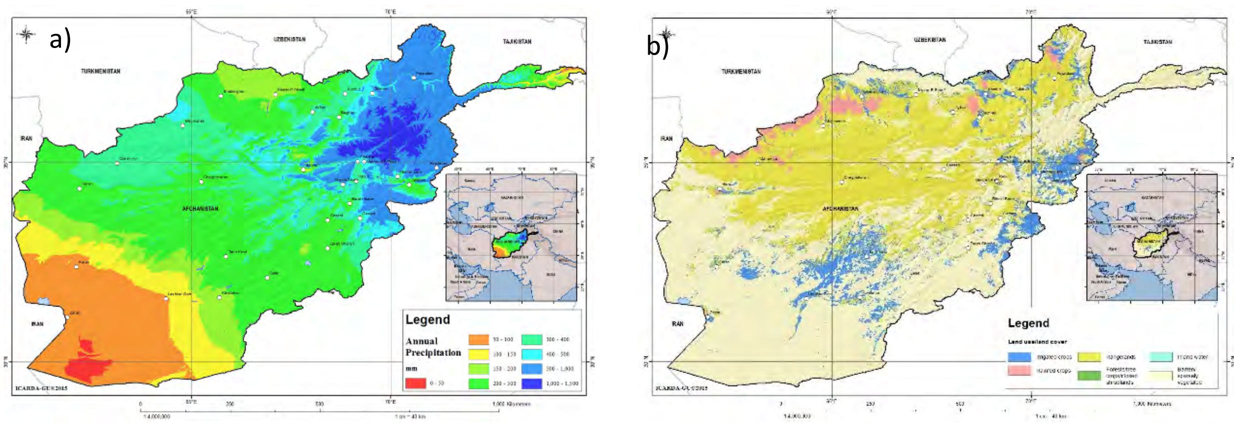

Figure 1. Annual precipitation (a) and land use/cover (b) in Afghanistan (Source ICARDA)

The area under cultivated fodder crops is less than 10% of the total arable land (USAID, 2012). Lucerne (*Medicago sativa* L.) is the most widely cultivated fodder legume. Persian clover (*Trifolium resupinatum* L.) is a prominent winter annual forage legume while berseem clover (*Trifolium alexandrinum* L.) is increasingly being cultivated in some relatively frost-free areas. Maize crops are generally sown at higher seed rates and later thinned for stock feed. Wheat and barley are often cut as green fodder during feed scarcity period in spring. In the higher altitudes of central Afghanistan, common vetch (*Vicia sativa* L.) and fodder beets (*Beta vulgaris* L.) are cultivated on a smaller scale (Bashir et al., 2013).

An ongoing ICARDA project on forages funded by ACIAR indicated a high yield potential of winter annual forage legumes and cereals under irrigated and dryland conditions. Preliminary results revealed that the annual dry matter production of irrigated forage legumes ranged from 8.2 for Hungarian vetch (*Vicia pannonica*) to 15.3 t/ha for Narbon vetch (*Vicia narbonensis*). Constraints of forage production include limited area under fodder crops, lack of quality seeds of improved cultivars, lack of research and poor adoption of improved technologies, and poor control measures for insect-pests, diseases and weeds.

Acknowledgement

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Growth Response of West African Dwarf Sheep Fed Guinea Grass Substituted with Mulberry

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Keywords: Nutrient intake, nitrogen utilization, *Panicum maximum,* mulberry, WAD sheep.

Introduction

A major constraint to livestock production in developing countries like Nigeria is either the scarcity or fluctuating quantity and quality of year round forage supply. Ahamefule *et al.* (2006) reported that natural pastures and crop residues available for animals in dry season are usually fibrous and devoid of essential nutrients which could support the growth and production of livestock. These deficiencies do result in weight loss, poor performance and increased mortality rate. Guinea grass (*Panicum maximum*) is a basal ruminant feed that is highly productive, persistent, and acceptable and can be fed solely or with supplement. Likewise, mulberry (*Morus alba*) is a leguminous plant with high crude protein content which could be a supplement for basal energy diets. This study therefore, evaluated the growth response of WAD sheep fed *P. maximum* substituted with *M. alba* forage.

Materials and Methods

The study was carried out at the Teaching and Research Farm and Nutrition Laboratory of Animal Production and Health, Federal University of Technology, Akure. The guinea grass and mulberry were collected at the Farm site. The forages were air-dried to reduce the moisture content and preserve the green colouration/nutrients. Twenty-five (25) WAD sheep aged 8-9 months with an average live-weight of 14.00$\pm$0.14kg were selected from flock, adapted before allotted into five diets: A (100% *P. maximum*); B (75% *P. maximum* + 25% *M. alba*); C (50% *P. maximum* + 50% *M. alba*); D (25% *P. maximum* + 75% *M. alba*) and E (100% *M. alba*) in a completely randomized experimental design. The experiment lasted for 63 days. Samples of feed, faeces and urine were analyzed (A.O.A.C. 2002) and all data obtained were subjected to analysis of variance using SAS 2008.

Results and Discussion

The nutrient compositions of the diets were adequate to support the growth of growing sheep and the dry matter (DM) contents were high and ranged from 89.03% to 90.16% (Table 1) and might be attributed to the age (maturity) of the forage, curing and season of harvest which might have contributed to its high lignifications. The crude protein contents were adequate to support the growth of sheep since it was above the critical 8% CP required by ruminants for optimum microbial activities in the rumen (Norton, 2003).

Table 1: Proximate composition of the experimental diets.

Nutrients (%)	A	B	C	D	E
Dry matter	89.03	90.16	89.68	89.14	89.18
Crude protein	11.40	13.72	16.39	18.28	21.05
Crude fibre	31.38	20.03	12.35	9.66	6.25
Ash	12.16	7.06	10.63	9.81	6.94
Ether extract	1.61	2.14	1.66	1.15	1.71

Nutrients intake were influenced by the treatment (Table 2) and were enhanced because diets are acceptable, tolerable and palatable to the WAD sheep. Hence, energy, nitrogen and fibre were available for utilization. Digestibility of nutrients except DM were statistically (P<0.05) influenced (Table 2), this could be attributed to the increase in the crude protein content of the diets which possibly enhance the digestibility of crude fibre and equally increase the activities of micro-organisms in the GIT and consequently attack the fibre more vigorously. The highest DM digestibility noted in WAD sheep fed diet E agreed with the report of McDonald *et al.* (1995) that protein quality and intake enhance digestibility. The nitrogen retention obtained however signified that the diets were adequate in their supply of nitrogen to the rumen. However, WAD sheep fed diet D (25% *P. maximum* + 75% *M. alba*) had the best weight gain which might be attributed to the contributions of *M. alba* forage to the diets.

Table 2: Intake, digestibility and performance characteristics by WAD sheep fed test diets.

Parameters	A	B	C	D	E	±SEM
Intake (g/day)						
Dry matter	1217.31	1395.65	1468.62	1517.60	1578.13	68.40
Crude protein	146.77[d]	191.60[cd]	240.72[bc]	277.43[ab]	372.20[a]	17.11
Crude fibre	387.51[a]	279.54[a]	181.38[b]	137.50[c]	98.63[d]	23.77
Ether extract	19.60[bc]	29.78[a]	24.38[abc]	17.45[c]	26.99[ab]	1.41
Nitrogen intake	22.20[c]	30.63[bc]	38.51[b]	43.59[ab]	53.15[a]	2.79
Faecal nitrogen	2.67	2.96	3.86	3.32	4.08	0.25
Urine nitrogen	0.75[bc]	0.57[c]	0.88[b]	0.75[bc]	1.17[a]	0.06
Nitrogen retention	18.78[d]	27.10[cd]	33.78[bc]	39.52[ab]	47.89[a]	2.59
Digestibility co-efficient (%)						
Dry matter	88.87	90.46	88.58	88.11	90.49	0.43
Crude protein	87.48[b]	90.54[a]	90.29[ab]	92.54[a]	92.14[a]	0.54
Crude fibre	97.19[a]	95.07[a]	89.43[b]	85.25[b]	69.54[c]	2.12
Ether extract	79.38[b]	75.94[bc]	61.12[b]	69.49[c]	87.26[a]	2.02
Nitrogen free extract	79.52[c]	87.17[b]	87.78[b]	86.62[b]	92.09[a]	0.97
Performance characteristics						
Initial weight (kg)	14.34	14.64	14.66	14.43	14.60	0.14
Final weight (kg)	15.36	16.32	16.74	17.00	15.96	0.28
Weight gain (g)	14.57[e]	24.67[c]	29.71[b]	36.86[a]	19.43[d]	2.11
Feed /gain ratio	84.59[d]	56.66[c]	49.44[b]	41.25[a]	81.78[d]	4.87

a-e = Means on the same row but with different superscripts are statistically (P<0.05) different.

Conclusion and Implications

From the foregoing, supplementing *P. maximum* with *M. alba* at 1:3 in ruminant feeding would meet their growth requirement and encourage production of small ruminants and cultivation/conservation of *P. maximum* and *M. alba*.

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Modeling of Radioactive Cesium Dynamics on Japanese Semi-Natural Grassland

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Key words: Grazing, model, nuclear power plant accident, radioactive cesium, *Zoysia japonica* Steud.

Introduction

The damage to the Fukushima Daiichi Nuclear Power Plant following the Great East Japan Earthquake and tsunami on March 11, 2011 resulted in serious radioactive pollution of Eastern Japan. In some grasslands of this area, radioactive cesium (RCs) content of grasses exceeded the provisional safety standard for use as feed for dairy and beef cattle of 100 Bq kg^{-1} fresh weight, and the livestock industry has been seriously affected in numerous ways. The spatial distribution of RCs in grasslands was complex in various scales (Tsuiki and Maeda, 2012a; 2012b). So it is difficult to estimate actual pollution level in grassland ecosystems. The transfer of RCs from soil to plant is affected by soil soluble potassium (K) concentration, pH, clay and organic matter contents (Absalom *et al.*, 2001; Tsuiki *et al.,* 2013). The RCs dynamics in soil-plant-animal system is complex and modeling is necessary to clarify the relationships. In this study, a model of RCs dynamics in *Zoysia japonica* Steud.-dominated grazing grassland was developed to predict RCs concentration of grass and grazing cattle.

Materials and Methods

Z. japonica Steud. dominated grazing grassland in Tochigi Prefecture, Japan (36° 55' 19.42 N, 139° 57' 12.85 E) was investigated from 2011 to 2014. Four breeding cows were grazed in 1.5 hectare pasture. ^{137}Cs concentration in vegetation, litter, feces and urine was measured once a month from May to October. Cows were slaughtered after grazing and ^{137}Cs concentration in beef was measured. System dynamics approach was used for modeling. Two kinds of RCs, ^{137}Cs (half life: 30.17 years) and ^{134}Cs (half life: 2.06 years), were released from the nuclear power plant. Dynamic flow of ^{137}Cs in *Z. japonica* dominated grazing grassland was simulated (Fig. 1). Soil unadsorped ^{137}Cs, soil adsorped ^{137}Cs, vegetation ^{137}Cs, litter ^{137}Cs, cattle ^{137}Cs, feces ^{137}Cs and urine ^{137}Cs were selected as level. The flow from soil unadsorped ^{137}Cs to soil adsorped ^{137}Cs was affected by radiocesium interception potential (RIP). RIP was calculated as the product of partition coefficient (K_D) and K in soil solution:

$$\mathrm{RIP} = \mathrm{K_D} \times \mathrm{K\ in\ soil\ solution} \qquad (1)$$

K_D was defined as the ratio of quantity of ^{137}Cs sorbed per unit mass of frayed edge sites in soil to the equilibrium concentration of contaminant in soil solution.

$$\mathrm{K_D} = (^{137}\mathrm{Cs\ adsorped\ to\ frayed\ edge\ sites\ of\ micaceous\ minerals\ in\ soil}) / (^{137}\mathrm{Cs\ in\ soil\ solution}) \qquad (2)$$

The flow from soil unadsorped ^{137}Cs to vegetation ^{137}Cs was affected by soil exchangeable K content. The flow from feces and litter ^{137}Cs to unadsorped ^{137}Cs was affected by air temperature. The growth of vegetation was decided by observed data with table function. The unit of levels was Bq m^{-2} and the unit of simulation time was day.

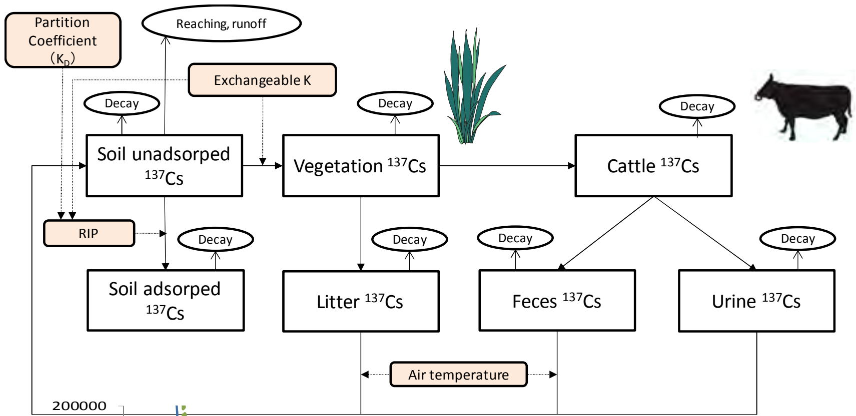

Figure 1. ^{137}**Cs flow in** ***Zoysia*** **type grazing grassland.**

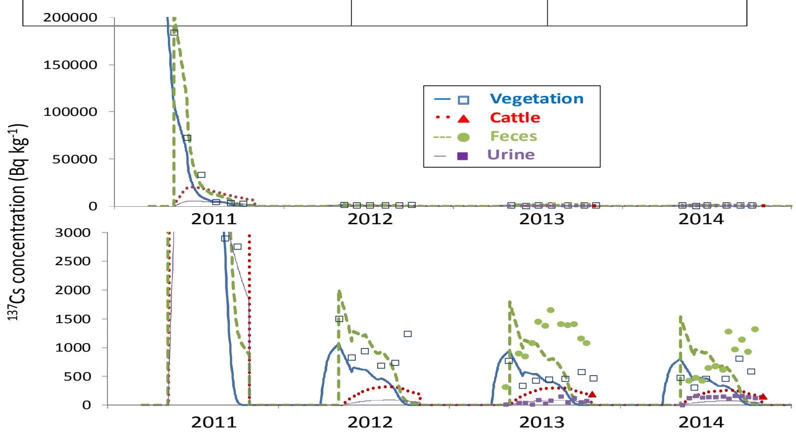

Figure 2. Simulation results of ^{137}**Cs dynamics in grazing grassland.**

Results and Discussion

Observed and simulated results of ^{137}Cs concentration of vegetation, feces, urine and beef are shown in Fig. 2. As fallout ^{137}Cs was deposited on the surface of vegetation just after the accident, ^{137}Cs concentration of vegetation and litter in 2011 exceeded 100,000 Bq kg^{-1}. Although ^{137}Cs concentration of vegetation went down year by year since 2012, its decline was quite slow. The range of ^{137}Cs concentration of vegetation was 400~1600 Bq kg^{-1}. ^{137}Cs concentration of feces was higher than vegetation. ^{137}Cs concentration of beef was 196 Bq kg^{-1} in 2013 and 153 Bq kg^{-1} in 2014.

Simulated results of yearly changes of ^{137}Cs concentration in vegetation, beef, feces and urine agreed with observed results. This indicates that the model may be applied to prediction of ^{137}Cs effects for following few decades. On the other hand, simulated results of seasonal changes did not necessarily agree with observed results. Seasonal changes of plant growth rate, nutrient uptake from root and decomposition of litter and feces affect seasonal dynamics of ^{137}Cs concentrations. Further improvement is necessary to predict the dynamics of RCs in grassland ecosystems.

Conclusions

A model of RCs dynamics in *Z. japonica* dominated grazing grassland was developed to predict RCs concentration of grass and grazing cattle. The flow from soil unadsorped ^{137}Cs to soil adsorped ^{137}Cs was affected by RIP. The flow from soil unadsorped ^{137}Cs to vegetation ^{137}Cs was affected by soil exchangeable K content. Yearly changes of ^{137}Cs content could be estimated by the model. But seasonal changes did not agree with observed results. Further improvement is necessary to predict the dynamics of RCs in grassland ecosystems.

Acknowledgements

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Soil-Vegetation Relationship in North African Saline Rangelands: The Case of a Salt Steppe in Tunisia

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Key words: Salinity, North Africa, vegetation, arid bioclimate, Tunisia.

Introduction

Tunisia is a North African country with a large portion of its land mass located in an arid bioclimate. About three quarters of the Tunisian territory is influenced by bioclimatic and edaphic aridity (Le Houérou 1995). These facts are the main reason for soil salinization. In addition, global changes in the form of higher temperatures and less precipitation are exacerbating soil salinity resulting in desertification. Furthermore, the costal land of this country is predisposed to salinity due to marine movement and the rising sea level. All of these interrelated factors are contributing to an expansion of saline area, especially in the central and the southern part of the country. Natural vegetation exposed to these conditions faces many changes like decreasing species richness and biomass productivity in the saline soil rangelands. A number of halophytes have been reported in previous studies conducted in the region (Abdelly et al 2006). Our research focused on the relationship between vegetation cover and electric conductivity (EC) among the relative halophytes that exist in these saline rangeland ecosystems. The main results can be extrapolated at the regional scale of North African saline rangelands.

Methods and Materials

A total of 16 sites were chosen randomly from the arid region in central Tunisia in order to study the pastoral species richness of the saline rangelands in this region (Chaieb, 2015). We avoided the coast line because of high levels of salinity due to contamination by sea water. An arid bioclimate has two zones, a higher arid and a lower arid bioclimate. An equal number of sites was studied in each zone (8). Each site was monitored using a map produced with Arc GIS 10.2. We started our description of each site through a global vision of the ecosystem. At this level, we decided to use the transect method for describing vegetation. The transect was performed according to a gradient of salinity measured by a HH2 Wet Sensor. The area of study was divided in 4 sectors, which were determined by the kind of halophile, especially the most dominant ones along with the different values of EC that change from one species to another. Next, we completed a count of the existing plants in each sector in a minimal area of 1 m^2 by following the transect. This experimental protocol was applied at all sites. Chemical analyses were performed in all sites according to a salinity gradient. Soils were sampled at two depths of 20 cm and 40 cm in order to identify the variation in salinity. Samples were analyzed essentially for EC, pH, soil water content, soil temperature, Na^+, K^+, Mg^{2+}, Cl^- and Nitrogen. Also, we worked on estimating vegetation cover using the linear method and species density in each $2m^2$. After completing the chemical analyses, statistical analyses of the results were completed using R 3.2.3 software.

Results and Discussion

The Principal component analyses (PCA) (Fig.1) shows different correlations between the parameters measured. According to the PCA figure below, we interpreted different relationships between the vegetation and soil quality parameters.

A negative correlation was found between the vegetation cover and chemical elements in the soil. Additionally, the similar correlation exists between the cover plant and EC. However, a positive correlation is found with Nitrogen and vegetation cover.

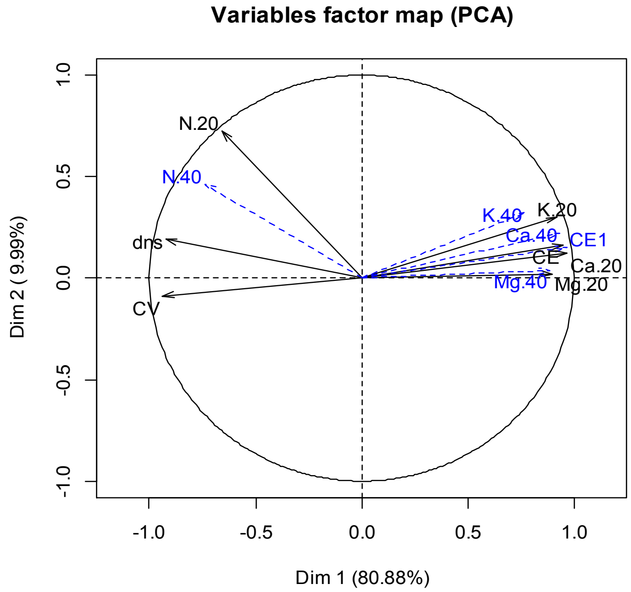

Figure 1. PCA of the interaction between salts, vegetation and nitrogen.
(CV: vegetation cover; CE: Electric conductivity; dns: Individual density; N: Nitrogen; K: potassium; Ca: Calcium; Mg: Magnesium; Cl: Chlore; 20, 40 : respectively soil depth 20 cm and 40 cm).

To better understand the relationship between salinity and pastoral vegetation, we calculated a linear regression for vegetation cover and EC. The results explain the distribution of pastoral vegetation in saline soils. The statistical test using a linear regression is highly significant Pr(>|t|) <2e-16 ***. Halophile cover decreases when the quantity of salt is too low. At the same time, vegetation is absent when salinity is very high. Pastoral vegetation struggles to grow in a saline environment. Even the most resistant species such as *Halocnemum stobulaceum* are found in only a very limited area. Thus, it is very important to study the effect of the climate on the level of salinity in arid regions and it's implication to plant adaptability to find solutions to conserve pastoral vegetation.

Conclusion

Increasing salinity in arid zones seems to have a harmful effect on vegetation. Several scenarios of global warming indicate that arid bioclimates may be transformed into desert areas. Therefore, it is important to study plant biogeography by bringing to light a pattern that estimates the degree of the effect of salinity and species migration.

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Ficus thonningii Silvopastures: An Indigenous Innovation for Livelihood Improvement, Climate Change Adaptation and Environmental Resilience in Northern Ethiopia

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Key words: Silvopasture, indigenous innovation, Ethiopia, *Ficus thonningii*

Introduction

Livestock production in northern Ethiopia has historically been affected by recurrent drought and rangeland degradation. Through repeated exposure to recurrent drought and consequent livestock feed shortage, herders in northern Ethiopia have developed an indigenous silvopastoral practice, using *Ficus thonnigii* as a focal species. The practice has resulted in improved livestock productivity and livelihoods, improved climate change adaptation and rangeland health. This paper is a synthesis of several studies conducted over seven years on this indigenous rangeland innovation.

Methodology

The studies involved questionnaire survey with 240 households in Ahferom district northern Ethiopia to understand the uses and traditional practices of local *Ficus thonningii* silvopastures. Moreover, standard field equipments were used to estimate the browse biomass production of silvopastures. Trial with different levels of replacement of commercial concentrate by *Ficus thonningii* leaf meal was also undertaken to understand the effect of feeding *Ficus thonningii* on productive parameters of local breed goats.

Results

Multipurpose merits of F. thonningii and trends in its use in silvopastoral systems

Ficus thonningii produces large amount of nutritious foliage (Balehegn et.al., 2012; Berhe and Tanga, 2013; Balehegn et al., 2014a). Other merits of this species include tolerance to lopping, absence of allelopathic effects on other species, ease of propagation. Moreover, *F. thonningii* silvopastures had higher soil organic matter, soil moisture and plant solute concentrations compared to soil away from canopy (Balehegn, 2011, Berhe et al., 2013). Appreciating its merits, local herders have extensively established silvopastoral systems using this species resulting in increases in the proportion of *F. thonningii* in rangelands compared to government introduced fodder species, as measured by ecological surveys in areas where *F. thonnigii* silvopastures are practiced (Balehegn et al., 2014a).

Indigenous practices of propagation and use of Ficus thonningii

Indigenous procedures and protocols for successful propagation of the plant, perfected by local herders include: procedures on mother plant selection, cutting preparation, incubation of cuttings or care during time between cutting and planting (1 week in dry season and 1-2 weeks in wet season), land preparation, protection of cuttings from wind shaking, animals nibbling using pegs, dung, thorny fences etc., and use of local plant smok for repelling pests associated with *F. thonningii* and different strategies for establishing silvopastures on wstelands, bakyards, farmlands and protected areas (Balehegn et al., 2014).

Figure 1. *Ficus thonningii* leaves cut from trees near houses are the first feed source for local livestock.

Browse Biomass Production by *Ficus thonningi*

The average values of browse biomass in dry matter estimated for old, medium and *F. thonningii* silvopastures are 125.89 ton/ha, 14.9 ton/ha and 2.28 ton/ha respectively (Balehegn et al., 2012). Such values are 500% higher than the values for commonly introduced exotic fodder trees and shrubs.

Nutritive Value of *Ficus thonningii* Foliage and Effect on Animals

Optimal average crude protein (CP) of 21.5%, coupled with a very low (0.06%) (tannin content could be a reason for higher intake of 47g DM/$W^{0.75}$-Day at 50% replacement of commercial concentrates by *F. thonningii* leaf meal, than that at lower levels of replacement. The 50% replacement has also resulted in higher body weight gain of 50g/Day, than those at lower levels of replacement (Balehegn et al., 2014).

Conclusions and Implications

The different studies reviewed in this paper revealed indigenous innovation based on the use of *F. thonningii*, a drought resistant multipurpose indigenous fodder tree as a key species in emerging silvopastural systems. This innovation enabled improvement of livestock productivity and soil fertility and the maintenance and enhancement of ecological integrity of degraded areas.

However, insufficient awareness about the merits of the system, lack of established guidelines for successful duplication of the system and pests associated with the with *F. thonningii* silvopastures are important reasons limiting the systems popularization in other similar areas. Therefore, effective strategies for adoption similar systems in 33 other sub-Saharan African countries, where the species is indigenous, should be designed.

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Level of Inclusion of *Acacia karroo* Leaf Meal in *Setaria verticillata*-Based Diets on Feed Intake, Digestibility and Live Weight Gain of Indigenous Pedi Goats

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Key words: Rangeland, Pedi goats, *Acacia karroo*, encroacher, nutrition.

Introduction

Indigenous goats play multiple roles in the communal rangelands of South Africa. However, their productivity is constrained by shortage of good quality feed, especially during the long dry season. Poor nutrition results in poor performance of the animals. There is need to identify more nutritious feeds to alleviate the prevailing nutritional problems.

Tree legumes such as *Acacia karroo* Hayne have been identified as important sources of fodder for livestock in communal rangelands of Southern Africa (Mapiye et al., 2011). The foliage is ever green and has potential to be used as a protein feed (12 % CP in leaves). *Acacia karroo* is considered an ecological threat to natural rangelands and tends to be an invasive species. Focus has now shifted from its eradication as a weed to its utilization as a protein feed for ruminants (Mapiye et al., 2011). Utilization of *Acacia Karroo* leaves is, however, restricted by the presence of certain compounds such as condensed tannins (CT) that reduce its nutritional quality. High CT intakes by ruminants may reduce diet intake and digestibility and hence adversely affect productivity of the animals (Makkar, 2003). However, information on the *Acacia karroo* leaf meal inclusion level for optimal productivity of Pedi goats is not available. The objective of the study was to determine the level of inclusion of *Acacia karroo* leaf meal in *Setaria verticillata* (L.) P.Beauv. based diets on feed intake, digestibility and live weight gain of indigenous Pedi goats (*Capra hircus*).

Materials and Methods

The study was conducted at the University of Limpopo Experimental farm (latitude 27.55 ºS and longitude 24.77 ºE) in October, 2014. Fresh leaves *of Acacia karroo* were harvested at the farm in August, 2014. *Setaria verticillata* hay was bought from the local farmer and is typical for the region. The hay was low in crude protein (7 %) and high in ADF (51 %). The grass and *Acacia karroo* leaves were passed through a hammer mill (13 mm screen) to reduce diet selection by the animals when fed. The method of grinding is typical on the farm. Twenty indigenous male Pedi goats with an average initial live weight of 18 ± 2 kg were assigned, in a completely randomized design, to five dietary treatments (4 replicates) containing *Acacia karroo* leaf meal inclusion levels of 20 % ($S_{80}A_{20}$), 25 % ($S_{75}A_{25}$), 30 % ($S_{70}A_{30}$), 40 % ($S_{60}A_{40}$) and 50 % ($S_{50}A_{50}$) of the total diet. The goats were fed *ad libitum*, allowing a 15 % refusal of each diet. There was a preliminary period of 14 days to acclimatize the goats with the feeds and research protocol. The feeding trial lasted for 21 days. At the end of the feeding trial, three animals per treatment were transferred to metabolic crates and each animal was fitted with a faecal bag for assessing *in vivo* digestibility. Faecal collection period lasted for 7 days for each goat. Feeds and faeces were dried and analysed for dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) (AOAC, 1990). All data on feed intake, in *vivo* digestibility and live weight gain of goats were analysed by analysis of variance using the General Linear Model procedures of SAS, 2010. Fisher's least significant difference test was used to separate significant differences ($P<0.05$). The responses in optimal intake, digestibility and body weight change to the level of treatment were modelled using the following quadratic equation:

$Y = a + b_1x + b_2x^2$

Where Y = feed intake (g/day), digestibility (decimal) or body weight change (g/day); a = intercept; b_1 and b_2 = coefficients of the quadratic equation; x = level of inclusion and $–b_1/2b_2$ = level of inclusion value for optimal production response.

Results and Discussion

All the experimental animals had similar (P>0.05) feed intakes (Table 1). This is similar to the findings of Dludla (2010) who reported non-significant differences in total intake when goats were fed *Acacia caffra* and *Euclea crispa* (with high CT concentrations), *Rhus lancea* (with moderate CT concentrations) and Ziziphus mucronata (with low CT concentrations). Diets containing 30, 40 or 50 % *Acacia karroo* leaf meal inclusion levels had improved CP digestibility, albeit the relatively higher tannin contents. *Acacia karroo* leaf meal inclusion level of 48.3 % optimized CP digestibility. Dietary CT protects plant proteins from microbial degradation in the rumen, leading to increase in protein flow to the intestines (Makkar, 2003). A diet containing 42.7 % *Acacia karroo* leaf meal inclusion level optimized NDF digestibility (Table 2).

Table 1. Effect of different inclusion levels of *Acacia karroo* on diet intake, digestibility and live weight change of Pedi goats fed *Setaria verticillata* grass hay-based diet.

	Treatment					
Variable	$S_{80}A_{20}$	$S_{75}A_{25}$	$S_{70}A_{30}$	$S_{60}A_{40}$	$S_{50}A_{50}$	SEM
Intake (g/day)						
DM	679	633	642	633	617	56.6
OM	621	580	588	581	566	51.9
CP	60	58	60	62	64	5.38
NDF	475	430	423	392	358	36.6
ADF	319	292	290	274	256	25.1
Digestibility (decimal)						
DM	0.57^{c}	0.58^{c}	0.67^{b}	0.72^{ab}	0.77^{a}	0.024
OM	0.56^{b}	0.56^{b}	0.57^{b}	0.73^{a}	0.75^{a}	0.030
CP	0.40^{b}	0.41^{b}	0.55^{a}	0.56^{a}	0.60^{a}	0.042
NDF	0.48^{b}	0.63^{a}	0.66^{a}	0.56^{ab}	0.66^{a}	0.038
ADF	0.36^{b}	0.36^{b}	0.37^{b}	0.49^{ab}	0.61^{a}	0.048
Initial BW (kg)	17.60	18.60	17.00	19.00	17.41	4.841
Final BW (kg)	17.74	18.77	17.24	19.25	17.83	4.610
ADG (g/day)	20^{c}	23^{c}	34^{b}	36^{b}	60^{a}	10.37

^{a,b,c}: Means with different superscripts in the same row are significantly different (P<0.05)
SEM: Standard error of the means, ADG: Average daily gain.

Table 2. *Acacia karroo* leaf meal inclusion levels for optimal dietary DM, CP and NDF digestibility (decimal) in Pedi goats on *Setaria verticillata* grass hay-based diet.

Factor	Formula	AK level	Optimal Y-Level	r^2
DM digestibility	$Y = 0.310 + 0.015x + -0.000108x^2$	69.4	0.830	0.959
CP digestibility	$Y = 0.000149 + 0.024x + -0.000248x^2$	48.3	0.580	0.877
NDF digestibility	$Y = 0.230 + 0.020x + -0.000234x^2$	42.7	0.657	0.345

AK level: *Acacia karroo* leaf meal inclusion level for optimal Y-value
r^2: Coefficient of determination

The increase in inclusion level of *Acacia karroo* leaf meal resulted in increased daily weight gains of goats. Higher (P<0.05) average daily weight gains were observed in goats consuming a 50 % *Acacia* *karroo* diet. The improvement in live weight gain might be associated with CP digestibility by goats on *Acacia karroo* diets.

Conclusions and Implications

The results indicated that higher *Acacia karroo* leaf meal inclusion levels improved nutrient digestibility and growth rate of Pedi goats but not live weights. This was despite the browse having high condensed tannins. Inclusion levels of 48.3 and 42.7 % optimized CP and NDF digestibilities, respectively. *Acacia karroo* leaf meal, therefore, has the potential of being utilized as a protein feed during the critical dry season when goats depend on low quality roughages.

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Natural Occurrence and Grazing Impact of Vesicular Arbuscular Mycorrhiza Associated Medicinal Plants in Free Range Lands of Tamilnadu, India

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Key Words: Vesicular Arbuscular Mycorrhiza (VAM), medicinal plants

Introduction

The Vesicular Arbuscular Mycorrhiza (VAM) fungi association has been known to enhance the growth of medicinal plants and improve the sustainability of rangelands. The Vesicular Arbuscular Mycorrhiza association has positive link with plant growth. It is associated with grazing, productivity and improves the health of grazing animals which in turn is beneficial for cattle and goat farmers. Medicinal and herbal plants have assumed greater importance in recent years due to their tremendous potential in modern and traditional medicine. Indian system of medicine (ISM) uses 25,000 plant species belonging to more than 1000 genera. Most of the medicinal plants are harvested from native rangeland and pasture land. The medicinal plants taken for this study are frequently grazed by cattle and goats of native rangeland. Besides the medicinal value, these plants have greater forage nutritive value and are attractive to goats and cattle. In the present study, thirty five medicinal plants were selected and analyzed for natural occurrence of *Glomus fasciculatum* (a form of VAM) and its impact on livestock grazing.

Materials and Methods

Thirty five range land medicinal plants were analyzed for the study. These medicinal plants are being grazed frequently by goats and cattle. The selected medicinal plants includes *Cynodon dactylon* Linn., *Abutilon indicum* Linn., *Tephrosia pupurea* (L)Pers., *Cleome viscosa* Linn., *Cleome gynandra* Linn., *Hybanthus enneaspermus* (L.) F.Muell., *Indigofera enneaphylla* Linn., *Leucas aspera* (Willd.) Linn., *Sida acuta* Burm (f)., *Sida rhomboidea* Roxb., *Ruellia tuberosa* Linn., *Asystasia gangetica* Linn., *Desmodium gangeticum*(L.) DC., *Desmodium triflorum* (L.) DC., *Pseudarthria viscida* (L) Wight and Arn., *Tacca pinnatifida* J.R.&J.G.Forst., *Kalanchoe pinnata* (Lam.) Pers., *Evolvulus nummularius* (L.) L., *Vernonia cinerea* (L.) Less., *Asparagus racemosus* Willd., *Basella alba* Linn., *Boerhavia diffusa* Linn., *Blepharis maderaspatensis* (L.) Heyne ex Roth., *Justicia simplex* Lindau., *Spermacose hispida* Linn., *Cassia auriculata* Linn., *Canthium parviflorum* Lamk., *Carissa carandus* Linn., *Aerva lanata* (L.) Juss. Ex Schult., *Cassytha filiformis* Linn., *Dipteracanthus prostrates* (Poir.) Nees., *Digera muricata* (L.) Mart., *Amaranthus tricolor* Linn., *Amaranthus viridis* Linn. *and Alternanthera sessilis* (L.) R.Br. ex DC. All these plants were collected from free rangeland and pasture land of Tamilnadu, India. Plant roots were cut into 1 cm bits and fixed in a standard FAA (formalin acecto alcohol) and processed further for the assessment of VAM colonization by tryphan blue staining. The stained roots were observed under the microscope and the presence of vesicles and arbuscules were noticed. The nutritive value and health of above mentioned plants were analyzed by morphological and biochemical studies.

Results and Discussion

The livestock selected and grazed medicinal plants have greater *Glomus fasciculatum* VAM colonization compared with non-grazed plants. The plant families such as Amaranthaceae, Poaceae and Fabaceae are on the top priority of grazing. The non-grazed plants have low VAM colonization with bacterial and fungal infections on leaves, and contained aromatic compounds such as volatile oils on their aerial parts.

They are not attracted by grazing animals. It is evident from the observation that the root systems of all medicinal plant species found to harbor abundant VAM association.

Table 1. Mycorrhizal root colonization of grazed and Non-grazed medicinal plants.

Types of Plants	Percentage of colonization	No. of arbuscules/ 1cm root bit	No. of vesicles/ 1cm root bit
Grazed plants	95-98	2 to 4	12 to 15
Non-Grazed plants	10-20	< 1	< 4

Glomus fasciculatum (VAM association) enhances productivity of nutritional and medicinal values of the host plants. It is a key practice in a sustainable management of natural resources to develop antagonistic activity against harmful micro-organisms of plants. VAM association in grazing medicinal plants reduces damage caused by soil borne pathogens. Prophylactic ability of VAM can be exploited with other rhizospheric microbes to improve plant growth and their health. The important interaction of VAM is essential for nutritional link from soil microbes to plants, from plants to livestock productivity. The Vesicular Arbuscular Mycorrhizae symbiosis is beneficial for plant development, reducing the soil borne disease and enhance soil nutrient uptake by plants.

Conclusions and Implications

Application of VAM (*Glomus vasciculatum)* spores in the rangeland and pasture land will have an enhanced nutritive value in the leaf, root and shoot. Feeding the VAM associated plants may enhance the immunity and betterment of the live stocks. This VAM study indicates plant nutrition, growth, defense mechanism against plant diseases, by plant microbe positive interaction. Further research is needed for clear understanding of eco-physiological parameters contributing to effectiveness and the mechanism involved by VAM association.

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Effect of Grazing System on the Carcass Characteristics of Yunnan Long-ling Yellow Goats

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Key word: Long-ling Yellow goat, grazing system, mountainous grassland, carcass traits;

Introduction

Yunnan province, located in the southwest of China, has 1.53 million hectare of natural grassland. Mountains occupy 84 percentage of Yunnan and it is within the subtropical monsoon climate, which provides the warm and moist condition for the growth of natural grassland. Long-ling goat is a native breed suited for grazing in Yunnan mountainous grassland, and famous for its meat with wonderful taste and less odor. However, natural grassland-grazing is not able to meet its nutritional requirements for faster body weight gain. Our previous study proved that different grazing systems had impact on body fat deposition, fatty acid composition and volatile compounds of meat quality in lambs (Wang et al. 2014, 2015). Grazing plus supplementary feeding has become more popular in recent years for the protection of ecological environment. How to raise the goat in the grassland-grazing is currently a hot issue. In this paper, the carcass traits of Long-ling Goats was studied based the different feeding systems.

Materials and Methods

This experiment was carried in Long-ling County, Yunnan province, China. The experimental area has the subtropical monsoon climate with average annual temperature of 14℃ and 1,850-meter altitude. The experiments were conducted from April 2015. After weaning, a total of 136 goats, which were 4 months old were selected and divided into three groups. Goats in Group A were referred to as ‘entire grazing feeding’, which grazed six hours per day. Group B had same grazing time with additional concentrate supplement. Finally, Goats in Group C were ‘total indoor feeding’, which were provided roughage （corn silage and ryegrass） and concentrate supplement （corn and soybean meal） every day. After ten months, a total of 24 castrated goats (8 animals in each group) were slaughtered at the abattoir. The non-carcass components such as skin, head, feet, liver, lungs and trachea, heart, spleen, testicles and gastro-intestinal tract were removed, and then hot carcasses were obtained. Carcass was weighed to determine the hot carcass weight and carcass dressing percentage. The weights of head, feet and skin were also measured. The data were analyzed as a completely randomized design using one-way analysis of variance of SAS 12.0. Duncan's method for multiple comparisons was used.

Results and Discussion

The carcass traits are listed in the following table.

Table 1. The carcass traits of Long-ling Yellow goats on different grazing systems.

Items	Groups			SEM	*P*-values
	A	B	C		
Live body weight /kg	19.18b	20.83b	27.17a	0.799	<0.0001
Hot carcass weight /kg	8.40b	9.12b	14.07a	0.553	<0.0001
Meat weight /kg	7.40b	8.10b	12.78a	0.524	<0.0001
Bone weight /kg	0.99b	1.02b	1.29a	0.035	<0.0001
Dressing /g kg^{-1}	437.8b	438.5b	518.1a	42.2	<0.0001
Meat yield /g kg^{-1}	389.6b	389.1b	470.3a	8.85	<0.0001
Meat: bone	7.44b	8.05b	9.89a	2.81	<0.0001
Non-carcass parts /g kg^{-1} live body weight					
Head	75.0a	75.7a	69.8b	1.02	0.028
Feet	24.3	23.7	22.4	0.04	0.155
Skin	60.9	61.3	60.7	0.21	0.990
GR / mm	6.48b	6.56b	9.96a	0.418	<0.0001

Means in the same column with different letters are significantly different at $P<0.05$.

Goats in group C had advantages in all carcass parameters (Table 1), which showed that indoor feeding caused improvement not only in live body weight gain, hot carcass weight and the weight of meat but also dressing percentage of meat and bone and GR values（$P<0.05$）. However, there were no differences ($P> 0.05$) in non-carcass components apart from the head in each group. Besides that, no differences ($P> 0.05$) were found between group A and group B for each parameter, which showed the concentrate supplement resulted in limited improvement in carcass traits. The goats in group B had more tendency to graze in the grassland instead of consuming concentrate supplement. Indoor feeding system, which allowed the goats to consume less energy, was becoming more popular in traditional grazing zones in China. However, the benefit of appropriate goat-grazing in the steppe ecology and subsequent improvement in meat quality should not be ignored (Wang et al. 2014, 2015).

Conclusion

The study showed that the indoor fed goats (Group C) had advantages in most carcass traits and meat-production. There were no differences in carcass traits for goats that were solely grazed and those grazed with additional feed concentrate.

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Chemical Composition of Seasonal Pasture in High Mountain Zone

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Key words: Proximate analyses, nutrition, forage plants, seasonal pasture

Introduction

The chemical composition of pasture grasses is different, with substances presented in various amounts. The Mongolian plateau area forage plants are considered valuable in nutrition if they contain protein, fat, minerals and have less crude fiber. The chemical composition depends on many facts like the geographic location, weather condition, type of pasture and development stages, and varies consequently. It is important to achieve the information about contents of macro and micro elements and the chemical composition of the seasonal pasture type and most palatable plant species of the high mountain zone for nomadic livestock husbandry. This is decisive for solving the problems related to feeding animals and to establish knowledge about the process of development of those zones.

Samples and Method

The samples of mainly represented seasonal pasture types were taken from high mountain zone. The samples of the most dominant palatable species (*Agropyron cristatum, Stipa krylovii, Artemisia frigida, Carex duriuscula, Bromis inermis*) were taken from the chosen pasture types. Chemical analyses were conducted in the feed evaluation laboratory of RIAH and in the soil laboratory of the Chemical Institute. Crude fat was extracted for 6 h with petroleum ether, whereas the Kjeldahl method was used to determine crude protein (Association official analytical chemists, 2005). Crude fiber, neutral detergent fiber (NDF) were determined using Ankom fiber analyzer as described by Van Soest et al. (1994). Mineral analysis was conducted using AAS 200 (Atom Adsorption Spectrometry-200).

Results and Discussion

Characteristics of soil

According to content of nutrition information of the seasonal pasture types, humus layer of dark brown and brown soil is 0-10 cm, the humus content has 4.48-5.3% of seasonal pasture soil. Soil pH 5.89-6.97 and ranges from weak acidity to neutral. Total absorbing phosphorus element sum in 100 gr soils is 0.27-1.95 mg-equivalent. This means that soil has no sufficient phosphorus.

Nutrition value and chemical composition of seasonal pasture types

The samples of seasonal pasture types in high mountain area have the following composition on average: moisture has 3.1-6.3 percent, crude protein 3.8-12.8 percent, crude fiber 23.9-32.8 per cent and ash 7.24-10.5 percent. By comparing of the chemical composition of the pasture type in different season indicates of winter sample contained less protein (3.8%), has more fiber and was less nutrition value than in the other season (see Figure 1).

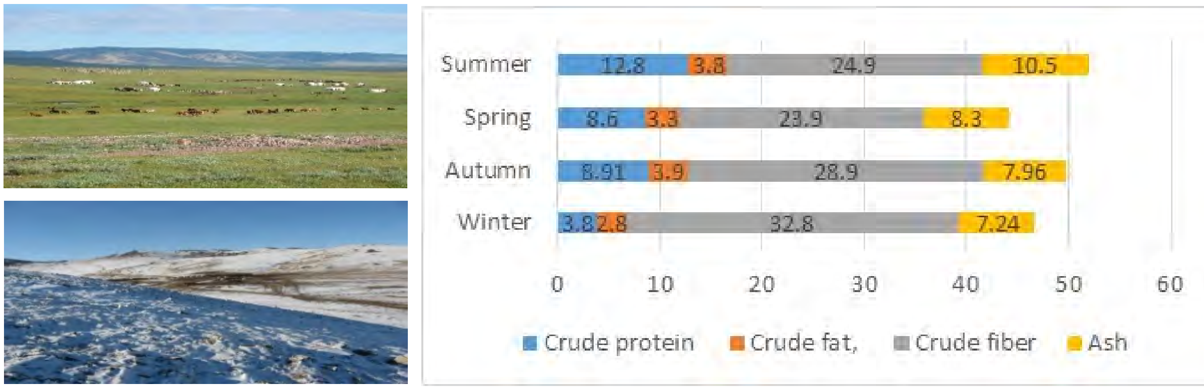

Figure 1. Chemical composition of seasonal samples of high mountain zone, %.

This result depend on vegetation period and growing stage and due to the various percentage of certain type of species among the common plants in pasture types. The protein content of forage species from pastures was less in the steppe-forest regions compared to the certain type of species, and was more in steppe zones (Tserendulam 2010).

The NDF content in pasture types was 49.2-62.5 % and summer pasture were 49.2% which means the pasture are more likely to be intake than other seasonal pasture. The higher NDF content of winter pasture which is indicated decrease to intake (Peter 1999). The comparison of the ME of the summer and autumn pasture types shows no significant differences of quality between, spring and winter pasture are differences in chemical composition which was influenced by growing stage. The higher nutrition value of summer pasture's per kg green mass is produced 1.7 liter milk yield.

The chemical composition and nutrition value of dominant palatable species were analyzed and compared to each other in seasonally. In summer and autumn, there were no significant differences ($p=0.001$) in regards to quality and nutrition value, when the content in macro, micro elements differed slightly. There was a low of nutrition value in spring and winter season.

The content of elements of forages

It is concluded that the higher ash content in the summer pasture type can be linked to the higher content of macro- micro elements in those zones.

Forage plants have more concentration of potassium then other macro elements and lower concentration of sodium (see table 1). In regards to the contents of macro elements summer pasture has more potassium and magnesium than the other seasonal pasture.

The pasture types in different season and dominant palatable species by choice have proved enough potassium content, but not sufficient content of sodium (Na) in high mountain zone and also not enough calcium for the animal requirements. All other elements were presented in sufficient amounts. The iron as microelement was presented more than any other elements.

The five chosen species from the seasonal pasture contained in average of calcium and sodium which is by lower than of pasture type samples. The highest content of sodium was proved in *Agropyron cristatum*, but it only meets the minimum needs of animals. The zinc was also found not sufficient, but *Artemisia frigida* has higher amount zinc in green mass. This study shows that the concentration of macro, microelements is related directly to the soil where the plants growing.

Table 1. Content of minerals in seasonal pastures.

Item		unit	Ca	K	Na	Mg	Fe	Zn
Samples of pasture								
Winter		mg/kg	3.69	7.90	0.32	2.15	478.47	9.97
Spring		mg/kg	4.56	8.94	0.53	3.16	486.63	29.50
Summer		mg/kg	4.37	9.09	0.98	4.37	437.81	19.90
Autumn		mg/kg	3.67	8.38	0.62	2.50	343.34	9.81
Forage species								
Agropyron cristatum	Green mass	mg/kg	2.14	7.98	1.69	2.27	334.05	9.83
	Litter	mg/kg	1.77	4.38	0.74	1.38	432.30	9.83
Stipa krylovii	Green mass	mg/kg	1.69	5.33	0.67	1.34	285.21	9.83
	Litter	mg/kg	2.46	5.63	1.40	1.88	288.61	19.90
Carex duriuscula	Green mass	mg/kg	3.58	7.77	0.44	2.44	366.63	19.82
	Litter	mg/kg	3.89	8.23	0.48	3.46	349.30	19.75
Bromis inermis	Green mass	mg/kg	1.93	5.39	0.33	1.51	295.28	9.84
	Litter	mg/kg	1.34	6.48	0.51	1.90	208.13	9.91
Leymus chinensis	Green mass	mg/kg	1.53	7.70	0.47	1.28	295.74	9.86
	Litter	mg/kg	2.63	7.82	0.54	2.04	275.27	9.83
Artemisia frigida	Green mass	mg/kg	5.58	7.82	1.05	2.39	288.67	29.86
	Litter	mg/kg	4.56	7.89	0.31	2.49	511.31	9.83

This research work would be the first of this kind because there was not yet done such complex studies to determine the various characteristics for one type of pasture in different season and establishing the chemical composition of common type of plants and their contents in macro, micro elements.

Conclusion

Result of the study indicates that nutrition value of the summer and spring pasture plants are better than other season. It has been shown by content of protein are decreasing and crude fiber has increased. Amount of calcium and sodium in all season pasture types is lower of animal requirements. Regarding the microelements the study indicates high level iron content in all season pastures.

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The Importance of the “Montado” Ecosystem on the Fat Quality of “Alentejano” Pig

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Key words: Autochthonous breeds, rearing systems, pork meat, fatty acids profile, oleic acid

Introduction

In Portugal, the traditional extensive systems included in agricultural systems use autochthonous low-productivity breeds, perfectly adapted to environmental conditions. Natural food resources from farms are used for feeding animals producing limited and specific transformed high quality food products.

One of these systems is “Montado”, which supports several livestock species and breeds. However, pigs are the most efficient species in using *Quercus* spp. fruits (acorns), providing some food products very appreciated by consumers. These are considered high gastronomic value products mainly manufactured by traditional and artisanal practices.

The “Alentejano” pig is an autochthonous breed from South Portugal, genetically similar to the Iberian pig and is traditionally reared and finished in the “Montado” free-range conditions (“Montanheira”). In finishing period, “Alentejano” pig is fed with pasture and acorns. It is an obese breed with slow growth rates and high lipogenic activity at early stages of development. The slaughtering occurs usually at 110-150 kg, at 18 to 24 months age and the meat is used to manufacture high quality dry-cured and dry-fermented meat products (Martins et al., 2015).

The ingestion of acorns rich in oleic acid favours fat composition and benefits the organoleptic characteristics of meat. The “Alentejano” pork meat shows high content of intramuscular fat, which favours succulence, tenderness and flavour attributes and its fatty acids profile protects from coronary heart disease (Martins et al., 2012).

The objective of this study was to compare the meat fatty acids profile of pigs reared in “Montanheira” with that of pigs reared in intensive systems.

Materials and Methods

Previous studies were used to compare the results obtained for both rearing systems with the “Alentejano” pig breed. Although there are several studies using Iberian pigs, only a few studies were found with the “Alentejano” pig breed and only the ones that used both systems were used. The values from Martins et al. (2015) and Teixeira & Rodrigues (2013) were adapted, in order to be comparable.

Results and Discussion

Table 1 displays the main components of intramuscular fat from "Alentejano" pigs reared in "Montanheira" and intensive systems.

Table 1. Summarised fatty acid composition (%) of "Alentejano" pig breed meat reared in two different systems.

Fatty Acids	"Montanheira"	Intensive systems	Adapted from:
SFA	41.4	46.3	Teixeira & Rodrigues, 2013
MUFA	51.8	41.1	
PUFA	6.8	12.6	
oleic acid (C18:1)	46.5	36.5	
SFA	38.4	38.7	Martins et al., 2015
MUFA	57.5	57.2	
PUFA	4.1	4.1	
oleic acid (C18:1)	52.4	52.1	

SFA-saturated fatty acids; MUFA-monounsaturated fatty acids; PUFA-polyunsaturated fatty acids.

According to Teixeira & Rodrigues (2013), the fatty acids profile shows a higher MUFA level in "Montanheira", contrasting with a higher saturated fatty acids content in pigs reared in intensive systems. Furthermore, oleic acid (C18:1), the most abundant fatty acid, has a significantly higher content in meat from animals bred in "Montanheira". Other results corroborate these findings, although the differences between the two rearing systems are not as evident (Martins et al., 2015).

The fatty acid profile of "Montanheira" pork meat is more beneficial to human health. The higher proportion of oleic acid and MUFA helps to reduce LDL cholesterol, without changing the HDL cholesterol levels (Martins et al., 2012). Besides its health benefits, MUFA favour sensory attributes of meat products, through the release of aroma and flavour compounds, resultant from lipid oxidation (Laranjo et al., 2016).

Conclusions and Implications

Free-range systems, such as the "Montado", produce meat with distinctive characteristics mainly due to the higher proportion of MUFA and oleic acid, when compared to the intensive systems. The production of "Alentejano" pigs in "Montanheira" has beneficial effects in the technological quality of meat, which results in a balanced content of MUFA. This may influence the oxidative stability of meat during storage or upon processing of meat products, as suggested before (Tejerina et al., 2012).

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Biogeochemical Processes of Flooding Pampa Rangeland Are Affected by the Use of Glyphosate

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Key words: Temperate grasslands, soil organic carbon, nitrogen, phosphorus.

Introduction

Temperate grasslands of Argentina are extensively grazed by domestic livestock. Their primary production follows a seasonal pattern, with maximum growth rate in late spring and minimum in winter. Hence winter forage productivity is encouraged through late summer applications of glyphosate, a practice that has become common during the last decade. This practice eliminates green vegetation growing in late summer to improve germination and establishment of cool season annual grasses in early winter, which, in turn, increases winter forage offered and meat production. However, recurrent application of glyphosate has a shifted species composition, reduced species diversity causing the local extinction of several native perennial species, and reduced the annual primary production and changed its seasonal distribution, favouring winter productivity over summer-autumn productivity (Rodriguez and Jacobo 2010, 2014). These changes could affect biogeochemical processes such as the carbon cycle, which in turn, exerts considerable control over the availability of nitrogen and phosphorus (Wedin 1996). We postulate that the shift in species composition, the reduction of primary production and its seasonal distribution caused by glyphosate application negatively affect the soil content of organic carbon, nitrogen and phosphorus.

Materials and Methods

The experiment was carried out on a commercial 1600 ha-farm located in the centre of Flooding Pampa region. The main activity is the management of an Angus and Hereford cow-calf operation under a rotational grazing system on 60 ha of paddocks. We selected three paddocks of native rangeland never treated with glyphosate and other three paddocks that have regularly received late summer application of glyphosate since 2002. The estimation of aerial net primary production was performed by harvesting biomass periodically from April 2006 to March 2008 (Rodríguez & Jacobo 2014). Soil organic carbon (SOC), total nitrogen (N) and total phosphorus (P) content were determined by extracting ten subsamples per paddock up 12 cm deep in 2008, 2010 and 2012. SOC was determined by Walkley and Black method, N content by Kjeldahl method and P content by perchloric acid digestion. Repeated-measures analysis of variance was performed, considering glyphosate treatments as main effect and years as within-subject effect, after being square-root transformed.

Results and Discussion

Glyphosate applications reduced SOC and P content of soil (Fig.1a, b) and did not affect N content (Fig. 1 c). SOC content gradually decreased in glyphosate-treated paddocks, and in 2012 it was 12% lower than in control paddocks (Contrast $F1= 36.7$, $P= 0.003$) (Fig. 1 a). Average P content during the whole period was lower in ghyphosate-treated paddocks than in control paddocks (5.4 vs 6.1 ppm respectively) (Fig. 1 b). Although N content did not show significant differences among treatments (Fig. 1 c), there was a trend to be lower than in control paddocks in 2012 (Contrast $F1= 6.5$ $P= 0.08$).

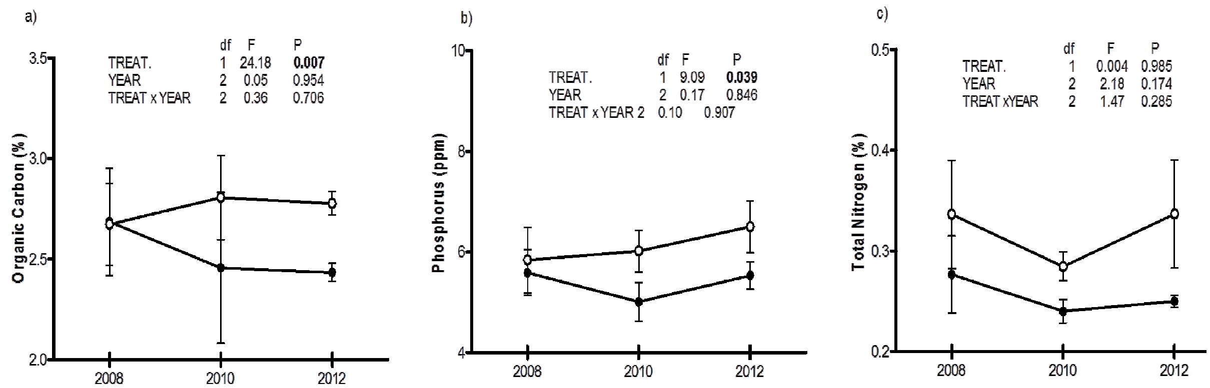

Figure 1. Pattern of Organic Carbon (a), total Phosphorus (b) and total Nitrogen (c) of soils in control (open symbols) and glyphosate treated paddocks (black symbols) from 2008 to 2012. Vertical bars show 1SE of the means. Insert: degree of freedom (df) F and P statistics for the main factor (Treatment) and within-subject effect (YEAR) and their interactions resulted from the repeated measures analysis of variance.

These responses can be attributed to the decrease of spring-summer primary production and to changes in the functional groups and floristic composition of the community (Rodriguez & Jacobo 2010), since it is well documented that changes in the magnitude and dynamics of the primary production and its composition can alter the carbon cycle, which in turn, exerts considerable control over the availability of nitrogen and phosphorus from the ecosystem (Wedin, 1996). A reduction of soil macro and microorganism activity, responsible of organic matter humification, may be expected in glyphosate treated paddocks as consequence of a) lower moisture and higher temperature at soil level during summer due to almost 80% of bare soil (Rodriguez & Jacobo 2010); b) the reduction of primary production, which determines detritus supply for microorganism and it is positively correlated with soil respiration in grasslands (Raich & Tufekcioglu 2000) and c) toxic effect to soil microorganisms, as it was demonstrated for symbiotic ones (Zobiole et al 2011) and arbuscular mycorrhizal fungi (Druille et al. 2013). In addition, glyphosate dramatically reduced the relative and absolute biomass contribution of legumes that have high rates of decomposition as a result of higher initial N content in their tissues (Montane et al. 2010). These factors would lead to a restriction on the quantity and quality of the substrate to decompose, explaining the reduction of SOC and P content. N content did not shown significant changes probably because for grasslands, up to 98% of the N pool is contained in relatively stable organic components of the soil organic matter with turnover times of thousands of years (Knops et al. 2010).

Conclusions

This study demonstrates that recurrent spraying of glyphosate in Flooding Pampa grassland causes the reduction of SOC; P and N content as a consequence of floristic composition and primary production changes, and suggests that this practice negatively modifies key biogeochemical processes for grassland conservation.

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Nutrition Value of Animal Feed and Requirement for Feed Supplements in Mongolian Livestock

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Key words: Forages, chemical composition, nutritive value, metabolizable energy

Introduction

Grazed pastureland provides 90% of the feed requirements of Mongolian livestock with variation in feed supply and quality across seasons resulting in varying suitability for animal use. Plant senescence and dormancy through the 150-180 day winter period reduces availability, animal intake, and forage quality. This reduction in feed intake and quality results in sheep losing 25-35% of fall body weight (Gendaram 1998) and indicates a need for supplemental feed to maintain sheep weight. The objective of the current study was to evaluate the nutrient composition of pasture samples and commonly available feed supplements to inform supplementation decisions.

Material and Methods

Forage samples were received throughout the winter from farmers, herders and intensive livestock producers from the Central Region of Mongolia. Feed supplements were received from animal feed manufacturers. Analysis for crude protein, crude fiber, crude fat, and ash (AOAC 2005) was carried out in duplicate on a total of 20 samples of hay, forage and supplemental feeds. Metabolizable energy values were estimated by based on analytical results according to calculation method (MNS 2005).

Results and Discussion

Chemical compositions and nutritive values of pasture plants

The analyzed compositions of wheatgrass-forb pasture are presented in Table 1.

Table 1. Analyzed composition (mean ± standard deviation) of Mongolian pasture and supplementary feeds.

Item	Sampling period or company	Crude protein, % of DM	Crude fat, % of DM	Crude fiber, % of DM	Ash, % of DM	Metabolizable energy, MJ per kg of DM
Wheatgrass-forb pasture	August	12.3±0.42	3.3±0.38	27.4±0.35	7.6±0.38	8.5±0.32
	October	8.6±0.33	3.1±0.21	29.7±0.29	7.8±0.35	7.9±0.41
	March	6.8±0.28	2.8±0.35	30.2±0.36	7.9±0.27	7.7±0.45
	April	6.1±0.46	2.3±0.09	31.3±0.42	7.0±0.32	7.6±0.38
Hay 1	Selenge province	8.6±0.22	3.2±0.26	29.8±0.29	5.8±0.34	8.6±0.28
Hay 2	Dornod province	7.5±0.35	2.4±0.32	29.5±0.36	6.0±0.28	8.2±0.32
Hay 3	Khentii province	7.2±0.34	2.8±0.37	31.9±0.45	6.5±0.32	9.2±0.41
Alfalfa 1	“Seed product” CoLtd	25.6±0.36	3.1±0.33	29.3±0.39	7.1±0.45	8.1±0.39
Alfalfa 2	“Arvin urgats” CoLtd	23.8±0.32	2.6±0.37	28.8±0.23	6.8±0.42	7.9±0.35
Wheat bran1	“Altantaria” CoLtd	10.0±0.33	2.4±0.28	29.2±0.29	7.5±0.38	7.2±0.35
Wheat bran2	“Altantaria” CoLtd	11.9±0.28	2.1±0.23	29.5±0.34	6.6±0.36	8.1±0.38
Mixed feed1	“Milk house” Co. Ltd	13.5±0.37	2.6±0.25	29.1±0.31	7.3±0.45	8.4±0.44

Mixed feed2	"Milk house" CoLtd	15.2±0.44	3.1±0.43	30.1±0.39	7.2±0.41	7.5±0.37

These results show the loss of nutritive value with the beginning of maturation and senescence in August and increasing losses due to weathering through the winter. Loss of crude protein was the most marked with an ca. 50% decrease from August to April. Loss of ME was ca. 10% over the same period. Mongolian pastoral livestock are well adjusted to extensive grazing and normally digest up to 88% of crude protein, 91% of crude fat, and 83% of crude fiber (Tserendulam, 2010). A sheep requires ca. 10.6 MJ of ME per day, meaning that at 7.1 to 7.6 MJ of metabolizable energy per kg of DM, sheep will require 1.4 to 1.5 kg forage DM per day (Gendaram, 1998). Availability of pasture forage that limits intake below this threshold requires supplementation to maintain body weight.

Chemical compositions and nutritional value of hays

Analyses of hay samples found commonly used hays in Mongolia have protein, fat, fiber and ash contents of 7.2-8.6%, 2.4-3.2%, 29.5-31.9% and 5.8-6.5% (Table 1). The contrast between the crude protein content of hay and pasture is related to hay being cut from valley meadows during the early vegetation stage, when quality is high. However, there is still an apparent need to provide protein supplements even when sheep are provided higher quality hay.

Chemical compositions and nutritional value of feed supplement

The protein content of various supplements ranges from 10-25.6% (Table 1). Protein is usually the most expensive part of the diet. Protein requirements are range between 9-13%, for pastoral sheep (Gendaram, 1998). The protein of supplementary feed contents can help meet the protein requirements of sheep.

Conclusion

The results of chemical analysis of dominant pasture and hay show sheep requirement for protein cannot be met without supplementation during the winter grazing season. Supplemental proteins are available and herders are recommended to use these feeds as required for sustainable grazing management.

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Livestock Grazing Increase Litter Decomposition among Plant Species across Alberta Rangelands

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Key words: Carbon cycle, northern grasslands, land use, nutrient cycling

Introduction

Grasslands cover more than 40% of Earth's terrestrial surface and provide many critical ecological goods and services (EG&S), including carbon (C) storage (Schuman et al 2002). The vast majority of terrestrial C is transformed from plant litter into soil organic carbon (SOC) via decomposition, which is regulated by climate and litter chemistry (Aerts 1997) Grazing alters vegetation by changing plant species composition leading to increase the amount of grazing tolerant species, but also affects the micro-environment such as temperature and moisture (Augustine and McNaughton 1998). Grazing tolerant species may have a different chemical composition than less tolerant species, which results in altered decomposition rates (Derner et al. 2006). The resulting changes in litter decomposition and rates of C residence time and nutrient cycling may ultimately alter ecosystem C accumulation. Understanding the effects of grazing on these ecological processes may provide opportunities for C conservation by Canada's livestock industry.

Materials and Methods

We conducted a field study to better understand how livestock grazing and regional climate influence decomposition. We placed litterbags containing the leaf litter from seven typical grass species that represent a range of grazing tolerance, plant community litter from each study site and pure cellulose paper at 15 study sites stratified across three Alberta natural subregions including Aspen Parkland, Foothills Fescue and Mixedgrass Prairie. All study sites had a grazed and non-grazed comparison. Litterbags were constructed using mesh screen (1 mm^2 openings) and filled with 2 g of one of seven litter types. The litterbags were retrieved after 0, 1, 3, 6, 12 and 18 months. Litter samples were weighed to determine ash-free dry mass loss. Data were analyzed with mixed model analysis of variance with species, natural subregion and grazing as fixed effects using retrieval times as repeated measures.

Results and Discussion

Grazing increased litter mass loss ($p=0.01$) over the 18-month study (Fig. 1). This suggests that direct (e.g.. herbivory, trampling, excrement input) and indirect (e.g. changes to local environment) effects of grazing may enhance the controls of litter decomposition (Adler et al. 2001). Additionally, mass loss varied among litter species (Fig. 2; $p<0.0001$), such that *Bouteloua gracilis*, *Poa pratensis* and *Festuca hallii* (Fig. 2) had the least mass remaining after 18 months, while *Festuca campestris* and *Agropyron smithii* had the greatest mass remaining, which indicate that may be due to the inherent chemical composition of different species (Aerts 1997). Decomposition was also affected by the interaction with natural subregion ($p=0.005$), such that Aspen Parkland/Grazed and Foothills Fescue/Grazed had the least mass remaining while the arid Mixedgrass Prairie had the greatest mass remaining at both nongrazed and grazed treatment after 18 months. This shows that litter decomposed more rapidly at cooler and more humid areas suggesting that litter decomposition may be affected by local environment (i.e., temperature and precipitation).

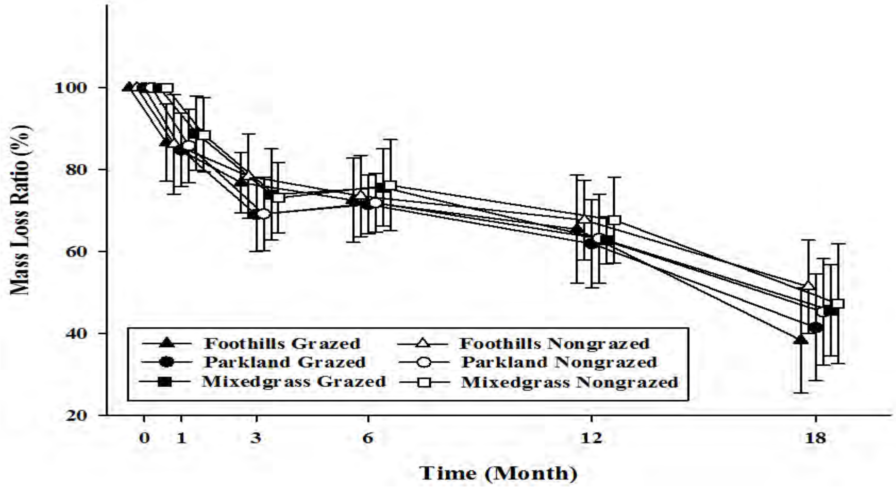

Figure 1. Effect of natural subregion and grazing on litter mass loss over 18 months (mean±SE).

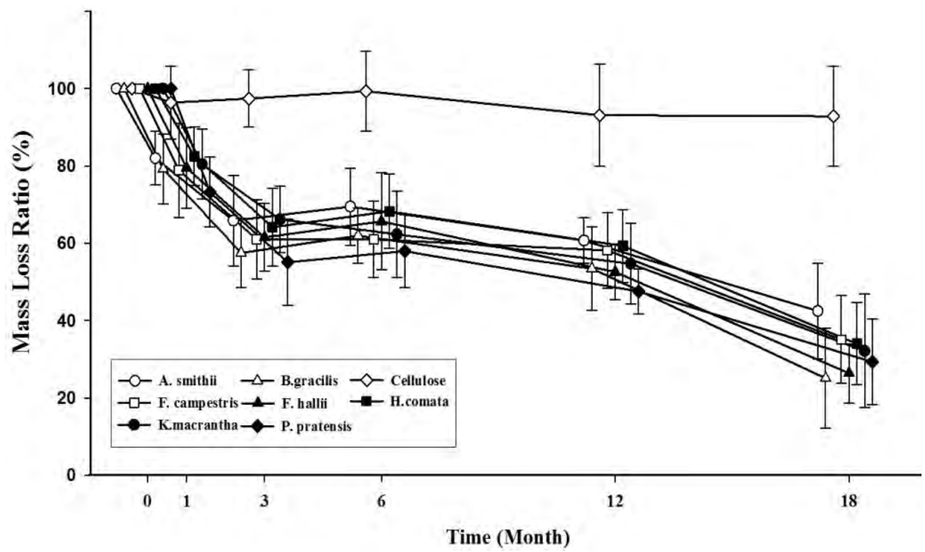

Figure 2. Litter mass loss (mean±SE) by species. Data are pooled across natural sub-regions at each month (mean±SE).

Conclusions and Implications

Our results indicate that long-term grazing increased litter decomposition, which in turn may alter C and nutrient cycling. Moreover, mass loss varied markedly among species, raising questions as to how shifts from grazing intolerant to tolerant species may alter litter turnover and C storage dynamics. Our continued research aims to understand if grazing could be managed in a way to increase SOC formation.

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Methane Suppression and Larval Migration Inhibition by *Bauhinia cheilantha* Fed to Sheep Grazing at Four Forage Allowances

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Key words: Caatinga, condensed tannins, sheep browsing, rangeland, tanniferous browse.

Introduction

Native rangelands in the Caatinga are essential for Brazilian livestock because they are abundant and inexpensive. Mororó (*Bauhinia cheilantha* Steud.) is a tanniferous browse, native specie cultivated in Brazil and is considered a forage source for ruminants. Condensed tannins (CT) in browse can provide benefits because of their anthelmintic and methane (CH_4) reducer activities when consumed at 20 to 50 g kg^{-1} dry matter (DM). Above these levels, animals may suffer negative consequences because of the strong linkage with enzymes, metal ions, and carbohydrates although browsers can neutralize CT via salivary proline (Armstrong et al., 2013; Naumann et al., 2013). The objective was to evaluate the biological activity of CT synthetized by mororó submitted to four forage allowance (FA).

Materials and Methods

The experiment was performed in Serra Talhada, Pernambuco, Brazil (7°59'S, 38°17'W) with undulating terrain, shallow, well-drained, medium to high fertility Luvisols, at 429-m altitude. The climate is Tropical semiarid, mean annual temperature is 25.7 °C and mean annual rainfall is 432 mm. The vegetation is mainly hyperxerophile, consisting of shrubland, thorn, and deciduous forest.

The collection area covered 0.72 ha of partially cleared Caatinga enriched with mororó and *Urochloa mosambicensis* Hack. overseeded in 1980. The assay design was a randomized block with three replications. Each experimental unit consisted of 30 x 20 m in which we tested the effect of four FA (2.0, 2.5, 3.0 and 3.5 kg DM/kg LW) grazed by sheep with 20.3 ± 2.2 kg. Browse from mororó was cut up to 6 mm and up to 1.5 m height before and after sheep (Dorper x Santa Inês) grazing during the rainy season (from March to July) in 2013 and 2014. That samples were oven dried at 55 °C for 72h and ground through a Wiley Mill using a 1-mm sieve.

Analyses of CT were determined as described by Naumann et al. (2014). In vitro gas production assay was used to determine CH_4 suppression as described by Tedeschi et al. (2009) in the Ruminant Nutrition Laboratories at Texas A&M University, College Station, TX. Anthelmintic activity was determined using a scaled-down version of the in vitro *Haemonchus contortus* larval migration inhibition (LMI) assay described by Armstrong et al. (2013) at the Texas A&M AgriLife Research laboratory, Stephenville, TX. Statistical analysis consisted of regression and comparison of means by Tukey test at 5% of probability using SISVAR version 5.3.

Results and Discussion

In relation to CT, significant effect ($P \leq 0.05$) occurred between years and among treatments in 2013 ($y = 85.5 - 59.8x + 10.5x^2$, $R^2 = 0.99$) and 2014 ($y = 217.2 - 32.1x$, $R^2 = 0.51$). There was effect ($P \leq 0.05$) between years as a minor factor, in which 2013 showed less CH_4 suppression (8.16 mM) than 2014 (5.63 mM). In 2013, as FA increased from 2.0 to 3.0 kg DM/kg LW, less CH_4 was suppressed with the intermediary treatments showing greater CH_4 and the treatment 3.5 kg DM/kg LW presenting less CH_4 ($P \leq 0.05$). In 2014, the behavior was inverse, in other words, as FA increased from 2.0 to 3.0 kg DM/kg LW decreased in CH_4, being the treatment of 3.5 kg DM/kg LW with greater CH_4 ($P \leq 0.05$) (Fig. 1). There was negative correlation between CT and CH_4 in 2013 (-0.70) and in 2014 (-0.20). Naumann et al. (2013) studied different tanniferous species and reported a similar correlation.

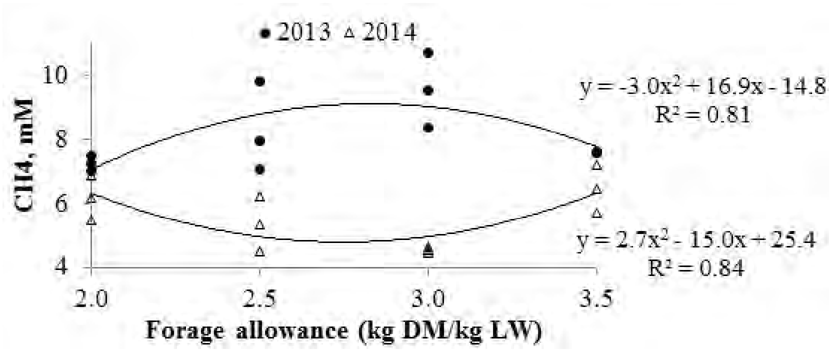

Figure 1. Regression between forage allowance and CH_4 suppression from *Bauhinia cheilantha* browse during 2013 and 2014 ($P \leq 0.05$), in Caatinga, Pernambuco, Brazil.

There was a difference ($P \leq 0.05$) between years; 2013 showed greater LMI (23.1%) than 2014 (9.0%). In 2013, LMI tended to decrease when FA increased and no difference ($P > 0.05$) was found among the three last treatments. In 2014, despite only 18% of the LMI explained by FA, the behavior was similar to 2013; however, the 2.5 kg DM/kg LW allowance showed less LMI compared to the others ($P \leq 0.05$) (Fig. 2). There was positive correlation between CT and LMI in 2013 (0.74) and in 2014 (0.53). Armstrong et al. (2013) also indicated tanniferous browse effectiveness against helminthic, reducing up to 65% of the motility using dry, fresh and distilled *Juniperus pinchotii* terpenoid oil.

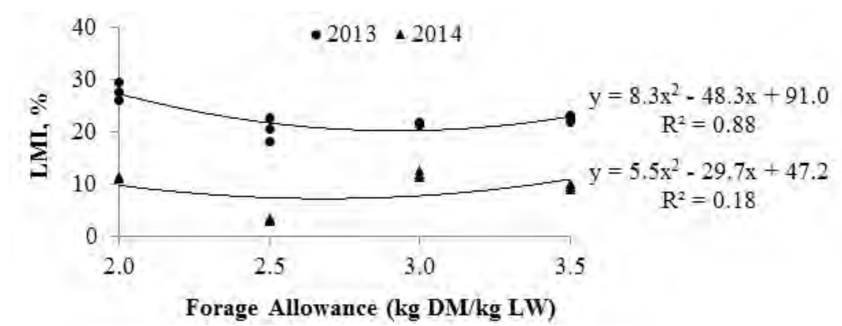

Figure 2. Regression between forage allowance and LMI from *Bauhinia cheilantha* browses during 2013 and 2014 ($P \leq 0.05$), in Caatinga, Pernambuco, Brazil.

Conclusions and Implications

Condensed tannins from mororó increased CH_4 suppression and *H. contortus* motility, but degree changes between years, likely due to other environment factors. When FA decreased, CT increased due to plant defense resulting lower LMI. However, CH_4 showed the opposite response.

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Crude Protein and Phenol Precipitated Protein from *Desmanthus pernambucanus* (L.) Thellung Submitted to Different Harvesting Regimes

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Key words: *Desmanthus* spp., phenol precipitated protein, condensed tannin

Introduction

Desmanthus spp. is one of the components of the ruminant diet when browsing Caatinga vegetation in northeast Brazil. Presence of polyphenols, such as condensed tannins, in *Desmanthus* species, might affect animal performance positively. These bind with proteins, reducing their degradation by rumen microorganisms. As a result, post-ruminal digestion of by-pass protein will increase availability of amino acids in the intestine, increasing its absorption by the animal. This study evaluated the crude protein and protein precipitated by polyphenols (PPP) in *Desmanthus pernambucanus* (L.) Thellung ecotypes managed under different harvesting regimes.

Materials and Methods

Plants were grown at the UFRPE Sugar Cane Experimental Station in Carpina, North Coastal Zone of Pernambuco State, Brazil. Three ecotypes of *D. pernambucanus* (6G, 7G and AusTRCF 49728) were cultivated in rows, and harvested at 40 and 80 cm aboveground. In March and October, 2015, leaves and stems < 6 mm were harvested with 75 and 120 days interval between cuts representing the dry and wet season, respectively. Treatments were allocated in split-split-plot arrangement in a complete randomized design, with two replications. Main plots were formed by *Desmanthus* ecotypes, harvesting intensities (40 and 80 cm) formed the split-plot, and harvesting interval (75 and 120 days) formed the split-split-plot. The PPP analyses were performed using a modification of the method used by Naumann et al. (2014). Crude protein was analyzed by dry combustion using a CN analyzer (Elementar Americas, Inc, Mt. Laurel, NJ, USA). Data was submitted to analysis of variance and means compared by Tukey test ($P \leq 0.05$). Means of cutting frequency and cutting intensity were compared using an F test and SAS statistical package.

Results and Discussion

Crude protein (CP) was affected by harvest frequency and plant fractions (leaf and stem), with leaves presenting greater CP than stems, when harvested both at 75 d (242 vs. 89 g kg^{-1}) and 120 d (201 vs. 84 g kg^{-1}), respectively. Leaf CP were considered high, but compatible with CP values observed in other forage legumes. It is important to further determine the proportion of the CP bound to the fiber component.

The PPP was affected by harvest frequency, harvest intensity, and ecotypes (Table 1). Observed PPP are compatible with the values reported by Cooper et al. (2014) in *Desmodium paniculatum*, with or without leaves, in distinct phenological stages, with averages ranging from 120 g kg^{-1} (flowering stage) to 32 g kg^{-1} (fruiting stage). Leaf fraction presented the greatest PPP values, with average of 58.1 mg g^{-1}, contrasting with 4.4 mg g^{-1} observed in the stems. The PPP values observed suggest a positive effect on animal performance, protecting the protein of *D. pernamucanus* from extensive ruminal degradation. This protection occurs because condensed tannins bind to proteins, increasing post-ruminal availability of proteins and amino acids for absorption by ruminant livestock and preventing bloating (Ramínez-Restrepo et al., 2004). The PPP values observed in *D. pernambucanus* might reduce methane emission from the rumen. Ramirez-Restrepo et al. (2010) indicated that condensed tannins may act indirectly by binding to dietary fiber and/or reducing ruminal digestion and fiber apparent digestibility, reducing the growth of methanogenic microorganisms as a result.

Table 1. Phenol precipitated protein (PPP) of *Desmanthus pernambucanus* (L.) Thellung ecotypes submitted to different harvesting regimes (mg g^{-1}).

Ecotype	75 d		120 d	
	40 cm	80 cm	40 cm	80 cm
		Leaf (mg g^{-1})		
6G	60.9 Aa	5.6 Bb	58.2 Ab	78.9 Aa
7G	13.4 Bb	77.9 Aa	102.5 Aa	105.6 Aa
AusTCF 49728	-	11.5 Bb	41.2 Bb	83.1 Aa
Ecotype		**Stem (mg g^{-1})**		
6G	4.4 A	-	-	1.2 Aa
7G	-	6.5 A	9.6 Aa	8.8 Aa
AusTCF 49728	-	-	0.3 Ab	0.4 Aa
Standard Error	9.9		7.0	

Means followed by similar lowercase letters within the same column, do not differ (*P*>0.05) by Tukey test.
Means followed by similar uppercase letters within the same row, do not differ (*P*>0.05) by F test.

Conclusions

Leaves of *D. pernambucanus* present great CP concentration, particularly when harvested at 75 d intervals. Harvesting frequency affects PPP. The *D. pernambucanus* ecotypes 6G and 7G presented greater PPP values when harvested every 120 days. The greatest PPP values were observed for the AusTRCF49728 ecotype, when harvested at 80 cm and every 120 days.

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Anatomical Structure of Leaves Originating from the Use of Annual and Perennial Pasture and Forage Plants Grown in the Desert Steppe of Mongolia

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Key words: Sudan grass, *Bromis inermis* Leyss, brome grass, leaf anatomy, irrigation

Introduction

Selection criteria for annual and perennial grasses and leguminous of pasture and forage grown in Mongolia include wintering ability, drought resistance, yield and high protein content. We carried out comparative research on physiological and anatomical structure in leaves of *Bromis inermis* and *Sorghum sudanense*.

Sudan grass is annual grassy and a forage plant. The native land for this species is the Sudan in North Africa. This species is drought-resistant, salt-tolerant and thermophilic, requiring 8-10°C temperatures for seed germination. The best temperature for seed germination is 25-30°C. This species is drought-resistant, that is why the root system consists of many long, fibrillose roots reaching more than 1-1.5 m in length. Intensive stalk growth begins from the moment of run out in the tube, and it stops at the end of flowering. Therefore, this species are reaped several times during the growing period with distinctive (The sowing annual grasses and leguminous of forage plants, 2011).

Materials and Method

Brome grass (*Bromis inermis* Leyss) was the perennial species examined and Sudan grass (*Sorghum sudanense*) was the annual species examined. These species were examined on irrigated and non-irrigated treatment in the region of Delgertsogt soum of Dundgovi province in first desert steppe of Mongolia in 2011.

We studied “novel” digital microscope with picture and anatomical structure of leaves in accordance method in plant anatomy (Gamalei, Shiirevdamba, 1984; Tserenkhand, 2013). We are carried degree of aridity and measure of leaf anatomy of quantitative and qualitative features in cells and tissue levels, which is used ocular micrometers and Goryaeva net instrument.

Results and Discussion

The first year, *Bromus inermis* was shortest at 23.8 cm tall. A *Sorghum sudanense* was high-yield 5890 kg/ha and stem 103 cm tall in irrigation area. But non-irrigated area was very low-yielding 1080 kg/ha and stem 61.3 cm tall (Bayasgalan, 2011).

Leaf anatomy of Brome grass

Leaf type is homogeneous; chlorenchyma had a thin cell wall of approximately 3-6 layers consisting of uniform parenchyma tissues. This species was linear of upper and lower epidermal cell wall, with large motor cells. Brome grass also had anomocyte type of amphistomatic in the stoma and a relatively large stoma valley. Collateral vascular bundle was surrounding the sclerenchyma.

Leaf anatomy of Sudan grass

Leaf type was homogeneous; chlorenchyma had 3-5 layers consisting of uniform parenchyma tissues. The upper layer was dome-shaped. This species had anomocyte type of amphistomatic situation in the stoma but upper epidermal cells had a low stoma and lower epidermal cells had a large number of stoma. Sudan grass has a collateral vascular bundle, which is sclerenchyma.

Cells and tissues of leaf anatomy structure in Brome grass and Sudan grass
When irrigated, brome grass had the following relative proportion of tissues: epidermal cells-8.45%, motor cells-5.01%, mechanical tissues (sclerenchyma)-2.13%, intercellular-16.5%, chlorenchyma-63.08%, vascular bundle-4.83%. Brome grass had increased number of epidermal cells, motor cells, mechanical tissues and intercellular when irrigated, leading to a decrease in tissues and vascular bundle in non-irrigated compared to the irrigated.

Brome grass was increased mean numbers of stoma from the non-irrigated 2.83 to the irrigated treatment 7.13. Sudan grass was increased mean numbers of stoma from the non-irrigated 30.13 to irrigated treatment 34.54. A motor cells numbers of Brome and Sudan grass was comparatively constant.

Brome grass was increased intercellular proportion from the non-irrigated 14.25% to the irrigated treatment 16.5%. Sudan grass had increased intercellular proportion from the non-irrigated 7.8% to irrigated treatment 8.6%. But the motor cells numbers of Brome and Sudan grass was comparatively constant. The irrigated treatment was sparse for comparatively in cell and tissues. Sudan grass is features the ability to resistant dryness (Figure. 1).

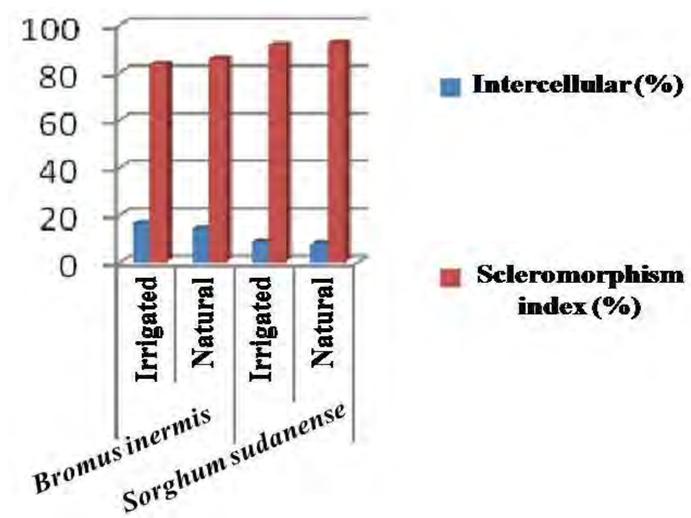

Figure 1. Intercellular and scleromorphism index (%).

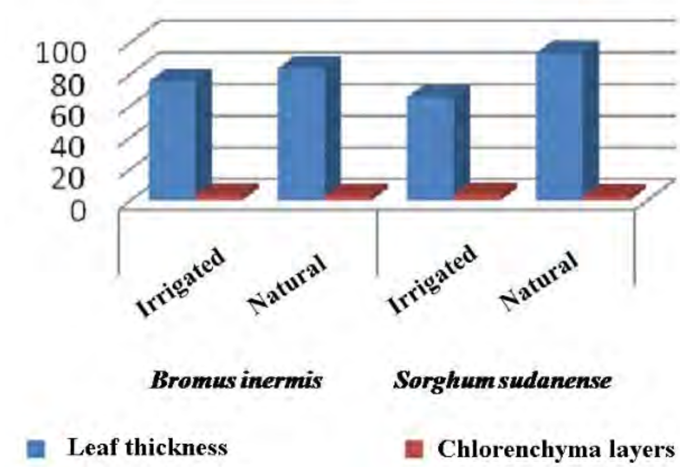

Figure 2. Leaf thickness and chlorenchyma layer.

Brome grass had increased leaf thickness and decreased layers in the non-irrigated treatment. Non-irrigated Brome grass had a leaf thickness 83.5 µm (mean mesophyll layers-2.86) compared to the irrigated treatment which had a thickness of 75.23 µm (mean layers-2.86). Chlorenchyma tissue and motor cells are cause from stored water. Irrigated sudan grass had increased leaf thickness treatment 65.12 µm compared to the non-irrigated 93.26 µm (Figure. 2).

Conclusion

The irrigated treatment had increased epidermal cells size, motor cells size, mechanical tissues size and intercellular size; also increased numbers of epidermal cells and stoma, number of motor cells, with thin leaves. The non-irrigated treatment had decreased chlorenchyma tissues size and vascular bundle size, increased cell wall and leaf thickness. In the non-irrigated treatment, intercellular has decreased and cell wall of epidermal cells has increased, it is directly related to environment of the specific plant. The irrigated treatment, Sorghum Sudanese was yields of 5890 kg/ha, it is compared to the non-irrigated treatment which realized yields of 1080 kg/ha. It presents, that much yields unavailable in ecological stress.

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Supplementation with Baked Rapeseed Causes Reduction of Methane Emissions from Growing Feedlot Yak (*Bos grunniens*)

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Key words: rapeseed, yak (*Bos grunniens*), methane emission, sulfur hexafluoride (SF_6)

Introduction

There are about 13.7 million yaks (*Bos grunniens*) in the world, of which more than 94% are distributed in China, mainly on the Qinghai-Tibet plateau in area of altitude ranging from 2500 m to 6000 m. The yak has been regarded as one of the most remarkable domestic animals since it thrives in extreme harsh environment and grazing conditions while providing a livelihood for people (Wiener *et al*., 2003). Methane emission inventories for yak enteric fermentation and manure management has been estimated at about 161.8 - 333.8 Gg/y for all grazing yaks in Qinghai-Tibet plateau (Xue *et al*., 2014). A century old grassland yak production cycle has been used, where the yak is expected to satiate in summer, fatten in fall, become thin in winter, and may die in the spring on the Qinghai-Tibetan plateau (Xue *et al*., 2005). Currently, to improve the efficiency of feeds utilization and reduce methane emission in yak production of Qinghai-Tibet plateau is a big challenge. The objective of this research was to elucidate how baked rapeseed supplementation reduces methane emissions in growing feedlot yak.

Materials and Methods

All experimental yaks were cared for according to the Guide for the Care and Use of Laboratory Animals of Qinghai Province (2002). A total of eighteen 3 year old growing yak steers were chosen randomly from the same herd and used in the experiment. The yaks were weighed during the experiment with an electronic balance. All experimental yaks were fed indoor and divided into three groups in which baked rapeseed were added to the base diet at 0% (Control), 10% and 21.75%. The DMI per yak was 4.0 kg on the base diet (concentrate: forage was 70:30, forage was oat hay). Methane emissions from the yaks were estimated using the sulfur hexafluoride (SF_6) tracer technique (Iwaasa *et al*., 2004). One week adaptation period on the SF_6 collection systems occurred, followed by two consecutive collection periods (one was six days and the other was four days) in which gas samples from yokes were subsampled. A Beifen GC 3420 (Beijing, China) was used to analyze SF_6 and CH_4. The SF_6 was measured with an electron capture detector operating at a temperature of 300 °C, and the CH_4 with a flame ionization detector operating at a temperature of 280 °C. All measurements were compared against prepared standards.

Results and Discussion

Absolute daily CH_4 emissions per yak was highest for the Control and the 21.75% group was numerically lower, but not significant (P>0.05). Compared with the Control results of Ding et al. (2010), methane emission of 10% and 21.75% feed supplemented groups were decreased by about 26.23% when baked rapeseed was added to the yak's diet. The tendency of CH_4 yield per unit DMI is similar to the result of CH_4 yield per day. The effects of the baked rapeseed additions were more pronounced when relating CH_4 yield per unit body weight gain. Comparing among groups, the CH_4 emission per unit body weight gain of the 10% rapeseed addition was lower ($P<0.01$) compared to the control and similar to the 21.75% rapeseed level.

Table 1. Influence of different levels of added baked rapeseed to diet of yak on methane yield (± SEM)

Items	Ding et al., 2010 Forage diet	0%	10%	21.75%
CH_4 yield per day, g/d	88.9	83.55±8.16	65.58±13.08	65.21±16.17
CH_4 yield per unit DMI, g/kg	23.2	20.52±2.01	16.23±3.24	16.08±3.99
CH_4 yield per unit body weight gain, g/kg • d, BWG	-	223.79±21.87 a	125.24±24.99 b	172.62±42.80 ab

Note: a-b Means in the same row with different letters are significantly different ($P<0.01$).

Conclusions and Implications

Growing feedlot yaks showed the lowest CH_4 emissions when diet contained 10% baked rapeseed, which was a very efficient tool to diminish methane emissions and improve performance of yak on the Qinghai-Tibetan Plateau.

Acknowledgments

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The Diversity of Fungi Associated with *Oxytropis kansuensis* among Three Locations in China

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Key words: Endophytic fungi, Locoweed, ITS, genetic diversity

Introduction

Locoweeds are prevalent in the western China, which are toxic legumes in the genera *Astragalus* and *Oxytropis* that pose a major threat to livestock. In China, locoweeds are primarily distributed in Inner Mongolia, Ningxia, Qinghai, Tibet, Xinjiang, Sichuan, and Yunnan provinces. Consumption of locoweeds by cattle, sheep, and horses induces a neurological condition termed locoism. Locoism symptoms in cattle range from weight loss to nervous impairment and death. The toxic locoweed plants (*Astragalus* and *Oxytropis* sp.) contain the alkaloid swainsonine. Several different fungi synthesize swainsonine, an indolizine alpha mannosidase inhibitor, including *Undifilum* sp., *Slafractonia (*formerly *Rhizoctonia) leguminicola*, *Metarhizium anisoplae* (an entomopathogenic fungus) and *Chaetothyriales* spp. *Undifilum oxytropis* isolated from locoweeds was shown to produce swainsonine. Nothing is known about the association of other fungi with locoweed plants. This study sought to evaluate the diversity of fungi associated with *Oxytropis kansuensis* locoweed plants collected from western China.

Materials and Methods

Oxytropis kansuensis plants were collected from Qilian county of Qinghai province (Qilian), Tianzhu county of Gansu province (Tianzhu) and Menyuan county of Qinghai province (Menyuan) in July to August 2012. Mature plants with flowers and seeds and healthy-looking plants were collected when available. Samples of similar tissues from a location were pooled and then were separated and processed in triplicate. Samples were dried using allochroic silicagel, taken back to the lab, and stored at -20°C.

Fungi were isolated from locoweed tissues and identified by morphological features and sequencing of the internal transcribed spacer (ITS) regions. Both α-diversity and β-diversity indices were calculated for fungi grown on different media and growth conditions using Estimate S.

Results

Fungal colonies (985) were isolated from 2489 tissues; *Undifilum* (443 isolates), *Alternaria* (196 isolates) and *Stagonosporopsis* (153 isolates) accounted for 45.0%, 19.9%, and 15.5% of the total respectively, which were assigned into 41 species. For β-diversity, Motisita-Horn index and Jaccard index showed that there was highest similarity in results from Qilian county and Menyuan county of Qinghai province.

Discussion and Conclusion

In our study, the growth of endophytic fungi was observed under different cultural conditions. Four hundred seventy isolates were cultured from 1104 tissues in dark (isolation rate of 42.6%), 515 isolates were cultured from 1234 tissues in the light (isolation rate of 37.2%), 507 isolates were cultured from 1385 tissues on PDA (isolation rate of 41.1%) and 482 isolates were cultured from 1255 tissues on BDA (isolation rate of 38.4%). Twenty-five species were isolated on PDA, 34 species on BDA, 32 species were isolated in the dark and 21 species in light. Five species were only isolated on PDA, and 14 species were only isolated on BDA, while 17 species were only isolated under dark conditions, and 7 species were only isolated under light conditions. These results suggest that the isolation rate could be improved by culturing in the dark on BDA media.

Environmental conditions effect which fungi will survive in a particular locations. Qadriet al. (2013) indicated factors such as soil conditions might also influence the colonization of endophytes in the plant tissues. Oldrup et al. (2010) showed that swainsonine levels were greatest for *O. sericea* and *Undifilum* cultures in PEG or hydrochloric acid-amended media, and plants grown in PEG-amended media had significantly greater dry mass, while *Undifilum* grown in PEG-amended media had lower dry mass than other treatments.

The plant phyllosphere is a dynamic environment in which biotic and abiotic factors affect the structure and species composition of the fungal communities that colonize roots, stems, branches, and leaves. The presence and composition of endophytic communities likely depend on the interaction with other endophytic and may vary according to season. In this study, *Undifilum* was isolated from the aerial parts of *O. kansuensis*; this might be caused by different species of locoweeds, or influenced by the different growing stages of sample collection.

In addition, plants were collected at different phenological stages. Most *O. kansuensis* in Tianzhu were in the late flowering/early pod stage, and only a few were at full pod, while in Menyuan, most of the plants were in the full pod/mature seed stage. During this sampling period, the plants were subjected to the most extreme environmental temperature differentials within the group. It is not unexpected that the diversity of fungi associated with a plant would change as a plant ages.

In this study, the three sites had similar climatic conditions and habitat (meadow steppe), and as the altitude increased, the temperatures were colder. This may explain why *Undifilum* had the highest isolation rate in Menyuan. Arnoldand Lutzoni (2007) found that endophyte communities from higher latitudes are characterized by relatively few species from many different classes of *Ascomycota*, whereas tropical endophyte assemblages are dominated by a small number of classes with a very large number of endophytic species. Our results suggested that as altitude increased, the number of species of fungi decreased, but the relative isolation rate of *Undifilum* increased.

The endophytic fungal community of *O.kansuensis* showed diversity. The results showed that Fisher-α index was from 5.7 to 8.7, Shannon index was from 1.8 to 2.0, and the Simpson diversity index was from 3.7 to 3.8. This work showed minimal differences in locoweed diversity among locations, which is likely due somewhat to pooling of samples. A different sampling plan without pooling samples and using the same number of plants from each location might show differences. In addition, the fungi isolated are common in semiarid grasslands, comparable to other similar climatic conditions (Khidir*et al.* 2009). Our experimental results showed that many factors, including culture conditions and growth environment influence the isolation rate and diversities of fungi. In agreement with previous research, in our study, *Undifilum oxytropis* was the species most isolated from *O. kansuensis*.

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Nutritive Value and Condensed Tannin Concentration of Some Tropical Legumes

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Key words: Tropical legumes, condensed tannins, forage, nutritive value

Introduction

Ruminant livestock production in Ghana and other parts of the world relies heavily on forages. Forages play an important role in the diets of ruminants by providing protein, energy, minerals and vitamins. Forage legumes in general have higher protein, pectin, carotene and vitamin content than grasses but have lower levels of water soluble carbohydrate, cellulose and hemicellulose (Frame, 2005). They are able to improve soil health by fixing atmospheric nitrogen and reduce use of fertilizer. Some forage legumes contain condensed tannins (CT), which are high molecular weight phenolics and bind forage proteins as the plant is masticated by ruminants. The CT protect the plant protein from microbial digestion in the rumen without significantly decreasing intestinal digestion or amino acid absorption (Wang et al. 2007). CT may also reduce the amount of methane (CH_4) produced in cattle consuming forage-based diets, a factor that could improve energetic efficiency in cattle and reduce their contribution to greenhouse gases. The objective of this study was to determine the nutritive values and CT concentrations of some tropical forage legumes.

Materials and Methods

Pure stands of six forage legumes made up of five herbaceous and one shrub species, *Centrosema pubescens*, *Macroptilium artropurpureum*, *Mucuna pruriens*, *Pueraria phaseoloides* and *Stylosanthes guianensis* (herbaceous), and *Cajanus cajan* (shrub) were established under rain-fed conditions at Pokoase in the Greater Accra Region of Ghana in 2010. Plot sizes were 4 m x 4 m with four replicates using a randomized complete block design. Plants were harvested in 2011 at full flower at 5 cm above ground for the herbaceous species. Samples were dried at 55°C in a forced-air oven for 72 h. Dried samples were ground to pass a 1-mm screen in a Wiley mill and analyzed for crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF). Forage samples for extractable condensed tannins (ECT) analysis were freeze dried and analyzed using methods described by Terill et al. (1992). Data were analyzed using ANOVA MIXED Procedure of SAS (2005).

Results and Discussion

The CP content of these forage legumes ranged between 13.8 and 17.6 g kg^{-1} (Table 1) and are similar to values of most temperate forage legumes but greater than reported mean values (≤ 10 g kg^{-1}) of most grass species used in pastures or on rangelands in Ghana. Three species (Cajanus, Mucuna and Stylo) contain moderate concentrations of ECT (2.0 to 3.2 g kg^{-1}) while the other three (Centro, Macroptilium and Pueraria) contain insignificant concentrations; less than 0.5 g kg^{-1} (Fig. 1). The CT in the three species will help improve N utilization in grazing animals especially during the dry season when the nutritive quality of most rangelands in Ghana is poor. These species could be seeded as monocultures and fed to ruminants without the fear of pasture bloat since CT-containing forages do not cause bloat in ruminants.

Table 1. Mean crude protein, acid detergent fibre and neutral detergent fibre (g kg^{-1}) composition of six forage legumes seeded in Accra, Ghana under rain-fed conditions

	Cajanus	Centro	Macroptilium	Mucuna	Pueraria	Stylo
			g kg^{-1}			
CP	14.2a	17.1b	16.1b	13.8a	13.6a	17.6b
ADF	40.3bc	42.0c	37.8a	36.5a	42.1c	38.6ab
NDF	46.4a	55.8b	48.3a	43.8a	53.1b	46.2a

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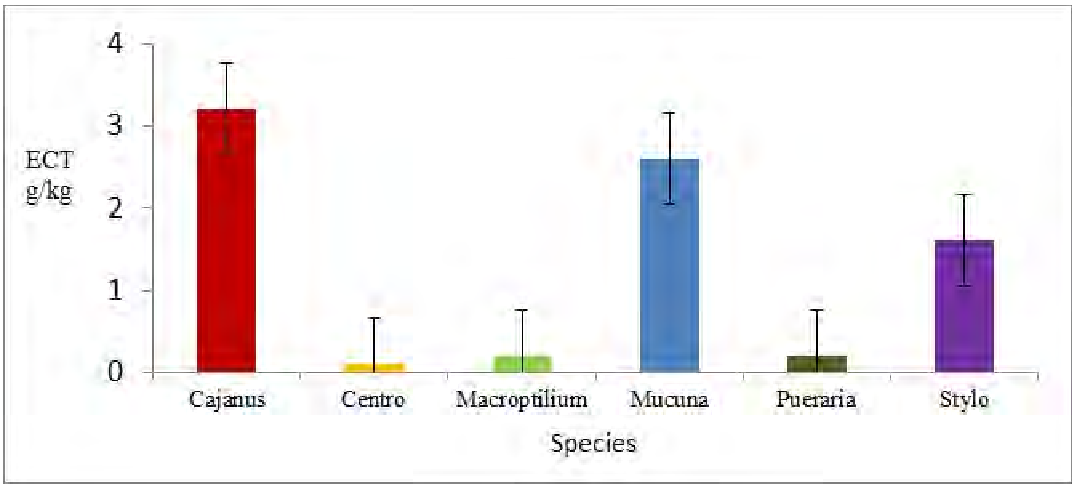

Figure 1. Extracted condensed tannin (ECT) concentration (g kg^{-1}) of six forage legumes seeded in Accra, Ghana under rain-fed conditions.

Conclusion

These species will serve as good forage legumes in mixtures with grasses because of their high CP concentrations, and they could be used for pasture restoration and improving rangelands. Grazing livestock will be able to utilize more efficiently the N from CT-containing species especially in the dry season when the nutritional quality of most forage species are low.

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Degradation Parameters and Crude Protein Fractions in Mature Tobosagrass Rangeland

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Key words: *Hilaria mutica*; grazing ruminants, protein degradability, rumen incubation

Introduction

Tobosagrass (*Hilaria mutica* [Buckl.] Benth) is a warm season, perennial grass that occurs from the southern end of the Great Plains of the central United States through west-central Texas into Arizona and south to north-central Mexico. In general, tobosagrass is considered to be low in quality for livestock. To improve livestock nutritional status on tobosagrass rangelands, supplemental feeding is required. Designing adequate nutritional program for cattle grazing requires knowledge of nutrient requirements, diet quality, and intake. Effectively using the National Research Council (NRC) beef cattle requirements model requires knowledge of dietary degradable intake protein (DIP) and crude protein (CP) fractions. A metabolizable protein (MP) system more accurately describes cattle requirements and types of proteins in feedstuffs (NRC, 1985, 1996) than does a CP system. Degradable intake protein must be supplied to meet the needs of rumen bacteria. Ruminants with high MP requirements for growth or lactation cannot usually meet their MP needs without supplemental undegraded intake protein (UIP) being supplied. Accurate measures of forage protein degradability are necessary to predict animal performance as well as appropriately supplement ruminants when high forage amounts are included in their diets.

Materials and Methods

To evaluate ruminal degradation parameters and protein fractions, extrusa samples were collected on tobosagrass rangeland. Three sampling periods were studied during two years using 6 rumen cannulated steers. In situ bags were incubated in the rumen at different times containing forage samples and using acid detergent fiber nitrogen (ADIN) as a control to correct microbial attachment. Objectives of this research were describing monthly changes during the winter season in crude protein fractions and protein degradation on native range. Samples were analyzed for CP, in vitro OM digestibility (IVOMD), and DIP. Regression equations to predict nutrients were developed from these data. *In situ* disappearance data was analyzed as a completely randomized design with periods (PER) as repeated measurements, and steers (REP) as experimental units for the test effect. Crude-protein fractionation was based on ruminal degradation described by Krishnamoorthy et al. (1983) where N is partitioned into Fractions A, B, and C. Fraction A is defined as the instantly soluble protein fraction plus nonprotein N; Fraction B corresponds to the slowly degradable portion for which the degradation rate is measurable; and Fraction C corresponds to the rumen undegradable portion. Fraction A was determined as the difference between the initial N in the sample and that remaining after incubation at 0 h, basically, that N solubilized in water. The OM and N disappearance from the dacron bags were expressed as a percentage of the original OM and N weighed into the bags. Protein (N) and organic matter degradation (extent and rate) were determined using the model of Orskov and McDonald (1979):

$$P= a+b (1-e-ct)$$

where a, b, and c are constants fitted by an iterative least-squares procedures. The calculated rate of CP degradation is associated with fraction B.

In situ effective degradability was calculated according to Orskov and McDonald (1979) as follows:

D = A + (B x Kd)/(Kd + Kr)
where
D = CP degradability (%);
A = fraction readily degraded (%);
B = fraction degraded at a measurable rate (%);
Kd = degradation constant rate of fraction B; and,
Kr = rumen passage rate (assumed to be 3.6%/h).

Results & Discussion
Dietary protein declined ($P<0.05$) from PER 1 to PER 2 in both years of this study. Crude protein levels increased ($P<0.05$) from PER 2 to PER 3. Furthermore, dietary protein content was similar ($P>0.05$) during PER 1 and PER 3. Protein fraction (A, B), and effective protein degradability decreased rapidly during February and increased to March (Fig. 1). In contrast indigestible protein, protein fraction C, increased during those months. Protein supplementation might be most effective during the second period (February) where the lowest forage protein contents were found. These data indicate that feed protein escape values may differ on different range types, even in winter.

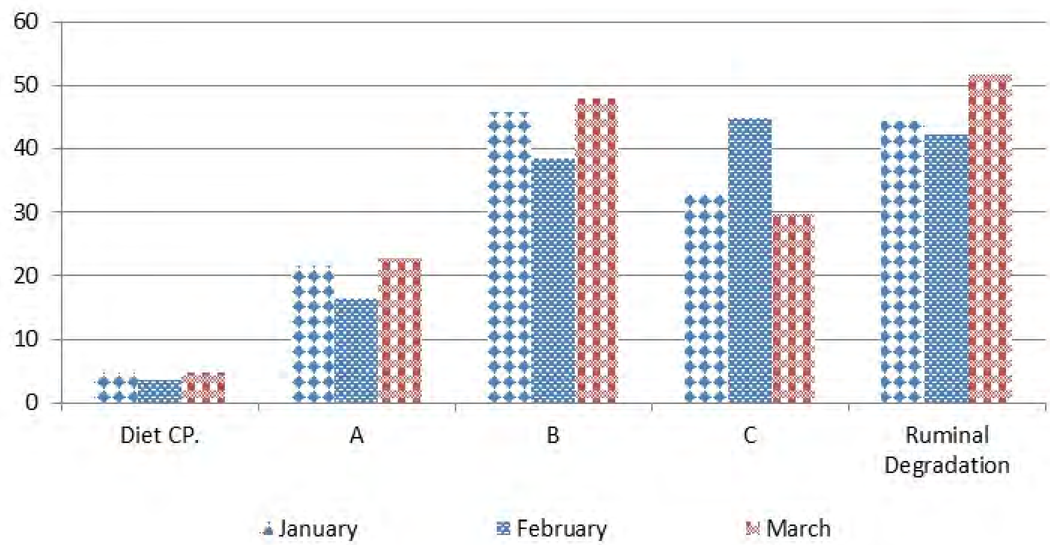

Figure 8. Crude Protein (CP) Fractions and effective protein degradation in dormant Tobosagrass Rangeland

Conclusions:
These results illustrate that no single estimate of protein escape can be applied to these feeding conditions. Therefore, there should be a combination of a rumen degradable as well as an escape protein to have a better animal performance.

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Beyond ad hoc Debates: A General Equilibrium Model Incorporating the Food–Feed Competition for Agricultural Land

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Key words: Food-feed competition, general equilibrium, land use, pasture-based production, price effect.

Introduction

Pasture based ruminant production systems can utilise land unsuitable for food production and therefore have the potential to contribute to global food security. However, ill-considered expansion of grasslands could also lead to reduction of human-edible cereals and unnecessary global warming, and thus the role of livestock production in the world economy has to be defined in a clear manner (Eisler et al., 2014). To date, investigations into this issue have primarily been conducted through the typical-farm approach (Kemp et al., 2013) and life-cycle analysis (Peters et al., 2010). While these studies offer valuable information regarding the relative desirability of studied farming systems, the majority of their solutions are only applicable to local regions. Economy-wide land allocation modelling (Van Kernebeek et al., 2015) partially overcomes this problem, but since the method operates under the unrealistic assumption of dictatorship, it fails to show the policy mechanism with which to achieve the resource allocation shown to be optimal by the model.

The objective of the present study is to propose a general equilibrium model (a class of economic model in which all prices move simultaneously to clear all commodity markets and factor markets) whereby the competition for land between food production and feed production is internalised under the standard assumptions of utility maximisation and profit maximisation. The proposed model allows us to analyse the price effect of policy interventions against livestock production (or equivalently carbon footprints) on the whole economy, and consequently to derive the optimal form of such interventions. The model has a mathematically explicit solutions and thus can be applied either theoretically or computationally.

Materials and Methods

The complete list of equations is available on request. In brief, the model consists of three players: representative producer, representative consumer and the government. Behaviours of each player and their interlinkage in the marketplace are described below.

Producers. Representative producer allocates the total land available to them between cereal production and grassland, the latter of which is used for pasture-based livestock production. The marginal productivity of cereal production decreases as they expand the arable land, while the marginal productivity of livestock production remains constant regardless of the area of grassland. Representative producer takes prices exogenously, and thus tries to allocate the land so as to maximise their profit given the relative price between cereals and livestock products (hereafter called "meat").

Consumers. Representative consumer allocates the total budget available to them between cereal consumption and meat consumption. For both the commodities, the marginal utility decreases as the level of consumption increases. Representative consumer takes prices exogenously, and thus tries to allocate the budget so as to maximise their utility given the relative price between cereals and meat.

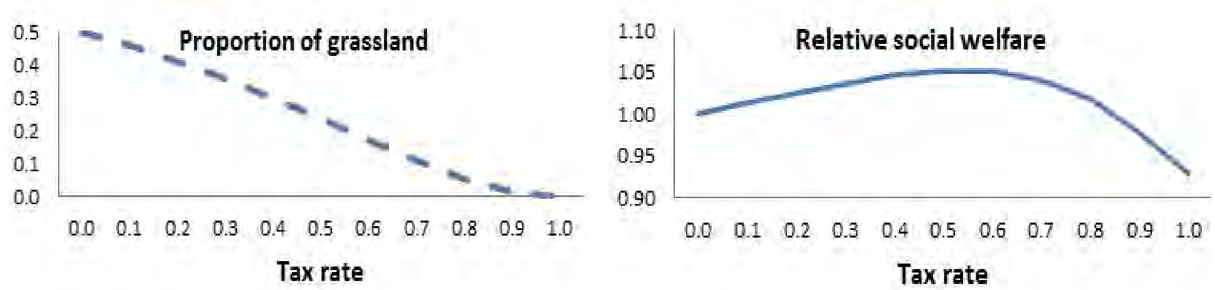
Ownership. Representative producer is owned by representative consumer. Thus, the profit earned by the former is returned to the latter in the form of the dividends. These dividends equate to the budget available to representative consumer. At the time of representative consumer's decision-making for their consumption, this budget constraint is taken as being exogenous.

Market. Given the producers' and consumers' behaviours outlined above, the profit-maximising supply for cereals and meat and the utility-maximising demand for cereals and meat can all be expressed as a function of the cereal price and the meat price (and the predefined set of parameters defining production technology and consumer preference, both of which are assumed to be constant). Thus at the market, these prices are endogenously determined at the levels where the demand for cereals matches that for cereals and the demand for meat matches that for meat. These prices are then given back to representative producer and representative consumer as exogenous information for their respective decision-making.

Government. Taking into consideration the global warming potential associated with meat production, the social welfare of the economy is represented as the sum of the consumer utility (positive) and the carbon footprint attributed to meat production (negative). The government tries to maximise this social welfare by intervening with the market through taxation, taking all other market behaviours exogenously. While taxation can take the form of either production tax or consumption tax, in the example below the government imposes production tax against meat production (or equivalently the landholding for pasture-based livestock production) at a constant rate. Because such tax has an effect to decrease the effective meat price for producers (but not for consumers), meat production is expected to decrease post-taxation. The tax revenue raised through this intervention is immediately given back to representative consumer, and thus it distorts the market from the free-market equilibrium without draining resources from the system.

Results and Discussion

Figure 1 depicts the effect of the meat production tax on producers' land allocation and the resultant social welfare derived under a set of model parameters. As quantitative solutions depend on parameterisation, the results of sensitivity analysis are available on request. Importantly, Fig. 1 suggests that excessive taxation on meat production lowers social welfare, a result that can also be demonstrated mathematically. This is so because the tax deters meat production and drives up the meat price, and consequently reduces consumers' purchasing power and thus utility. This finding challenges the real-world applicability of the dictatorship model and reiterates the importance of considering price effects in global warming studies, which has previously been discussed in the context of arable crop production (Li



et al., 2011).

Figure 1. Effect of the meat production tax on the area of grassland (left) and social welfare (right). While the left panel confirms that the production tax deters livestock production as expected, the

right panel demonstrates that excessive taxation drives up meat price too high (not shown) and thus is counter-effective to social welfare.

Conclusions and Implications

The general equilibrium framework proposed in the present study is expected to contribute to the evidence-based debates on the role of extensive livestock production for global food security. The model is now in the process of calibration using the dataset collected by Global Farm Platform, the largest consortium of livestock research farms in the world (http://www.globalfarmplatform.org). The model is further extendable to include livestock consumption of human-edible cereals and food wastes (amongst others), and thus can also be used to analyse, for example, the effect of food not feed policies on the social welfare.

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2.2 Carbon sequestration in rangelands

Trade-offs Between Management of Grazing Intensity, Soil Carbon and Biodiversity

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Key words: Total grazing pressure, ground cover

Introduction

High and prolonged grazing intensity results in negative impacts on sustainable production, biodiversity and soil carbon. Many studies have failed to accurately account for the additional grazing pressure from native and feral herbivores. We examined where trade-offs between soil carbon (C) and the natural resource (ground cover and biodiversity) occur through the control of total grazing pressure (TGP) by using partial exclusion fencing and incorporation of long periods of rest for red soils (Lixisols) in Australian semi-arid rangelands. These results are part of a larger, recently completed study.

Materials and Methods

Five paired analogue sites were used to examine the effects of rotational grazing with TGP exclusion fencing (treatment) on two commercial pastoral enterprises (Gilgunnia and Etiwanda). Contrasts between treatment for three vegetation communities (Box, Yarran and Ridges) were compared to no stock + high TGP (Gilgunnia) and no stock + high and low TGP (Etiwanda). At least twenty randomly located soil cores (0-5cm) were taken for each contrast in the centre of a 0.25 m^2 quadrat and total organic carbon (TOC) determined using LECO combustion (Waters *et al.* 2015). Particulate organic carbon (POC), resistant organic carbon (ROC) and humic carbon (HUM) were determined using Mid Infrared Spectroscopy (MIR) (Baldock *et al.* 2013). Ground cover and floristic diversity was measured in two 0.25 m^2 quadrats (soil core and randomly located quadrat). The percentage of perennial, annual, litter, cryptogam, dung, rock, bare and course woody debris (CWD) ground cover and the number of plant species within each quadrat, ultilisation of perennial grasses, proximity to a shrub or tree (<1m; <5m; >5m) were recorded. Invertebrate diversity was measured using pitfall traps along two (50 m) randomly located transects within each site and all specimens identified to the Family. At each site a 2 ha, randomly located plot was used to measure bird diversity and Microbat diversity for 2 hours (morning and dusk) and one night using an Anabat SD2™ Bat Detectors for birds and bats respectively. Mixed linear models fitted to TOC, POC, ROC and HUM were used to examine the treatment effect and correlations between soil and biodiversity measures using R statistical package.

Results and Discussion

Consistently higher ground cover (perennial and litter) was found where grazing intensity was controlled and combined with long periods of rest (90 to 300 days) (Fig. 1). Higher levels of TOC were found on one vegetation unit (Ridges) at Gilgunnia where grazing intensity was controlled (Rotational grazing + TGP fence) (Table 1). Ridges are susceptible to erosion and C decline, with more rudimentary soil formation compared to low lying, natural drainage areas (e.g. Yarran and Box). Feral goat populations tend to congregate on a ridge, which is confirmed by the higher levels of dung (Fig. 1) and higher perennial grass utilization (92 %). It is likely that where grazing intensity is controlled C is both accumulating in soil and protected from loss due to higher levels of ground cover (perennial and litter). Reduced soil loss is supported by the higher levels of POC and ROC with the management of grazing intensity (Table 1). While POC is the most labile fraction of C in soil and is considered to be a sensitive indicator of grazing management, we found no significant relationship between ground and woody cover and POC. However, there were significant differences in the more stable ROC and HUM C fractions. The significant correlation between increasing CWD cover and ROC ($R^2 = 0.83$, $P<0.005$) suggests that differences in ROC may not be due to grazing management but associated with trees and shrubs. Evidence supporting this is found at Etiwanda where the highest values of CWD were found with No stock + high TGP (Fig. 1) corresponding with higher tree density (4.9 vs 2.4 ha^{-1}) and higher TOC (1.38 vs 1.15 g/100g, Table 1) compared to the TGP fence treatment. The highest tree density (8.8 ha^{-1}) and the highest cover (perennial and litter) but lowest TOC was found on No stock + low TGP treatment (Table 1). As perennial grass utilization levels were low (3 %) for this treatment a lower grazing intensity may be preventing C accumulation and reducing C cycling through either lower root growth and/or turnover. Links between increased biodiversity associated with ground cover changes from the management of grazing intensity were found. Lower bare ground related to increased bird diversity ($R^2 = -0.72$, $P<0.05$) and increased perennial ground cover with greater plant diversity ($R^2 = 0.67$, $P<0.05$). However, invertebrate diversity was associated with higher amounts of dung ($R^2 = 0.67$, $P<0.05$) found in unmanaged areas (no stock + high TGP) suggesting invertebrates may be negatively affected by domestic livestock grazing. We conclude, while trade-offs in biodiversity may occur with the management of grazing intensity, the benefits of increased soil protection through higher perennial ground over and reduced loss of C in some part of the landscape will allow long-term sustainable rangeland pastoralism and the reversal of land degradation.

The Australian Federal Government, Department of Agriculture, Fisheries and Forestry (Soil Carbon Research Program), NSW Department of Primary Industries funded this research.

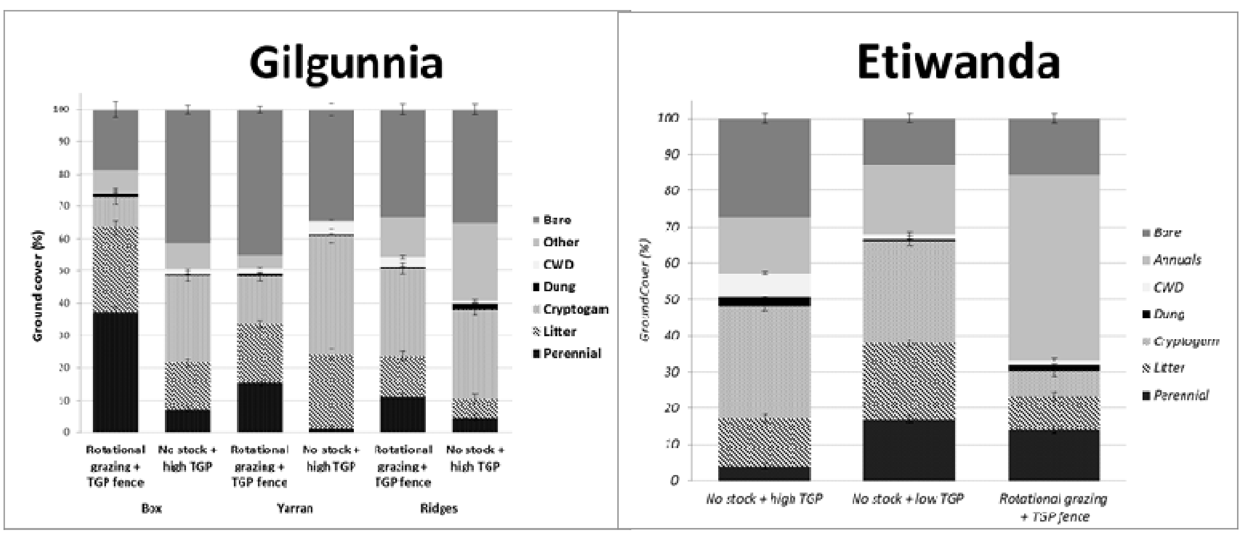

Figure 1. Differences in ground cover components for different grazing treatments (8 years) on pastoral properties (Gilgunnia and Etiwanda) in Australian semi-arid rangelands.

Table 1. Mean total organic carbon (TOC), particulate organic carbon (POC), resistant organic carbon (ROC) and humic carbon (HUM) in g/100g for 0-5 cm under different grazing treatments (8 years) in the semi-arid Australian rangelands. Counts are for invertebrate Families (Invert) and species (birds, plants and bats). LSDs TOC (0.18), POC (0.15), ROC (0.06), HUM (0.21).

	Gilgunnia	TOC	POC	ROC	HUM	Invert	Bird	Plant	Bat
Box	Rotational grazing + TGP fence	1.02^{bc}	0.21^{ab}	0.29^{a}	0.85^{bc}	27	12	26	8
	No stock + high TGP	0.90^{ab}	0.07^{a}	0.24^{a}	0.65^{ab}	34	46	9	7
Yarran	Rotational grazing + TGP fence	1.08^{bc}	0.11^{a}	0.26^{a}	0.70^{ab}	11	35	25	8
	No stock + high TGP	1.01^{bc}	0.11^{a}	0.24^{a}	0.56^{a}	24	20	10	10
Ridges	Rotational grazing + TGP fence	1.09^{c}	0.63^{c}	0.30^{a}	1.55^{e}	24	16	8	4
	No stock + high TGP	0.79^{a}	0.55^{c}	0.24^{a}	1.33^{d}	28	25	3	7
Pine	Etiwanda								
	No stock + high TGP	1.38^{d}	0.27^{b}	0.42^{b}	0.96^{c}	63	42	26	8
	No stock + low TGP	1.01^{bc}	0.12^{ab}	0.24^{a}	0.55^{a}	39	55	33	7
	Rotational grazing + TGP fence	1.15^{c}	0.17^{ab}	0.28^{a}	0.66^{ab}	31	54	24	9

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The Implications of the Emerging Carbon Economy for the Management of the Rangelands of Western New South Wales

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Key words: Carbon sequestration, rangelands management, invasive native species.

Introduction

Improving the land condition of Australia's rangelands has the potential to sequester 100 million tonnes (Mt) of CO_2e per year for 40 years (CSIRO, 2009). Improved herd management could lead to an additional 20% reduction in greenhouse gas emissions (GHG) with an 80% reduction possible by 2050.

Rangelands cover 81% of Australia (over 6 million km²) and improving land management of the degraded areas provides the single largest GHG sequestration opportunity in Australian agriculture. Australia's estimated total emissions for the 2014-15 period are 549 Mt CO_2e. Achieving the full potential for rangelands sequestration would exceed Australia's current total emissions from agriculture.

The full potential for GHG emissions reductions from the rangelands will not be realised through carbon economy participation. This is due to the complexity and cost prohibitive nature of measuring actual GHG changes and also to the framework of regulations and international agreements that prevent a number of activities being eligible to generate a tradeable carbon credit.

Materials and Methods

The Emissions Reduction Fund (ERF) is the Australian Government policy for managing GHG emissions. This policy aims to achieve the lowest cost abatement by enabling activities across the full scope of the Australian economy to generate a tradeable Australian Carbon Credit Units (ACCU). This includes the land sector (foresters, farmers and ranchers) who generate ACCUs by undertaking land and livestock management activities to increase sequestration or reduce emissions.

The eligible activities for generating an ACCU are outlined through project methods. The methods outline how to carry out a project and measure the resulting reductions in emissions. The ERF has been developed with the intent that activities with negative impacts will be excluded through the method design. Methods applicable to the rangelands include emissions reductions activities including feeding nitrates to beef cattle, improving herd management to reduce the emissions per kilo of beef turned off and managing late season fires in the northern sub-tropical rangelands. Sequestration activities include increasing carbon in grazing system soils, avoided deforestation of native forest (a vegetation community with greater than 20% canopy cover of trees greater than two metres tall and greater than 0.2 hectares) or forest regrowth and human induced regeneration of a native forest.

Invasive native species (INS) are native species of woody vegetation (within their natural geographic distribution) that regenerate densely following disturbance or invade plant communities where they previously did not occur, changing vegetation structure and/or composition (State of NSW, Local Land Services, 2014). INS occurrence is caused by a combination of interacting factors including suppression of fire, intensified total grazing pressure and adverse climatic conditions.

Many areas of the semi-arid rangelands of NSW that have a dense understorey of INS, were reportedly grassy plains with a few tall trees and shrubs at the time of European settlement. INS results in increased management costs, reduced cover of perennial grasses and herbage, reduced stock carrying capacity and an increased risk of soil erosion, amplifying the effects of drought (Jessop, 2009).

Results and Discussion

The first ACCUs were issued in 2011 and over 214 projects have been registered across the Australian Rangelands. Forward contracts for the land sector have identified the provision of 66.7 million tonnes of abatement, which equates to 71.9% of the total 92.8 million tonnes of abatement contracted across all sectors. In the rangelands of Western NSW over 139 projects have been registered with the government regulator, 81 of which are contracted to deliver ACCUs to the Australian Government through the ERF.

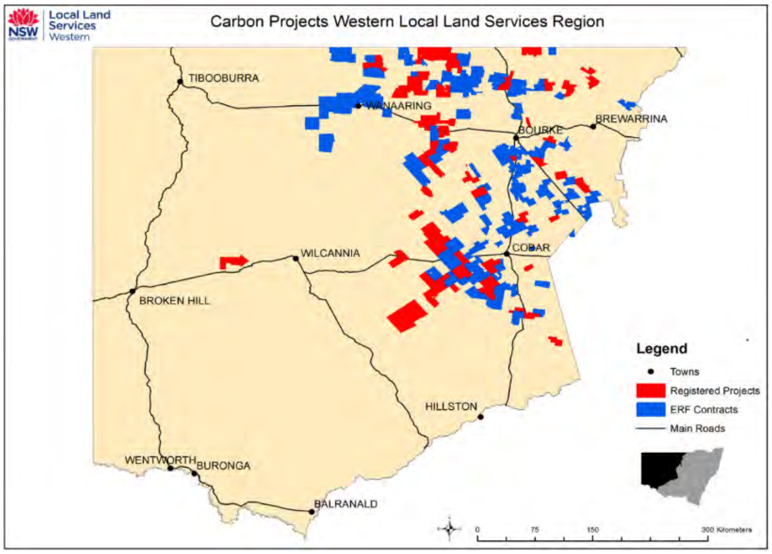

Figure 1. Properties with registered carbon farming projects (red) and sales contracts (blue) in Western NSW.

All current projects in Western NSW involve the avoided deforestation (landholders surrender clearance permits intended to enable the clearance of INS for cropping or to improve native grass cover for grazing) or human induced regeneration methods (changed land management practices to support the regeneration of native species through in-situ seed sources) and maintenance of the carbon store for either 25 or 100 years.

The full value of the ACCUs that have been sold or are contracted for sale over the next 7–10 years is not publicly available however estimates based on the published average price achieved indicate a value of approximately $400 million (AUD) over 10 years. This compares favourably to the value of traditional industries (wool $76 million/yr, cattle $42.5 million/yr, sheep $66.7 million/yr).

Conclusions and Implications

The emergence of the carbon economy provides a new income source in a pastoral economy dealing with increasing challenges to profitability. However this new industry brings many challenges for land managers and regulators with a number of conflicting outcomes between traditional pastoral practices and carbon sequestration projects.

Current management recommendations for INS are targeted at clearing existing areas and preventing further spread, to reinstate a mosaic grassy woodland supporting stable perennial pastures. This is in conflict with the desire to preserve and increase INS for carbon storage. Additionally, increased groundcover through the management of total grazing pressure will increase the fire risk and project proponents are liable for losses of carbon stocks through fire.

Landscape-scale changes in pastoral and ecological values due to thickening and encroachment are widely-documented in rangeland literature. The avoided deforestation and enhanced regeneration models challenge existing wisdom on what are good outcomes for rangelands. On the other hand, funded projects provide a once in a generation opportunity for landholders to develop infrastructure and improve property management.

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Taking into Account Carbon Sequestration of Pasture in Carbon Balance of Cattle Ranching Systems Established after Deforestation in Amazonia

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Key words: Deforestation, carbon (C) sequestration, C balance, livestock systems, GHG

Introduction

Livestock development in the Amazonian basin has fuelled a lively international debate in recent decades. According to the FAO, approximately 80% of deforested areas were converted into pastures resulting in rapid carbon (C) emissions (~ 733 $tCO_2eq.\ ha^{-1}$) (Blanfort et al., 2014). Thus, efforts to curb deforestation should continue to be a priority to preserve C stocks and forest biodiversity. In addition, this also needs to be accompanied by sustainable management of areas that were converted into pastures, including strategies for greenhouse gas (GHG) mitigation. Few references are available in tropical areas and there is still important work to be done to establish the baselines and strategies to support sustainable grazing activity in these regions. In French Amazonia, a regional research platform contributes to the Carbon Observatory (GEC) aiming to provide solutions to these problems. The first stage of research focuses specifically on how cattle ranching systems affect C stocks in pastures where *Brachiaria* spp. is the dominant implanted grasses following deforestation. The eddy covariance flux measurements and a chronosequence study in 2012-13 showed that pastures issued from deforestation two decades after their introduction stored in the soil between 6.4 and 19.4 ± 7.7 $tCO_2eq.\ ha^{-1}\ yr^{-1}$ (Blanfort and al., 2014 ; Stahl and al., 2016). Considering these results, a second phase of research, presented in this article, consists of establishing C/GHG balance and efficiency of livestock systems of French Guiana.

Materials and Methods

Data were collected on 8 cattle farms from the French Livestock Institute network representing 3 typical stages of development of Guiana's livestock: 2 small land owners (SLO), 3 developing farms (DF) and 3 large land owners (LLO). Direct and indirect GHG emissions from farm scale (CO_2, N_2O and CH_4) were calculated in 2013 using the ACCT method (a tool for energy and emissions analysis in farms based on different international standards and protocols, AgriClimate Change project, 2013). According to specific studies led in Guiana (Stahl and al., 2016), C sequestration from grassland in 2013 is considered as null for recent pastures, and of 6.4 $tCO_2eq.\ ha^{-1}\ yrs^{-1}$ for those of more than 24 years old. The GHG emissions resulting from the past conversion from forest to grassland (C stock variations on the aerial and underground compartments) are estimated using a tier 2 IPCC method (Fig 1). Livestock systems of Guiana are compared to i) an extensive ranch in central Africa based on traditional use of natural *Hyparhenia* spp. savanna and *Brachiaria* spp. improved grasslands (Lecomte, 2015), ii) Brasil Amazonian cattle extensive farm (Clerc et al., 2012), iii) temperate grazing system.

Results and Discussion

GHG emissions from the livestock systems studied, varied in response to their degree of development. The GHG emissions of smallholders and developing farms (DF & SLO: 2.8±0.8 $tCO_2eq.\ ha^{-1}$) are close to the references of the Congo ranch on *Bracharia* spp. (2.3±0.5 $tCO_2eq.\ ha^{-1}$). However, the developed farms have greater emission rates (LLO: 5.1±1.0 $tCO_2eq.\ ha^{-1}$) close to systems in the French temperate area (5.6 $tCO_2eq.\ ha^{-1}$). Thus, the dynamic of development over time of farms (DF > LLO) seems to lead to an increase of GHG emissions per hectare, due to the rise in the stocking rate and inputs (fertilizers, oil consumptions etc…). Nevertheless, these stable systems (LLO) are characterised by a yearly C sequestration of older grasslands (i.e. >24 years old) that compensates on average for up to 80% of the GHG farm's emissions in 2013. GHG emissions linked to deforestation are mainly due to variations of C stocks of the aerial compartment (CO_2, N_2O, CH_4 emissions from the forest biomass combustion) (Fig. 1). The underground C stock variations are more important in deep soil than in the surface layers on farms where deforestation is most recent (RF). In stable farms (LLO), deforestation goes back more than 20 years and the conversion of forest into grassland induces an increase of C contained in the deep ground.

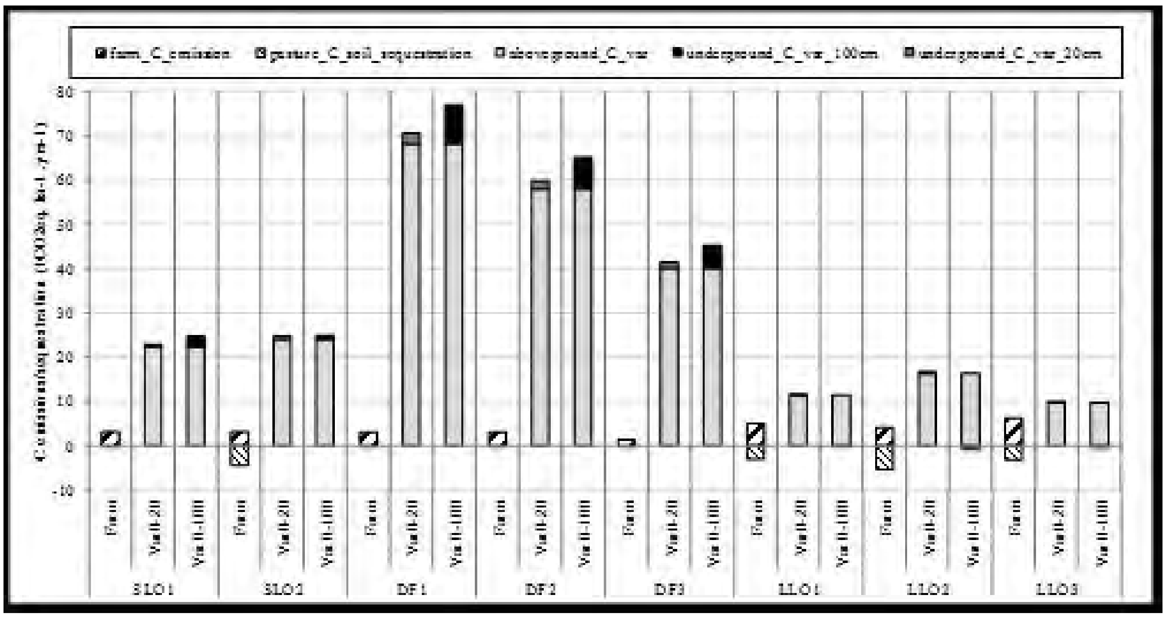

Figure 1. C emissions / sequestrations of 8 livestock systems in French Amazonia: C stock variations after deforestation (i) in the aboveground compartment (aboveground_C_var), ii) in the underground compartment for the first 20 cm (underground_20cm) and iii) on 1m of depth (underground_100cm).

Conclusions and Implications

In Amazonia, the current challenge is to manage the deforested areas to maintain the productivity of livestock systems alongside their capacity to mitigate GHG. This study offers to combine different methodological approaches incorporated in the diagnosis GHG tool of pasture systems. This tool allows to take into account the yearly direct and indirect emissions of livestock systems, grassland C sequestration, and the yearly GHG impact of deforestation. An increased effort in sampling, and a focus allowing to assess the impact of practices, would be necessary to confirm these tendencies, and will be the object of further studies. From a broader point of view, this study contributes to the emergence of references in the Amazonian basin, for a more sustainable management of deforested lands. This study also highlights the importance of considering deep soil layers in grassland's C balance establishment (according to Stahl and al., 2016), in comparison to the current IPCC method based by default on the first 30cm.

Acknowledgements

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Methane and Nitrous Oxide Emissions from Cattle Dung and Urine Patches on a Tame Pasture

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Key words: Greenhouse gas emission, grazed grassland, semi-arid climate, dung, urine

Introduction

In western Canada, the cow-calf system accounts for 80% of total greenhouse gas emissions from beef production. About 23% of emissions from manure are derived from N_2O and 4% from CH_4 (Beauchemin et al. 2010). In Canada, specific emission factors for beef cattle dung and urine have not been developed, instead default greenhouse gas emission factors for manure (dung + urine) excreted onto pastures are used. Accounting for the N_2O and CH_4 emissions from both dung and urine is important for improving estimates of the greenhouse gas contribution of the cow-calf system in western Canada, and for developing management practices that mitigate N_2O and CH_4 emissions.

Using N_2O as an example, the default IPCC emission factor for cattle excreta deposited by grazing animals onto pastures is 2% (no distinction between urine and dung), with an uncertainty range from 0.7% to 6% (IPCC, 2006). If data are available for a country, specific emission factors can be used for national inventories or communications, which are important for accurately assessing greenhouse gas emissions. New Zealand uses a country-specific emission factor of 1% for urine and 0.25% for dung (New Zealand, 2012), while Australia uses 0.5% for urine and 0.4% for dung (Australia, 2012). However, there is limited information available on N_2O emission and even less on CH_4 emission from dung and urine excreted on pastures in semi-arid regions of Canada. Therefore, the objective of this research was to quantify CH_4 and N_2O emissions from cattle dung and urine patches on a tame pasture in the semi-arid climate of southern Alberta.

Materials and Methods

The field experiment was conducted from June 2014 to June 2015 on a tame pasture at the Lethbridge Research and Development Centre (Latitude: 49.693142, Longitude: -120.762950). The pasture was predominantly orchard grass (*Dactylis glomerata* L.) and smooth brome grass (*Bromus inermis* Leyss.). The study site was mainly used for moving cattle and was occasionally grazed to control biomass and weeds. Beginning in summer 2014, the site was rotationally grazed by sheep at stocking rates of 16 AUM ha^{-1} and 19.6 AUM ha^{-1} in 2015. The dung samples were collected from a cow-calf operation on a pasture near the field site and mixed thoroughly prior to application. Urine samples were collected from a controlled metabolic study.

A randomized complete block design with three treatments and four replications was used in this study. The treatments were: urine, dung and a non-amended control. Vented static chamber bases (30-cm dia. x 15-cm ht.) were inserted 5-cm into the soil. Fresh 1.5 kg (wet mass) samples were placed in chambers designated for dung treatment and 0.55 L urine was added to chambers designated for urine treatment, while 0.55 L distilled water was added to the control chambers at the start of experiment on June 23, 2014.

The urine contained 11.4 g C L^{-1} and 8.5 g N $L^{-1}$and had a pH of 6.7. The dung contained 271 g total C kg^{-1} and 19.2 g total N kg^{-1} with a dry matter content of 314 g kg^{-1} and pH of 7.5.

Gas samples were collected from each chamber two to three times for the first two weeks and weekly thereafter. At the time of gas collection, chambers were covered with lids and 10 mL gas drawn from the chamber at 0, 15, 30 and 60 min after chamber closure and injected into pre-evacuated vials. The gases were analyzed with a gas chromatograph (Varian 3800) for CH_4 and N_2O concentration. The gas fluxes were calculated assuming the hourly flux was representative of the daily flux and adjusted by the mass of fresh dung or urine applied. The cumulative emission over the 52-week was estimated assuming the daily flux was representative for the time interval between gas collections. Once checked for normality and outliers with the UNIVARIATE procedure, then a MIXED model analysis of variance was conducted (*SAS Institute Inc*., 2008). Means were separated with the LSD test ($p < 0.05$), when treatment effects were significant ($p < 0.05$).

Results and Discussion

The CH_4 fluxes sharply increased immediately after dung and urine applications. The CH_4 flux from dung reached 29 mg C kg^{-1} fresh dung day^{-1}on day 2 and was still elevated at 0.9 mg C kg^{-1} fresh dung day^{-1} on day 5, before dropping to background levels. Similarly, the CH_4 fluxes from urine were greatest on day 2 (6.7mg C kg^{-1} urine day^{-1}), decreased to 0.18 mg C kg^{-1} urine day^{-1} on day 5 and returned to background levels thereafter. The cumulative CH_4 emission was greater ($p < 0.05$) from dung (77 mg C kg^{-1} fresh dung) than urine (11 mg C kg^{-1} urine), while the non-amended control was a small CH_4 sink (-0.51 kg C ha^{-1}). The annual CH_4 emission represented 0.20% and 0.09% of the total C applied for urine and dung, respectively.

The N_2O fluxes increased after dung and urine application but unlike CH_4, did not reach the peak flux until day 5 for dung (0.15 mg N kg^{-1} fresh dung day^{-1}) and day 15 for urine (14.8 mg N kg^{-1} urine day^{-1}) before dropping to background levels the following week. For dung, the N_2O fluxes stayed low for the next 6 months and peaked again in late-January when mean daily air temperature rose above zero for 10 days in a row. For urine, two more N_2O flux peaks were observed in July and August and remained low thereafter. Over the 365 days, the cumulative N_2O emission was greater ($p < 0.05$) from urine (160 mg N kg^{-1} urine) than dung (4.62 mg kg^{-1} fresh dung), while the non-amended control was a much smaller source of N_2O (0.40 kg N ha^{-1}). The annual N_2O emission factor was 1.54% for urine and 0.44% for dung in our study, lower than the 2% IPCC default value.

Conclusion and Implications

The elevated CH_4 fluxes lasted < 3 weeks, but elevated N_2O fluxes lasted over two months for dung and urine treatments. Additional peak N_2O fluxes occurred when soil temperature and moisture conditions were conducive for N_2O production via nitrification and denitrification processes. Our data suggests that N_2O emission factors may be improved by using specific values for dung and urine.

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Estimation and Economic Valuation of Aboveground Carbon Storage in the Semi-Steppe Rangelands of Middle Alborz Mountains

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Key words: Carbon Sequestration, Ecosystem goods and services, Exclosure, Rangelands

Introduction

Rangelands provide a vast range of ecosystem goods and services in addition to forage and non-forage products. The goods provided by the forage rangelands include a wide range of ecological, social and cultural values. These values whether direct use or indirect use of existence or optional need to be expressed in common monetary value. One of the important ecological roles of the rangelands is carbon sequestration. The rangelands play an important role both as carbon sink and as carbon source. Because of rangelands extent, a small change in soil carbon (C) stocks across rangeland ecosystems would have a large impact on greenhouse gas (GHG) accounts (Follett et al., 2001). One of the most widely suggested option to sequester more C in rangelands is the rangeland restoration by grazing exclusion. Studies of grazed soils worldwide have shown both increases (Niknahad et al, 2015) and decreases (Yong-Zhong et al., 2005) in carbon storage and accumulation as compared to the adjacent non-grazed soils. The objectives of the present study were (1) to quantify C storage in the plant system in Hezar-Jarib rangelands on the exclosure and grazing areas and (2) Economic valuation of C storage in the plant– soil system of the areas.

Materials and Methods

The study area consists of a 40660 ha rangeland located in the East Mazandaran province with a mean annual precipitation of 350 mm and average temperature of 11 ^{o}C. The area lies at (Lat: 55◦ 00' - 54◦ 09' E, Long: 36◦ 26' - 36◦ 31' N).

Sampling from vegetation was carried out in key area (5 years exclosure) and rotation grazing system area. Three parallel transects (the length of 100 m and intervals of 20 m) were established in a key area inside and outside the exclosure. In each transect, ten plots (1m2) were established systematically. In each plot, the number of plant individuals for each plant species was recorded and used to estimate the density of each species per unit area. In order to estimate the mean fresh weight of plants, a few individuals of each species were sampled by the clipping and weighing method. The moisture content of aerial biomass was calculated after drying 500 g of each sample in an oven (after 24 h at 70°C) and used to calculate their total dry weight by applying this ratio to the amount of wet weight of In each key area (Niknahad et al, 2015).

Results and Discussions

Plant composition, density and productivity

The results indicated that exclosure had a significant impact on plant characteristics. Total dry matter (kg/ha) of dominant plant species in exclosure *Artemisia aucheri*, *Astragalus gossypinus Fisch. P* and *Onobrychys Cornuta* were 459.15, 173.24 and 820 respectively. Also total DM for the plant species in grazing area were 330.72, 111.28 and 57.26 (kg/ha), respectively.

Plant carbon sequestration rate in exclosure and grazing area

The mean carbon sequestration rates (kg/ha) of plant biomass on the exclosure and grazing areas are shown in Table 1. Statistical analysis revealed that there were significant differences ($P<0.01$) between plant species in terms of estimated carbon sequestration rate (Table 1).

Table 1. The mean estimated carbon sequestration rate (kg/ha) plant biomass on the exclosure and grazing area.

Area	Plant species	Aerial Biomass OC*%	Root Biomass OC%	Total OC (g/plant)	Plant Density (Per ha)	Total OC (kg/ha)
Exclosure	*Artemisia aucheri*	20	15	19.9	47400	469.3[b]
	Astragalus gossypinus Fisch. P	50	36	75.09	10475	786.6[a]
	Onobrychis Cornuta	75	55	21.96	6000	131.8[c]
Grazing area	*Artemisia aucheri*	10	15	12.9	3785	48.8[c]
	Astragalus gossypinus Fisch. P	48	35	55.3	8235	455.4[a]
	Onobrychis Cornuta	74	53	18.26	5500	100.4[b]

OC*= the amount of carbon mass in soil (g C/kg soil)
The means of total OC with the different letters were significantly different based on Turkey method P< 0.01

Economic values of carbon sequestration

Considering that carbon forms 27% of the weight of atmospheric carbon dioxide the weight of atmospheric carbon dioxide, so there is 270 kg carbon per atmospheric carbon dioxide. As a result, each ton of the sequestered carbon is equivalent to 3.7 tons of atmospheric carbon dioxide. With reference to the mean value of carbon sequestration ($200 per ton) (Niknahad, 2015) and the differences in carbon sequestration by vegetation between inside and outside of the exclosure 0.783 ton/ha (Table 2) it can be argued that the value of C sequestration per ha in Hezar-Jarib exclosure will equal to 578 over 5 years which is equivalent to 115.6 $ per year.

Table 2. The economic value of carbon sequestration over 5 years.

Variable	Carbon (ton/ha)	Atmospheric CO2 (ton)	Economic Value ($/ha)
Differences in carbon sequestration by vegetation between inside and outside of the exclosure	0.783	2.89	578

Conclusions and Implications

Results revealed that the response of aboveground carbon storage to the exclosure is positive in Hezar-Jarib rangelands and there are significant differences between the total amounts of the stored carbon of plant biomass on the exclosure and grazing areas. Our results agree with studies that had shown the increases (Niknahad, 2015) and disagree with those that had shown the decreases (Yong-Zhong*,* 2005) in carbon storage and accumulation as compared to the adjacent non-grazed soils. After a 5 year exclosure, the value of carbon sequestration per hectare in Hezar-Jarib rangelands was estimated as 115.6 $/h per year. It can be argued that the education and extension of carbon sequestration in Iran will offer new incentives to restore the degraded rangelands.

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Grazing and Soil Carbon: Comparing Effects of Management Strategy across Vegetation Types

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Key words: Grazing, soil carbon, grasslands, rotational grazing, C_3 vs. C_4 grasses

Introduction

Grasslands occupy approximately 40% of the Earth's terrestrial surface (Wang & Fang 2009) and so represent a large reservoir of soil organic carbon (SOC), accounting for between 10-30% of global SOC stocks, or about 200-300 Pg (Scurlock & Hall 1998). However, due to widespread overgrazing and land degradation, many grasslands have lost large quantities of SOC and thus, have the potential for increased carbon storage with shifts in management practices. Yet this potential remains largely untapped due to uncertainties regarding the types of management that will promote accumulation of soil carbon rather than its depletion. This uncertainty is further confounded by the contrasting effects of management on SOC that have been found across grasslands that vary in precipitation, soil texture, and vegetation. A finding from a previous meta-analysis (McSherry & Ritchie 2013) suggests that aspects of grazing management (*i.e*. grazing intensity) may affect SOC stocks differently depending on whether vegetation is dominated by C_3 or C_4 grasses. This study therefore tests the hypothesis that grazing 'best management practices' aimed at maintaining or increasing SOC differ according to the dominant vegetation type of the grassland (McSherry & Ritchie 2013). To this end, we explore how variation in grazing management affects soil organic carbon density and associated above- and below-ground properties across two sub-humid/semi-arid grassland types: C_3-dominated grasslands of northern Patagonia, Argentina and C_4-dominated grasslands of northern Kenya. Additionally, as grazing-induced changes in plant allocation of carbon to belowground biomass (*i.e*. roots) has been implicated as a possible mechanism by which grazers may affect SOC (Derner *et al.* 2006), we will also measure the magnitude of root biomass under contrasting grazing management.

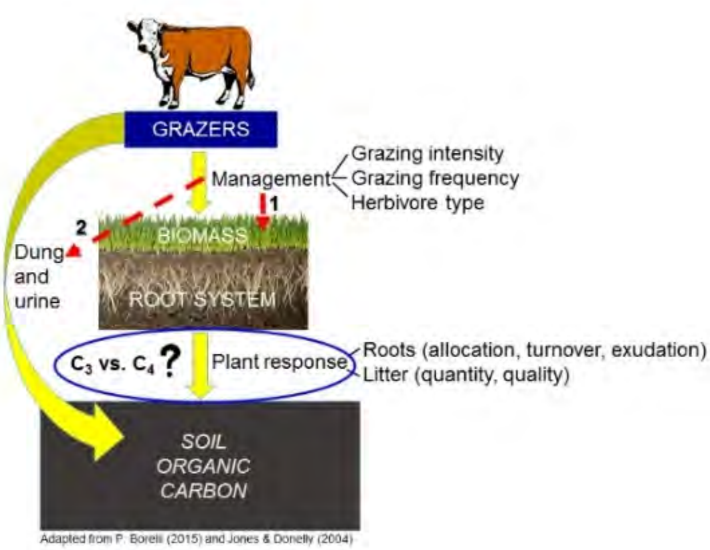

Figure 1. Simplified depiction of grazer effects on grassland carbon cycling, highlighting how variation in grazing management can modify both 1) quantity of aboveground plant biomass and 2) quantity of dung and urine inputs, both of which have effects on soil organic carbon. Pathway 1) results in subsequent changes in plant carbon inputs to the soil and may be an important driver of differences in effects between C_3 and C_4 grasslands.

Materials and Methods

To understand how effects of grazing management on SOC differ across C_3- and C_4-dominated grasslands, we have established -- within each country (and associated grass type) -- a suite of sites with similar environmental conditions (mean annual rainfall, soil texture) and varying management practices. In Kenya, these sites consisted of paired group ranches in which one ranch had begun practicing some form of planned grazing management (consisting of rest/rotation scheduling, and/or 'bunched' grazing) and the other practices the more traditional unrestricted, unplanned grazing. In Argentina, sites were selected within three large private ranches along a gradient of management and animal use intensity. At each of these sites, we are collecting monthly data on vegetation composition and aboveground biomass production and measuring herbivore use (and proportion of use by livestock vs. native herbivores) with camera traps and temporary exclosure cages.

Soil organic carbon stocks and associated belowground properties, including particulate, mineral-associated, and total SOC, total nitrogen, and total root biomass, were sampled across sites within each region. After controlling for variation in rainfall and soil texture, data will be analyzed to assess the effect of grazing intensity, frequency, and dominant herbivore type on SOC (total, particulate, and mineral-associated OC), N, and root biomass. Differences in vegetation cover, species diversity, and productivity will also be compared across sites differing by management.

Results and Discussion

While complete analyses are forthcoming, preliminary results from Kenya show that a rotational system of management has positive impacts on aboveground productivity and species composition.

Conclusions and Implications

Understanding which grazing management strategies are optimal to increase SOC across ecosystems with varying soil properties, precipitation regimes, and dominant vegetation is critical to achieving large-scale increases in global soil carbon storage. These management strategies may also provide considerable benefits to pastoralists and other livestock managers around the globe through improvements in vegetation and livestock productivity and, for some, increased compatibility with wildlife conservation (and potential for wildlife tourism) and/or eligibility for participation in carbon credit programs, which facilitate the sale of carbon credits on the global market. All of these activities have the potential to provide additional revenue to help pastoralists and other livestock managers sustainably manage their lands and critical grazing resources (Henderson *et al.* 2015).

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Environmental Services of Montado Ecosystem

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Key words: Soil, water, air, fire-prevention, biodiversity

Introduction

"Montado" is an agro-silvo-pastoral ecosystem with a typical landscape that characterizes the Mediterranean region of the Iberian Peninsula. It was built by Man and preserved among centuries by control of shrubs and using natural resources. These are used for animal feeding and complemented with farming activity in order to obtain high quality products for economic support of rural population (Potes & Babo, 2003).

Materials and Methods

The methodology used in our experiments and studies are the methods traditionally used by farmers looking for an efficient management of the multifuncionality in Montado ecosystem. Two main methods are the implementation of *Montado Crop Rotation* (Potes & Babo, 2003) and the optimization of the *Feeding Scheme of Extensive Animal Production Systems* (Potes, 2008).

Results and Discussion

Considering that in Mediterranean conditions the systems of agriculture are characterized as an extensive way of production, or low productivity levels, the income revenues from the several products obtained, despite their high level of quality, are often not sufficient for an economic support of results.
So, it is very important to find new economic valorizations from the outputs of the ecosystem. The evolution of environmental services appears as the adequate solution for an ecosystem that using the correct management is technically and environmental sustainable (Potes, 2011a).

Potes (2011b) presented environmental services of Montado as follows:

- Restore *soil* productivity by consolidation of Organic Matter (OM) levels and structure as a consequence of improvement of Mediterranean permanent Pastures, the main resource for the feeding scheme of extensive animal production systems (Potes et al, 2005);
- Improve the cycle of *water* in the soil by the circulation between roots from trees and pasture plants at distinct levels in soil (David et al, 2013) and storage by the increasing levels of OM;
- Improvement of *air* by the carbon sequestration as a consequence of the dynamic of the ecosystem working in a balanced way, which can achieve levels of sequestration in average of 6.7ton CO_2/ha/year (Potes, 2011b);
- Prevention of *fire* as a result of the control of shrubs which can be considered the essence of Man intervention in the ecosystem because the presence of combustible biomass of arbustive plants in a long, dry and hot summer is higher risks (Fernandes, 2009);
- Sustainability of high levels of *biodiversity* that characterizes the Mediterranean nature and systems of production.

Conclusions and Implications

The intensification of systems of agriculture in Mediterranean environments must be very careful because the outputs of the system cannot be enough to cover the in-puts and the system breakdowns. This shows that we must look for the diversification and quality of products instead of quantity, by using more factors of production. So the economical support should be founded in environmental services and less by increasing products.

More research is needed for better evaluation and economic valorization/quantification of environmental services identified in Montado ecosystem.

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Carbon Sequestration Potentials of Semi-arid Rangelands under Traditional Management Practices in Borana, Southern Ethiopia

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Key words: Aboveground carbon stock, belowground carbon stock, rangeland management, semi-arid areas, soil attributes

Introduction

Rangelands occupy about half of the world's land mass (Friedel *et al.,* 2000) and are estimated to store more than 30% of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses at the natural state or moderately disturbed by grazing (Vashun and Jayakumar, 2012). As such, proper management of rangelands can aid in the mitigation of rising atmospheric carbon dioxide concentrations via carbon storage in aboveground vegetation and organic matter stored in the soils to mitigate climate changes (Derner and Schuman, 2007). Many rangeland management techniques including rehabilitation and grazing enclosures have been intended to increase forage production as well as atmospheric carbon sequestration both in soils and aboveground vegetation (Homann *et al.,* 2008). Although many studies have been conducted in Borana rangelands on vegetation structure (Gemedo *et al.,* 2005; Bikila *et al.,* 2014), information on carbon sequestration potentials under different rangeland management practices are limited. The only study that can be quoted along this line is that of Hassan *et al.* (2013) who developed allometric equations for the common eight encroaching bushes species for biomass estimation. Hence, this study was designed to investigate and determine carbon sequestration potentials in aboveground vegetation and soils under three traditional rangeland management practices; (a) rangelands enclosed for about 20 years as dry season grazing, (b) prescribed fire managed rangeland unit which was applied before five years and (c) communally owned grazing areas.

Materials and Methods

This study was carried out in Yabello district of Borana zone, southern Ethiopia. Yabello district was selected due to its potential to possess the three traditional rangeland management practices as well as its potential to support a bigger economic values in terms of livestock production and social implication. The three traditional rangeland management practices evaluated in this study were: i) rangelands enclosed for 20 years for dry season grazing reserves or standing hay making locally called *Kalo* or grazing enclosures, ii) prescribed fire managed rangeland unit which was applied before five years and iii) communally grazed rangeland areas. A plot of 30 m x 40 m was used and replicated four times within each traditional rangeland management practice. All soil and vegetation data were collected in 2013 immediately after the main rainy season of the Borana zone (March-May). Tree and shrub parameters were measured on the 5 m, 15 m, and 25 m transects along the 30m side of the plot (Fig. 2). On each of the 5 m, 15 m, and 25 m transects, five circular plots with a radius of 2 m were centered at the 7, 14, 21, 28, and 35 meter marks along the 40 m side of the plot (Fig. 2). Tree and shrub diameters at breast height (DBH at 1.3 m), circumference of the stem at ankle height (5-10 cm aboveground), tree and shrub height, canopy width and length of all trees and shrubs rooted in a 2 m radius of the circular plots were measured. Tree/shrub biomass and their carbon sequestration potentials were estimated on permanent plots in a non-destructive manner by utilizing biomass regression equations through allometric measurement for each specific tree/shrub species developed by previous studies (Henry *et al.*, 2011; Hassan *et al.,* 2013). All biomass values were converted to carbon using a conversion factor of 0.5 according to IPCC (1996). Herbaceous biomass was measured through a destructive method (mowing herbaceous vegetation at the ground level) on the 10 m and 20 m transects along the 30 m side of the plot (Fig. 2). On each of the herbaceous biomass transects, 5 quadrats (0.5 m x 0.5 m) were centered at the 4 m 12 m, 20 m, 28 m, and 36 m marks along the 40 m side of the plot (Fig. 2). All herbaceous vegetation within the plots were identified as grasses and non-grass species and clipped at ground level and then placed in a plastic bag separately for dry matter analysis. Like herbaceous data collection, the same procedure was applied for litter data collection. All litter samples less than 2.5 cm diameters in the quadrat were collected manually. Motorized soil core ring with a radius of 2.983 cm was used to collect soil samples from three depth levels i.e. 0-10 cm, 10-20 cm and 20-30 cm. The soil samples from the five points as indicated in Fig. 2 were composited to represent a plot according to their respective depths. The composited soil samples were then oven dried at 105^{o}C for 24 hours and one sub-sample of approximately 1 kg was taken per plot for analysis. Carbon contents in the soil samples were calculated using the specified formula below.

Soil C kg ha^{-1} = BD (kg cm^{-3}) x (1 – rock/gravel content) x d x 100,000,000 x C %,

Where: d = soil sampling depth (cm), BD= bulk density in kg cm^{-3}, C % = percentage carbon content of the sample, and 100,000,000 is the conversion factor = (kg cm^{-3}) x (10,000 cm^{2} m^{-2}) x (10,000 m^{2} ha^{-1}).

Analysis of Variance (ANOVA) was applied to test for differences in aboveground and belowground carbon stocks using a General Linear Model (GLM) procedures of Statistical Analysis System (SAS) version 9.1 (SAS, 2002), with traditional rangeland management practices (TRMP), soil depth (SD) and their interaction (TRMP x SD) as independent factors. Tukey HSD test with P < 0.05 was employed for mean comparison. Mean comparisons for the interactions effects between rangeland management practices and soil depths were not performed for all parameters due to the lack of non-significant effects.

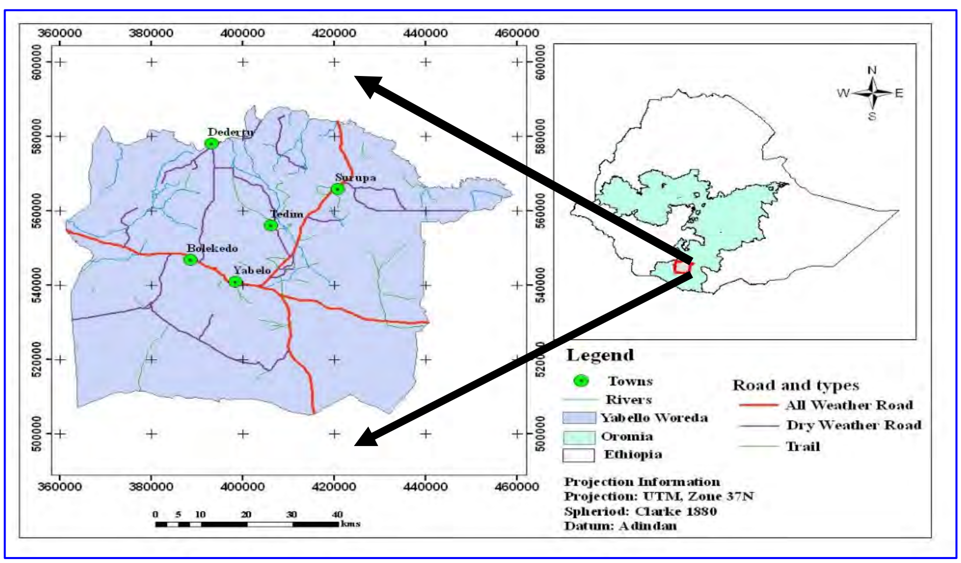

Figure 1. Map of the study area, Yabello district of Borana rangelands, southern Ethiopia.

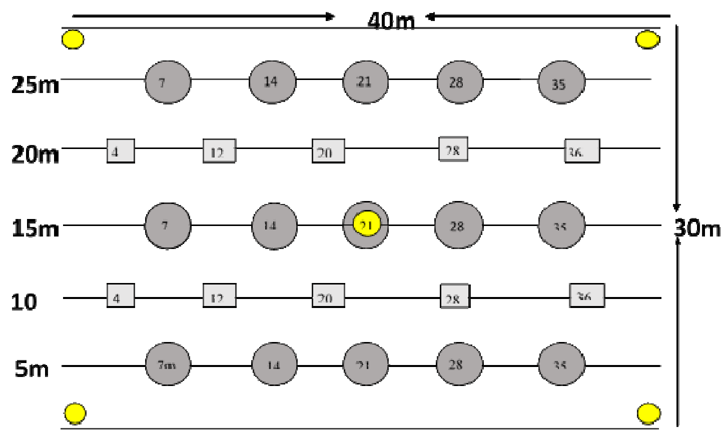

Figure 2. Field plot layout of the experimental site. Key: Transects at 5 m, 15 m and 25 m were allotted for tree/shrub sampling (larger circles), transects at 10 m and 20 m were for herbaceous and litter sampling (rectangles) and the smaller circles at the four corners and at the center of each plot (highlighted in yellow) were used for soils sampling. Plot orientation was set in such a way that the 30 m side of the plot runs from east to west or vice versa and the 40 m side of the plot runs from north to south or vice versa to make all the plots arrangement uniform.

NB: The above design was provided as sample for one plot and similar design was applied for all 12 plots.

Results and Discussion

Tree and shrub carbon were significantly higher in grazing enclosures than in the other two types of traditional rangeland management practices which might be due to the availability of high density of trees and shrubs in grazing enclosures (Table 1). The total aboveground carbon stocks in grazing enclosures, rangeland units managed by prescribed fire and communally owned grazing areas were 61.49, 10.51 and 13.11 $tCha^{-1}$, respectively (Table 2). At this juncture, it should be noted that the total aboveground carbon stocks included carbon stocks in all the trees, shrubs, grasses, non-grasses, dead litter and dead standing tree and/or shrub species under each traditional rangeland management practice. The highest total aboveground carbon stocks in grazing enclosures are also supported by John *et al.* (2010) who reported 13.01 $tCha^{-1}$ for the south eastern Ethiopian rangelands, even though, it is smaller by 48.48 $tCha^{-1}$ than the current study. This difference might be due to the variations in climatic, edaphic and aboveground vegetation between the Borana rangelands and south eastern Ethiopian rangelands. A significantly ($P < 0.05$) higher soil organic carbon was stored in grazing enclosure (237.36 $tCha^{-1}$) than in the rangeland units managed by prescribed fire (172.67 $tCha^{-1}$) and communally owned grazing areas (127.86 $tCha^{-1}$) (Table 2). Grazing enclosures had a higher total belowground carbon stocks (238.89 tCha-1) than rangelands managed by prescribed fire and communally owned grazing areas. Total belowground carbon was greater than the corresponding total aboveground carbon in each rangeland management practice. The findings of the present study is in agreement with previous study (Fynn *et al.,* 2009), who reported that soil contains about three times more organic carbon than aboveground vegetation. Total carbon stocks including both total belowground and aboveground carbon stocks was significantly ($P < 0.01$) higher in grazing enclosure (300.4 $tCha^{-1}$) than in both rangelands managed by prescribed fire (184.93 tCha-1) and communally owned grazing areas (141.5 $tCha^{-1}$, Table 2). The highest total carbon storage in grazing enclosure is in line with previous study (Fynn *et al.,* 2009). Furthermore, root and soil organic carbon significantly ($P<0.01$) varied along the soil depths (Table 3).

Table 1. Means (n =12) of aboveground carbon across rangeland management practices (tCha^{-1}).

Management system	TrC	SC	GC	NGC	LC	DSC
Communal	10.22^{b}	1.99^{b}	0.14^{b}	0.26	0.28	0.22
Enclosure	57.55^{a}	2.87^{a}	0.39^{ab}	0.33	0.34	0.008
Prescribed fire	8.62^{b}	0.43^{c}	0.57^{a}	0.42	0.43	0.0375
±SE	1.57	0.15	0.08	0.06	0.08	0.11
P value	0.0001	0.0001	0.02	0.29	0.41	0.43

Means with the same letter superscripts along columns are not different at α = 0.05 or 0.01 level of significance, TrC = Tree carbon, SC = Shrub carbon, GC= Grass carbon, NGC = Non-grass carbon, LC = Litter carbon, DSC = Dead standing carbon, tCha^{-1} = ton of carbon per hectare.

Table 2. Total aboveground, belowground carbon stocks and total carbon (tCha^{-1}) across the three rangeland management practices (n = 36).

Range management practices	ROC	SOC	Total belowground carbon	Total aboveground carbon	TC
Communal	0.53	127.86^{b}	128.39^{b}	13.11^{b}	141.5^{b}
Enclosure	1.53	237.36^{a}	238.89^{a}	61.49^{a}	300.38^{a}
Prescribed fire	1.75	172.67^{ab}	174.42^{ab}	10.51^{b}	184.93^{b}
±SE	0.59	25.77	25.28	1.57	24.72
P value	0.36	0.045	0.045	0.0001	0.0098

Means with the same letter superscripts along columns are not significantly different at α = 0.05 or 0.01 level of significance, ROC = Root organic carbon, SOC = Soil organic carbon, TC = Total carbon, tCha^{-1}= ton of carbon per hectare

Table 3. Carbon stocks (tCha^{-1}) along soil depths (n = 36).

Depths	ROC	SOC	Total BGC
0-10cm	1.11^{ab}	246.77^{a}	247.88^{a}
10-20cm	2.14^{a}	171.85^{b}	173.99^{b}
20-30cm	0.56^{b}	119.26^{c}	119.82^{c}
±SE	0.20	8.82	8.92
P value	0.004	0.0002	0.0002

Means with the same letter superscripts along columns are not significantly different at α = 0.05 or 0.01 level of significance, SOC = Soil organic carbon, BGC = Belowground carbon, tCha^{-1} = ton of carbon per hectare, ROC = Root organic carbon, ±SE = Standard error.

Conclusions and Implications

Traditional rangeland management practices especially making of grazing enclosures and prescribed fire application to a rangeland unit evidently maintained substantial amount of carbon stocks in the soils and aboveground vegetation. The present study suggested that sustainable use of the rangelands in the southern Ethiopia would require paying greater attention to regulating the expansion of grazing enclosures and re-introduction of prescribed fire to control the expansion of bush encroachment so as to establish good and palatable herbaceous forage biomass stands for both domestic and wild ungulates. Hence, the policy should recognize the importance of making grazing enclosures as a dry season grazing and forage reserves in the forms of fodder banks and as ecologically important carbon sequestration potential in semi-arid rangeland ecosystems.

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Carbon Sequestration in Silvi-pastoral Systems in Arid and Semiarid Regions of India

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Key words: Agroforestry, climate change, degraded rangelands, Green India, restoration

Introduction

In arid and semi-arid region of India; silvi-pastoral systems, combinations of fodder trees and pasture species, are being promoted on degraded lands for meeting diverse rural requirements on one hand and environmental conservation on the other (Pathak and Roy, 1995). Such systems are beneficial in direct near term storage (decades to centuries) of carbon in trees/pastures and soils and also in offsetting immediate greenhouse gas (GHG) emissions, associated with deforestation and subsequent shifting cultivation. Species composition, structure and function of various components and prevailing socio-economic factors have important implications (Murthy et al., 2014). The objective of the study was to present a review of research work done on such aspects and their potential role in climate change mitigation and adaptation.

Materials and Methods

After a through scanning of research papers, other publications and reports on biomass production and carbon storage (> 30-60 cm) associated with silvipastures in two major regions of the country viz., arid and semiarid, analysis of the scenario was done (Table 1). The role of carbon sequestration through such systems is highlighted.

Table 1. Summary of attributes in this study.

Attributes	Details	
# publications consulted	105	
# reports consulted	20	
# major regions covered	02 (arid and semiarid)	
Silvipastoral system	Arid	Semiarid
Tree species	*Acacia tortilis, Colophospermum mopane, Prosopis cineraria*	*Acacia, Albizia, Colophospermun, Dalbergia, Hardwickia, Leucaena, Prosopis*
Pasture plant species	*Cenchrus ciliaris, C. setigerus, Laisurus sindicus,*	*Cenchrus, Chrysopogon, Dichanthium, Heteropogon, Panicum*
Tree densities	100-440 trees ha^{-1}	
System rotation	5 years (short term); 12 years (medium term); > 20 years (long term)	
Carbon sequestration estimations	in biomass and soil	

Results and Discussion

Literature search since 1961 revealed 105 research, 20 reports and other publications in the area of biomass assessment in plant parts and carbon sequestration in arid and semiarid regions of India. The tree density varied from 100-200 trees ha^{-1} in arid regions to 300-440 in semiarid regions. In arid regions trees were primarily *Prosopis cinerea* and *Colophospermum mopane* whereas in semiarid regions all trees except *Prosopis cineraria* were available. Among grass species, arid regions exhibited primarily *Laisurus sindicus* and *Cenchrus ciliaris/setigerus* relative to semiarid region where all species were available except *Laisurus sindicus*.

The available research studies indicate that total carbon sequestration potential varies from 10-45 Mg ha^{-1} in semiarid regions on a rotation of 5-20 years and 4-21 Mg ha^{-1} in arid regions on a rotation of 4-21 years (Kaur et al., 2002; Goswami et al. 2013; Murthy et al., 2013; Shamsudheen et al., 2014). Other studies on carbon storage through such practices indicated that average carbon sequestration in the range of 9-63 Mg ha^{-1} in subtropical to temperate regions (Murthy et al., 2013). The variations in total carbon stored in different components of silvipastoral systems and soil are affected on account of site, species composition, tree density and rotation. The semiarid sites in general stored more carbon (long term) due to higher tree growth as well as diverse plant species. In semiarid region with 440 trees ha^{-1}, the combination of *Leucaena leucephala* with *Panicum maximum* and *Acacia tortilis* with *Cenchrus ciliaris* stored 45 Mg ha^{-1} in more than 20 years period however, in arid region with 200 trees ha^{-1}, the combination of *Prosopis cineraria* with *Cenchrus ciliaris* stored only 21 Mg ha^{-1} in more than 25 years period. Silvipastoral systems in India, originally designed for economic utilization of unproductive lands/rangelands through livestock production, play a major role in storing carbon in above and below ground biomass as well as soil (Pathak and Roy, 1995; Murthy *et al*. 2013).

The current climate change negotiations highlight the importance of alternate land use systems in mitigating climate change as agriculture alone contributes over 12 per cent of GHGs. Net gains to higher carbon may be achieved through incorporation of tree component and also perennial grasses/crops on a unit of land (Shamsudheen *et al*. 2014). In India, large land areas are classified under waste/degraded categories and it includes rangelands as well. Such soils are usually low in soil organic carbon, providing high opportunity to increase carbon sequestration. Therefore, restoration of such lands through well designed and need based agroforestry/silvipastoral systems will be extremely useful for carbon sequestration and stabilization on one hand and meeting society's diverse needs on the other.

Conclusions and Implications

The available research work in India on silvipastoral systems indicate that carefully designed systems on waste/degraded lands may sequester carbon in biomass and soil. The Green India mission under National Climate Change Action Plan has a target to promote agroforestry/silvipastures on 1.5 million ha of degraded lands and fallows. This is expected to provide an excellent opportunity for carbon storage. By 2025 an area of 25.36 million ha will be under agroforestry, including tree borne oil seeds and silvipastures. However, in order to realize the full potential of climate change mitigation through silvipastures, there is a need for strengthening research on similar aspects and overcome all the technical, financial and institutional barriers. Overall, there is a possibility of evolving such systems as an alternate option to reduce the vulnerability of farming system to climate variability and climate change impacts.

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Carbon Sequestration in *Themeda triandra* and *Heteropogon contortus* Dominated Grazing Lands of Tamil Nadu in South India

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Key words: Productivity, ecosystem, biomass, grasses

Introduction

Grazing lands cover nearly 40% of the global terrestrial area. They represent an important compartment for terrestrial carbon dioxide off set and it is a significant sink for long term carbon sequestration. Carbon is the main source of food as well as pollution and it is necessary to manage ecosystem carbon. Plants play a vital role to reduce the atmospheric carbon and fix it as a source of food for living things. Native and improved grazing lands have an important role in mitigating global climate change. Because grazing lands occupy a vast area throughout the world, small changes in the amount of carbon stored in that ecosystem can have significant change in the overall carbon cycle and atmospheric carbon dioxide level. Hence, the study of carbon sequestration is of global importance. Based on this information the present study is focused on carbon sequestration in *Themeda* and *Heteropogon* dominated grazing lands at Tamil Nadu in South India.

Materials and Methods

Themeda triandra dominated grazing land is located at Sirumalai (12^0 41' N, 77^0 55' E) and *Heteropogan contratus* dominated grazing land is located at Hogenakal (9^0 31'N lat. 77^0 45' E long). Biomass estimation was done at monthly intervals in five randomly selected sites by following harvest method of Milner and Hughes (1968). Above-Ground Live (AGL), Standing Dead (SD), Litter (LIT) and Below-Ground (BG) root compartments were analyzed for biomass. Dry matter dynamics study was done by following the method of Singh and Yadava (1974). Litter Disappearance (LD) and Root Disappearance (RD) values give total disappearance value. Estimates of carbon fixation were made by following Schlesinger (1991) using the formula C= 0.475*B, where C is the carbon content by mass and B is the oven dry biomass.

Results and Discussion

In *Themeda* dominated grazing land, the net carbon fixation of above-ground live and below-ground compartments were 584 and 248 $g/m^2/yr$ respectively and the total net carbon fixation was 832 $g/m^2/yr$. In this 70% of the fixed carbon was transferred to above-ground live and 30% to below-ground. Nearly 64% of the above-ground fixed carbon was transferred to standing dead and 27% to litter compartment and annually about 152 $g/m^2/yr$ of fixed carbon was disappeared. In *Heteropogon* dominated grazing land, the net carbon fixation of above and below-ground compartments were 409 and 391 $g/m^2/yr$ respectively and the total net carbon production was about 800 $g/m^2/yr$. In this 51% of the total fixed carbon was transferred to the above live and 49% to the below-ground respectively. Nearly 70% of the above ground fixed carbon was transferred to the standing dead and 60% standing dead was transferred to litter compartment and annually about 500 $g/m^2/yr$ of carbon was disappeared (Fig. 1).

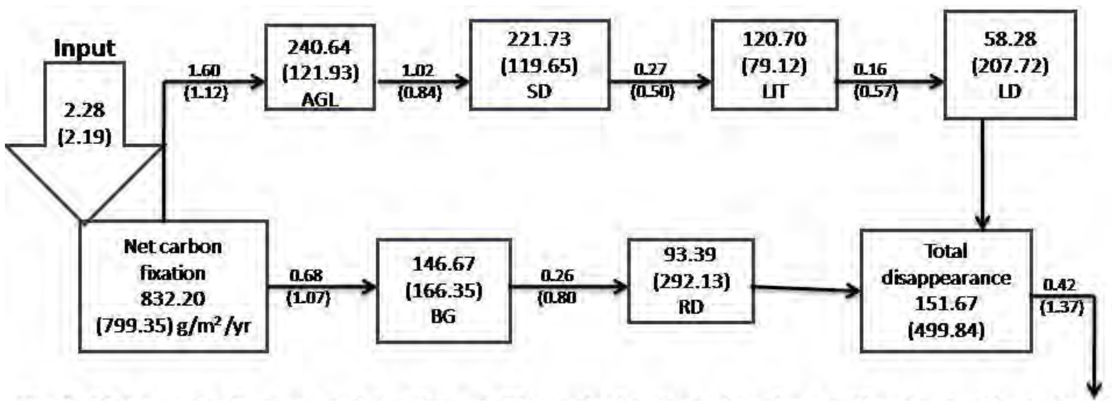

Figure 1. Net carbon fixation and its flow at *Themeda* dominated (values without parentheses) and *Heteropogon* dominated (values in parentheses) grazing lands in Tamil Nadu. Numerical values in the boxes are the amount of carbon fixed (g/m^2) and the values in the arrows show the rate of net carbon flux (g/m^2/day).

In *Themeda* dominated grazing land, the carbon fixation was more in above-ground live and less in below-ground. This may be due to higher above-ground vegetative growth enhanced by abiotic and biotic factors of that area. In *Heteropogon* dominated grazing land, the below-ground carbon flux rate was higher than the *Themada* dominated grazing land and the higher root disappearance in *Heteropogon* dominated grazing land showed the stability of grazing land. Similar observations were observed by Sims and Singh (1978).

Conclusions and Implications

The present study indicates that carbon fixation and carbon flux rate play a major role in productivity and stability of grazing lands. *Heteropogon* dominated grazing land is more stable than *Themeda* dominated grazing land. With controlled management of grazing practice, instability of the *Themeda* dominated grazing land ecosystem can be minimized.

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Changes in Plant Cover Induced by Grazing Affect the Soluble Fraction of Soil Organic Carbon – But Not the Total Pool Size in the Arid Rangelands of Patagonian Monte, Argentina

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Key words: Water soluble carbon, grazing pressure, SOC pool

Introduction

Soil is the largest organic C (SOC) pool in the biosphere (Lal, 2004). The size of this pool depends on the primary production and SOC residence time which are controlled by biome type, climatic conditions and land management (Lal, 2004). In arid ecosystems, these controls are strongly related to the amount and seasonal distribution of precipitation (Sala et al., 1988). However, the low plant cover (< 40 %), the spatial heterogeneity of plants, and the selectivity of grazing by domestic livestock may also influence SOC dynamics and stability. Most changes in plant communities induced by grazing are not reversible after removal of this disturbance agent (Briske et al., 2003). Accordingly, our ability to predict and mitigate consequences of grazing disturbance on ecosystem function and global change depends, in part, on a better understanding of the effects of vegetation changes on the size and composition of SOC pools. The objectives of this study were (i) to analyze whether the effects of grazing pressure on plant canopy are reflected in the size and composition of the SOC pool, and (ii) to identify easily measurable variables related to SOC that could be used as indicators of changes in organic C pools in grazed rangelands.

Materials and Methods

The study area is representative of the Patagonian Monte, Argentina (42º 12´ S, 64º 58´ W). Mean annual temperature is 13° C and mean annual precipitation is 188 mm (15 years series). Soils are a complex of Typic Petrocalcids-Typic Haplocalcids. Vegetation community is dominated by *Larrea divaricata* Cav. and *Stipa* spp. arranged in randomly distributed patches on a matrix of bare soil. This area has been grazed by sheep since the beginning of the past century with a mean stoking rate of 0.13 sheep ha^{-1}. Based on the sheep faeces density (i.e. indicator of grazing pressure), we selected six sites with increasing signs of grazing disturbance. Total plant cover was assessed at four randomly located transects using the line intercept method.

Sampling was carried out in winter and summer in two consecutive years (2011 and 2012) (4 sampling dates). At each sampling date, we randomly selected the four most representative plant patches per site and we collected a soil sample (0-30 cm depth) under the patch canopy and another in the middle of the nearest bare soil area. Roots were separated from each soil sample and soil was air-dried (c.a. 20º C), sieved to 2 mm mesh and weighed. We assessed the concentration of total soil organic C, organic C in humic substances and water soluble C (Page et al., 1982). These C fractions differ in the residence time (C in humic substances > water soluble C). Then, we calculated the size of total SOC pool as the product of soil mass and the organic C concentration. SOC composition was calculated as the product of (i) the soil mass and the concentration of C in humic substances, and (ii) the soil mass and the concentration of water soluble C.

The relationships among total plant cover, grazing pressure, total SOC pool size, and SOC composition were assessed by regression analysis using the mean values of each variable per site. Statistical analyzes were performed using SPSS software. The significance level used throughout this study was $p \leq 0.05$.

Results

Total plant cover responded negatively to grazing pressure ($y=-8.69*\ln(x) + 53.24$, $r^2= 0.76$, $p= 0.02$, $n= 6$). Perennial grasses were the most negatively affected by grazing pressure (data not shown). Total plant cover did not predict total SOC pool size (Fig. 1a) or C content in humic substances (Fig. 1b). However, total plant cover was significantly related to the content of water soluble C (Fig. 1c).

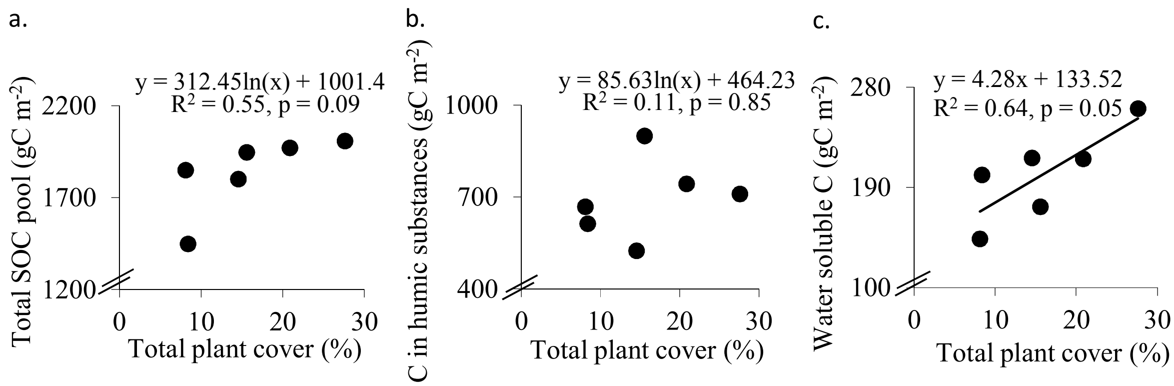

Figure 1. Relationship between total plant cover and a. the size of the total SOC pool, b. the content of C in humic substances, and c. the content of water soluble C.

Discussion

Although increased grazing pressure had a negative effect on total plant cover, the size of the total SOC pool did not change. However, the reduction in plant cover induced by grazing disturbance negatively affected the content of water soluble C. This could be related to changes in litter chemistry and stability induced by species shifting in grazed disturbed areas (mainly replacements of perennial grasses by long-lived evergreen woody plants). Litter in degraded areas, dominated by shrubs, has lower concentration of chemically labile compounds and higher concentration of complex C compounds (i.e. lignin) than litter from sites with low grazing disturbance (Follet 2001). In contrast, C content in humic substances (recalcitrant fraction) was not reduced with grazing disturbance. This could be associated with high litter recalcitrance to decomposition inducing high SOC residence time as found in other studies (Follet 2001). Based on these results, the periodic estimations of plant cover and/or the monitoring of changes in soil water soluble C could be used as indicators for early detection of degradation processes involving C losses in the ecosystem.

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Impact of Grazing Management on GHG Emissions Intensity for Canadian Beef Production Systems Using Life Cycle Analysis

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Key words: Beef production, grassland, grazing management, holos, life cycle analysis

Introduction

Recently, the beef production sector has received negative publicity due to its contribution of greenhouse gas (GHG) emissions, mainly methane (CH_4) from rumen fermentation. The objective of our study was to evaluate the impact of grazing management on the GHG emission intensity of Canadian beef production using data from short- and long-term grazing studies. Four grazing management scenarios were evaluated: i) light continuous grazing (LC), representing the best-case scenario for continuous grazing, ii) heavy continuous grazing (HC), representing the most commonly-used grazing management, iii) light continuous grazing for the cow-calf pairs and moderate deferred-rotational grazing for the backgrounders (LCDR), and iv) heavy continuous grazing for the cow-calf pairs and moderate deferred-rotational grazing for the backgrounders (HCDR).

Methods

The simulated farm includes a beef production operation with 120 cows, four bulls and their progeny, a cropping operation, hay production operation and a pasture production operation (native prairie pasture and seeded mixed native pasture) and was located in the county of Vulcan in southern Alberta, Canada (Ecodistrict 799). Life cycle analysis for the beef cattle was conducted over an 8-yr period to represent the life span of the breeding herd within the beef production cycle (Beauchemin et al., 2010). Primary data on crop and pasture complex as well as on grazing management were from several short- and long-term grazing studies. Greenhouse gas emissions from the farm were estimated using a farm scale model, Holos (Research *V2.2,* www.agr.gc.ca/holos-ghg). Holos is an empirical model based on the IPCC Tier 2 methodology modified for Canadian production systems. Estimated total farm GHG emissions include: enteric CH_4, manure-derived CH_4 and nitrous oxide (N_2O), on-farm N_2O emissions from soils and cropping; off-farm N_2O emissions from nitrogen leaching, runoff and volatilization (indirect N_2O); and on-farm carbon dioxide (CO_2) emissions from energy use and off-farm CO_2 emissions from farm inputs. On-farm CO_2 emissions and carbon (C) sequestration due to soil C change was estimated using the Introductory Carbon Balance Model. Greenhouse gas global-warming potentials for a 100-yr time horizon were expressed as CO_2 equivalent units (CO_2e), where: $CO_2 = 1$, $N_2O = 265$ and $CH_4 = 28$ on a mass basis. Emissions intensity was expressed as total farm GHG emissions per unit carcass weight.

Result and Discussion

Emissions intensity of beef varied among grazing management strategies and ranged between 24-27 kg CO_2e kg^{-1}carcass weight (Table 1). Emissions intensity decreased with increasing stocking rate, with the LC treatment having 9% greater emissions than the HC treatment (26.5 *vs* 24.1 kg CO_2e kg^{-1} carcass weight). There was no difference in emissions intensity estimates between LC and LCDR, or between HC and HCDR, indicating that the use of moderate deferred-rotational grazing for the backgrounding operation in LCDR and HCDR has no effect on emissions intensity. However, the LCDR management had 7% greater emissions intensity than HCDR (25.9 *vs* 24.2 kg CO_2e kg^{-1} carcass weight). Intensity estimates for beef production at the farm gate vary considerably and estimates from our study were comparable to previously reported values for Canadian production systems, 22-23 kg CO_2e kg^{-1} carcass weight (Beauchemin et al., 2010). Regardless of the grazing management, CH_4 from enteric fermentation was the major contributor (67-68%) followed by N_2O (14-16%) and CH_4 (9-10%) from manure management (Table 1). When soil C sequestration was included in the analysis, emissions intensity was reduced by 25 to 30% for the different grazing systems. The largest reduction was observed for the LC (27%) and LCDR (30%) because the system sequestered 46-61 Mg yr^{-1} more net CO_2 than the HC and HCDR managements (Table 1). Studies reported that inclusion of C sequestration in whole-farm GHG analysis could reduce emissions up to 43% (Phetteplace et al., 2001), or even negate all the emissions and make the farm a net GHG sink (Wang et al., 2015). However, such offsets are limited in time until the C sequestration potential has been realized.

Table 1. Greenhouse gas emissions and beef production for the different grazing managements.

Items	Grazing management[a]			
	LC	HC	LCDR	HCDR
Greenhouse gas emissions (Mg CO_2e)				
Enteric CH_4	4,894,531	4,364,896	4,698,436	4,254,217
Manure CH_4	673,570	648,777	677,900	643,192
Manure N_2O	1,019,626	1,005,130	1,012,163	996,855
Soil N_2O	369,871	285,357	320,526	305,092
Energy CO_2	270,410	185,351	217,154	206,790
Total emissions	***7,228.0***	***6,489.5***	***7,057.3***	***6,518.0***
System net CO_2 sequestration (Mg)	-1,975.0	-1,608.2	-2,124.8	-1,637.5
Total emissions (including CO_2 sequestration, Mg CO_2e)	***5,253.0***	***4,881.3***	***4,932.5***	***4,880.5***
GHG emission intensity (kg CO_2e kg^{-1} carcass weight)				
Without soil carbon sequestration	26.5	24.1	25.9	24.2
With soil carbon sequestration	19.3	18.1	18.1	18.1

[a]LC = light continuous grazing, HC = heavy continuous grazing, LCDR = light continuous grazing for the cow-calf pairs and moderate deferred-rotational grazing for the backgrounders, HCDR = heavy continuous grazing for the cow-calf pairs and moderate deferred-rotational grazing for the backgrounders.

Conclusions and Implications

The results showed that in all management scenarios, emissions were mainly contributed from enteric fermentation and manure management. The HC and HCDR management scenarios had lower GHG intensity compared to the LC and LCDR grazing managements. Conversely, GHG emissions intensity was reduced by larger proportion for the LC and LCDR management systems when soil C sequestration was included in the total GHG analysis. Soil C was lost from native pasture grazed by cow-calf pairs due to overgrazing in the HC and HCDR. This emphasizes the importance of accounting for all the emission sources and sinks within the beef production system while estimating its environmental footprint.

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Exclusion as Soil Organic Carbon Restoring Strategy in Halophyte Grasslands of the Flooding Pampa, Argentina

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Key words: Halophyte steppe, exclosure, carbon sequestration, productivity

Introduction

The Flooding Pampa (FP) comprises 60,000 km^2 in the central-east area of the province of Buenos Aires, Argentina. Mesothermal grassland is the predominant biome and it is estimated that 10,000 km^2 is community of halophytes. In those environments, overgrazing caused damage to the vegetation which resulted in reduced aboveground net primary productivity (ANPP) as well as loss of soil organic carbon (SOC, Vecchio, 2014). Several studies have investigated the SOC restoring impacts of exclosure on degraded Mesothermal grassland at a local and global scale. However, information on the impact of exclusion on SOC and ANPP from halophyte grasslands is lacking. Therefore, the aim of our study was to investigate the dynamics of SOC post-exclusion in those halophyte communities under the hypothesis that exclusion modify the plant community functioning and improve SOC.

Materials and Methods

The mean annual precipitation in FP is 1,000 mm. Halophyte communities are found in mosaics inter-connected with other grasslands communities, generally more fertile. Three grazing sites predominantly covered by halophytes community were selected and excluded from grazing since 1999 (Exc1), 2004 (Exc2) and 2010 (Exc3). Previously, the sites were managed under continuous grazing with a livestock density of 0.9 animal unit per ha (considering 400 kg live-weight per animal), exceeding its carrying capacity (0,4-0,6 animal unit per ha). In each exclosure four sampling sites (n=4) were installed. Soil sample from the top 10 cm was taken from Exc1, Exc2 and Exc3 and composite sample was analysed for the determination of oxidizable carbon (Walkley and Black, 1934). In Exc3aboveground net primary productivity was estimated every three years until 2013 (cutting method, Sala, 1988). Soil organic carbon in Exc 1, Exc2 and Exc3, and ANPP in Exc 3 were compared statistically between years using ANOVA and comparison of means was conducted using Tukey test (P = 0.05).

Results

In all exclosures, SOC content was increased post-exclusion (Figure 1), which is consistent with results reported by Hoffmann et al. (2008) and Vecchio (2014). The highest accumulation rate was observed in the first three years post-exclusion, double relative to values in year 0. After the sixth year, curves show certain level of flattening (Fig. 1). Soil C input depends on photosynthetic carbon (biological C) and transposition rate as SOC. In the exclusion, practically the total C assimilated would be incorporated into the soil and as such exclosure could be used as a strategic method for regenerating SOC by initiating the soil-vegetation virtuous circle.

Aboveground net primary productivity continuously increased over the years except for in year 9. The increase more important (approximately ten times its value) was after first three years of exclusion (Figure 2a). The 14-year exclosure increased productivity with respect to year 9 post-exclusion. In that exclosure, the vegetation growth curve changed from a typical modal curve in year 0 to a bimodal curve in year 14, with higher growth-rates (Figure 2b). Exclusion studies in Mongolia, China, showed a similar outcome (Li et al 2008). Vegetation cover restitution in degraded grassland would generate more photosynthetic capacity, and therefore greater contributions of carbon to the soil. Restoring degraded grasslands using exclosure would represent a natural and low cost way to capture atmospheric carbon to restore soil fertility.

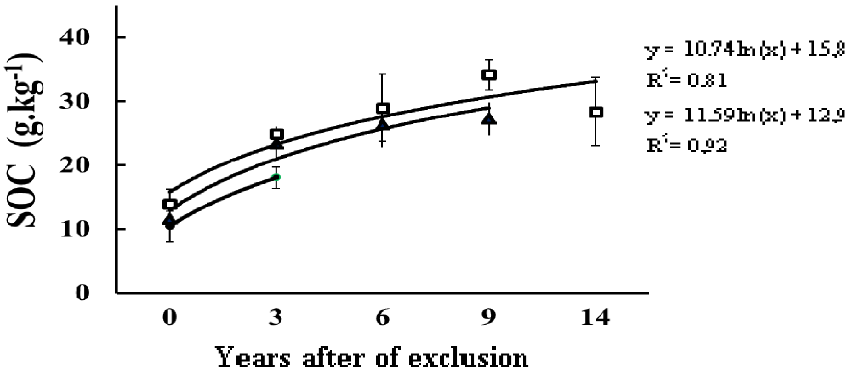

Figure 1. Soil organic carbon (SOC, g kg^{-1} soil) in three exclosure areas (with predominantly halophytes community) enclosed since 1999 (Exc$_1$, open square), 2004 (Exc$_2$, triangle) and 2010 (Exc$_3$, circle) until to 2013. 0 is beginning of exclusion, and 3, 6, 9 and 14 years after of exclusion from grazing. Vertical lines indicate standard error of the mean of sites (n=4) in each exclosure area.

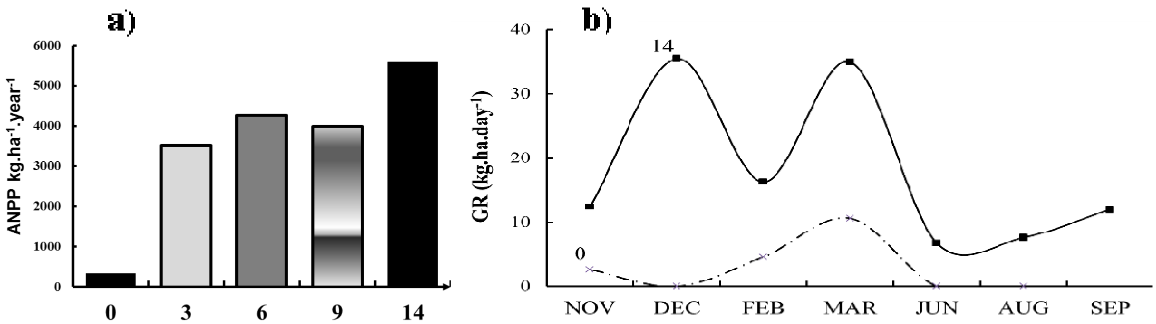

Figure 2. a) Aboveground net primary productivity (ANPP, Kg dry material ha^{-1} year^{-1}) in halophyte grassland for year 0 (beginning of exclusion), 3, 6, 9 and 14 years after exclusion. b) Curves of growth rate (GR, Kg dry material ha^{-1} day^{-1}) in the halophyte grassland for beginning of exclusion (0) and 14 years after exclusion (14).

Conclusion and Implications

Exclusion in degraded halophyte communities in grasslands in FP, Argentina, shows a strategic way for ANPP increases and SOC regeneration. After three years of exclusion the differences were approximately 10 times in ANPP and 2 times in SOC with respect to their initial values at year 0. This work shows exclusion can potentiality be used to restore soil fertility and the functionality of halophyte communities degraded by overgrazing. The output from this study would be useful to design strategies to restore degraded grassland dominated by halophyte communities.

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Productivity and Transfer Dynamics of Tropical Grassland of Western Ghats, Kodayar, Tamil Nadu

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Key words: Grazing land, Kodayar, productivity, transfer dynamics, Western Ghats

Introduction

Grasslands in India are seral in nature attaining the status of disclimax in many places, due to biotic operations such as grazing, fire and clipping. Grassland in Western Ghats region emerged from excessive cutting and felling of trees. Biomass and transfer dynamics of grasslands in northern (Singh and Yadava, 1974), north-eastern (Ramakrishnan and Ram 1988) India have been studied. Very little information exists on structure and function of the Western Ghats grassland ecosystems in southern India. The present study aims to understand the productivity and transfer dynamics of tropical grazing land ecosystem at Kodayar dominated by *Themeda cymbaria* Hak., and *Cymbopogon flexuosus* W.Watson.

Materials and Methods

The present study was carried out in Kodayar, located in the western part of Kanniyakumari district of Tamil Nadu, Southern India ($8^0$25'N, $77^0$17'E). The mean annual rainfall recorded in the study was 2190 mm, of which 83% occurred from June to November. Average monthly maximum and minimum temperatures were 32^0C and 27^0C in summer and 26^0C and 22^0C in winter, respectively.

Biomass was estimated by harvest method (Milner &Hughes 1968). Ten quadrats were sampled randomly monthly interval. The harvested samples were separated into live shoots and dead shoots. The surface litter was collected from each plot. The root mass harvested and separated by washing thoroughly under running water using 2 mm mesh screens. All the plant samples were oven dried at 80^0C till the constant weight was obtained. The aboveground net primary production (ANP), below ground net production (BNP), net accumulation and disappearance rates of dry matter were calculated following Singh and Yadava (1974).

Results and Discussion

Monthly changes in live shoots, dead shoots, litter and below ground parts are depicted in Fig. 1. The biomass of live shoots ranged from 128 to 1402 g/m^2 during the study period. Monthly changes in live shoots and below ground parts showed a bimodal pattern. The higher above ground biomass of this study area could be a function of the species, grazing and human interference etc. A substantial amount (227-779 g/m^2) of dead shoot biomass was recorded throughout the study period. First peak was occurred in April and the second major peak was in the month of October. The litter biomass ranged from 41-328 g/m^2. Litter biomass was gradually increased from January to April and there was sharp decline in May and June, again a sharp increase in the month of July. The maximum litter fall could be due to the tall grasses and tree litter. The fluctuation in the litter throughout the year is the net result of litter production and disappearance (Singh and Yadava, 1974). The below ground biomass ranged from 56 - 352 g/m^2, the maximum peak was noticed in the month of July, because of translocation of primary materials from live shoots to the below ground parts. The above ground net primary production was 2506 g/m^2. The peak community biomass was 1403 g/m2. Thus the estimate of net production obtained from the sum of species peak was greater than peak community biomass by 44% during the study period. The below ground net primary production was found to be 528 g/m^2 and the total net primary production was 3034 g/m^2. The net accumulation and disappearance of dry matter in the present study was shown in Fig.2. Of the total input of 8.3 g/m^2/day in to the system, about 83% and 17% were channelled to live shoots and below ground. About 48% of aboveground net production was transferred to dead shoots and 57% to litter. The rate of litter disappearance was 1.8 g/m^2/day and that of below ground was 1.3 g/m^2/day. The sum of these values gives a total disappearance of 3.1 g/m^2/day, which was 37% of the total input for the tropical grassland at Kodayar. There was a net surplus of organic material in the present grassland ecosystem showed seral nature of grassland to woodland condition.

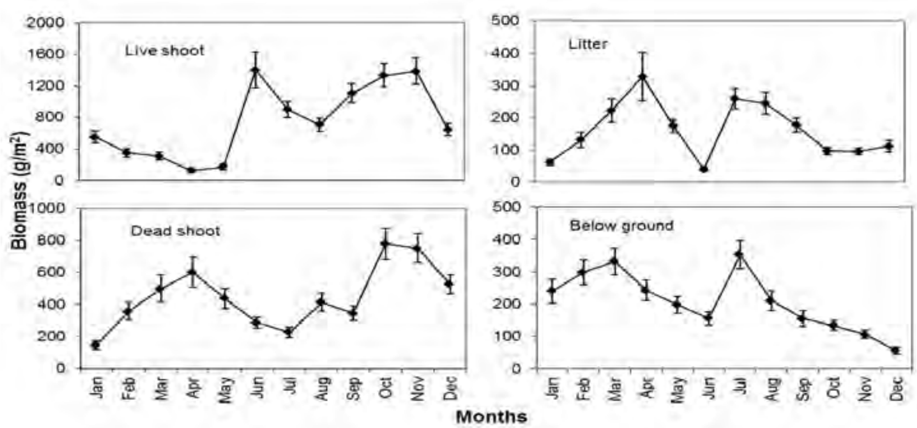

Figure 1. Monthly variation in biomass of various compartments in tropical grassland of Western Ghats in Kodayar. Vertical bars represent ± SD.

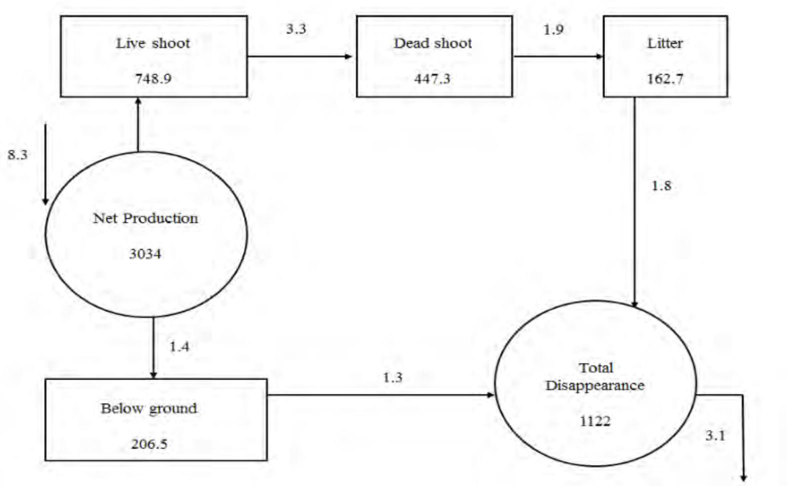

Figure 2. Net dry matter flow through the producer compart-ments in a tropical grassland of Western Ghats in Kodayar. Values in boxes are mean annual standing crop (g/m^2/year); values in circles are total net primary production and disappearance; values on the arrows are net flex rates in g/m^2/day.

Conclusions and Implications

The present study showed there was a net surplus of organic material as the rate of disappearance was slower than the rate of dry matter accumulation. Moderate grazing in humid climates often increases the above ground net primary production through more tillering. With proper management, degradation of the grassland ecosystem can be minimised to maintain the stability and diversity of these grassland ecosystem.

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Ecosystem-Level Carbon Stock Assessment in Two Savannah Ecosystems of Western Ghats, India

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Key words: Hottest hotspot, diversity, woody biomass, soil carbon, Wildlife Sanctuary

Introduction

In this crucial era of global warming and climate change, assessment of carbon stocks are necessary to prioritize different ecosystems for conservation, greenhouse gas mitigation and adaptation programmes. Grasslands cover approximately 30% of land globally and account for 23% of the global terrestrial ecosystem carbon stock (Trumper et al., 2009). Therefore, an attempt has been made to assess the biomass and carbon stocks of two savannah ecosystems in Western Ghats, a biodiversity hottest hotspot, to understand the carbon storage potential.

Materials and Methods

Carbon inventory was done on two savannah ecosystems (Sites I & II) at the Kanyakumari Wildlife Sanctuary, Western Ghats, India (77°10'-77°35' E and 8°5'-8°35' N). Average annual rainfall of 1369.5 mm and the average monthly maximum and minimum temperatures are 30 and 24 °C at these sites. Ten plots of 20 m x 20 m each were laid in each site and all the individuals of woody species ≥ 10 cm GBH (girth at breast height) were enumerated as adults and those below are considered as juveniles. A total of forty quadrats (4 in each plot) of 1 m x 1 m were laid in each site to study the understorey. Standard allometric equations were used to estimate the biomass of woody vegetation and harvest method was used to estimate herbaceous vegetation biomass (Chave et al., 2005). Carbon is considered to be a fraction of 44.53% of biomass (Junior et al. 2016). Soil carbon-to-nitrogen ratio was quantified for a depth of 0-30 cm (30 replicates each for 0-10 and 10-30 cm in each site) using CHNOS Elemental Analyzer.

Results and Discussion

The two sites varied in terms of diversity, density, biomass and carbon stocks (Table 1). Overall, 75 species were recorded from 41 families, of which 18 contribute to understorey. *Aporosa cardiosperma* was more prevalent in juvenile stage in Site-II and in adult stage in Site-I. *Psychotria glandulosa* dominated among the juveniles in site-I and *Terminalia paniculata* dominated among the adults in site-II. Site-I showed diversity in understory with 18 species, but had lesser density, while site-II was dominated by *Themeda cymbaria* and had very high density (Fig. 1). Site-I had more species diversity, more density of woody vegetation, greater biomass from woody vegetation, carbon stocks and higher C:N than site-II. However, site-II had a higher soil carbon than site-I due to the adventitious root binding and leaching of surface carbon by grasses, preventing it from runoff, which is absent in the latter. Herbaceous biomass and carbon stock was significantly greater in site-II than site-I, which could be due to domination of the grass, *Themeda cymbaria*. However, on an ecosystem level, both the sites had almost equal carbon stocks. The variations could be explained due to the difference in terrain characteristics, where site-I is sloped, while site-II is flat. Site-I was observed to be a savannah in 1993, which has since been left undisturbed and is therefore now in a transitional stage of succession from savannah to moist deciduous forest. This follows the report of Hughes et al. (2002), which says that the abandonment of grasslands and their conversion to forest results in increased aboveground carbon stocks (Nagler et al., 2015). In contrast, site-II has a known history of annual fires, which although occasional in recent years, helps maintain its savannah structure.

Table 1: Diversity, abundance, basal area, biomass and carbon of two savannah ecosystems in Western Ghats, India. (Values in the parentheses represent the C and N% at 10-30 cm depth.)

Parameter	Site-I	Site-II	Parameter	Site-I	Site-II
No. of woody species (No./4000 m^2)			**Biomass and carbon (Mg/ha)**		
Adults (≥ 10 cm GBH)	42	18	Woody aboveground biomass	391.38±45.0	333.41±36.6
Juveniles	38	28	Woody belowground biomass	63.77±7.0	50.73±4.78
Total no. of woody species (> 1 cm GBH)	50	30	Woody biomass carbon	202.68±21.1	171.05±18.4
No. of understorey species	18	1	Aboveground biomass of understorey	3.19±0.39	36.91±1.63
Abundance (No./ha)			Belowground biomass of understorey	0.83±0.10	9.60±0.42
Adults	1485	685	Understorey biomass carbon	1.79±0.22	20.71±0.97
Juveniles	8423	1015	Total vegetation carbon	204.47±23.1	191.76±18.2
Total no. of woody individuals	9908	1700	Total soil C% (0-10 cm)	6.88±0.46 (1.47±0.06)	3.2±0.16 (2.28±0.15)
No. of individuals in understorey (No./40 m^2)	1198	1579	Total soil N% (0-10 cm)	0.2±0.01 (0.12±0.06)	0.24±0.07 (0.13±0.01)
Basal area (m^2/ha)			Soil carbon	172.3	183.52
Adults	37.8±4.0	31.6±2.6	C:N (0-10 cm)	34.8	17.5
Juveniles	1.33±0.4	0.21±0.1	Total ecosystem carbon	376.77	375.28

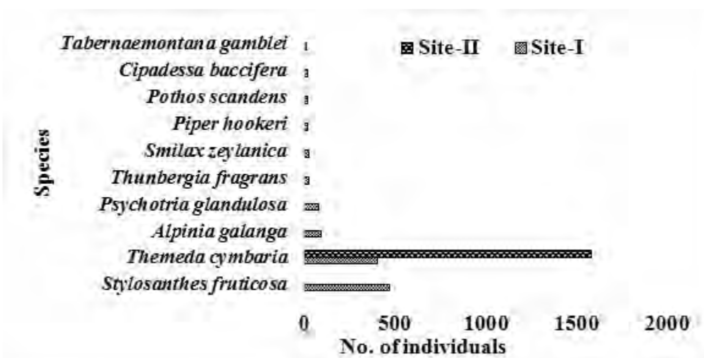

Figure 1. Abundance of understorey species in two savannah ecosystems of Western Ghats, India.

Conclusions and Implications

The study emphasizes the crucial role of savannahs in stocking considerable amount of carbon in this critical period of increase in atmospheric CO_2. The study shows that intact savannahs stock more carbon in soil, than the biomass, as seen in other forest types. It is also evident that savannahs can sequester more biomass carbon in the future, when left unperturbed for decades, by its conversion into a natural forest.

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Intra-Annual Variability of the Greenhouse Gas Balance of a Sylvo-Pastoral Ecosystem in Semi-Arid West Africa

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Key words: Ecosystem functioning, animal-soil-plant interactions, landscape, Senegal

Introduction

Extensive pastoral ecosystems, a quarter of the earth's land surface, are said to be major contributors to global warming. In sub-Saharan Africa, they are supposed to be responsible for the highest rates of greenhouse gas (GHG) emissions per unit of animal product (Steinfeld *et al.*, 2006). Main reasons put forward are the low productivity of herds, low management level of pastures and high methanogenic potential of feed intakes. Pastoral landscapes are characterized by constraining climatic conditions with little precipitation falling in a limited time frame that creates high seasonal variability in forage availability. The GHG balance for these landscapes is commonly calculated at regional and yearly scales. This study proposes a dynamic vision of a sylvo-pastoral landscape functioning by examining the intra-annual variability of the GHG balance. The objectives of this study are to describe the functioning of the sylvo-pastoral ecosystem during a full year and to propose a first assessment of the intra-annual temporal variability of its GHG balance. The study is original in its capacity to integrate the various components of the ecosystem (animals, soil, plants) and to consider all components of the GHG balance at the landscape level.

Material and Methods

The studied landscape is a circular area of 15 km centred on the Widou borehole (15°59'N, 15°19'W, 706 km²) representative of the sylvo-pastoral Ferlo Region in Sahelian zone of West Africa (North of Senegal). For this study, an original measurement protocol was implemented from May 2014 to October 2015 to estimate full GHG emissions and carbon accumulation in the studied landscape. Methane emissions from livestock enteric fermentation were evaluated using indirect approach: according to livestock resource intake and digestibility estimated through near-infrared spectroscopy analysis applied to faeces (F-NIRS) as described in Decruyenaere *et al.* (2009). Nitrous oxide (N_2O) and methane (CH_4) emissions in the soil and water due to manure deposition were measured with the static chamber method proposed by Khalil *et al.* (1998). The other sources of emissions (CH_4 from termites, CO_2 from fuel consumed by borehole motor pump and CO_2 from bush fires) were evaluated with the use of emission factors proposed in the literature. In the soil, net carbon exchange was quantified from the difference between total carbon inputs and outputs in the soil. Total carbon accumulation in trees aboveground and belowground biomass was evaluated with in situ surveys and specific allometric equations available in the literature for the main species encountered in the region. The evaluation of monthly variations of herd composition (by a survey among the herders) and herd weight evolution (in situ measures) were used to evaluate carbon sequestrated in the livestock. Supplementary data on herbaceous biomass production were also collected to better explain the dynamic functioning of the studied ecosystem. The GHG balance for the whole landscape unit was calculated by subtracting the total of carbon accumulation from the total GHG emissions.

Results and Discussion

Livestock related biomass fluxes and stocks

Total livestock in Widou area is 31560 Tropical Livestock Units (one TLU is equivalent to an animal of 250 kg live weight) with 49% cattle, 32% sheep and goats, 19% donkeys and horses. The study shows that this area supports a stocking rate ranging from 0.34 to 0.21 TLU/ha depended on livestock seasonal movements. Besides water, the herbaceous layer constitutes a basic element in the functioning and survival of the pastoral systems in semi-arid regions such as our studied landscape. The peak of forage availability is observed in September with a total aboveground herbaceous biomass of 1.49 t DM/ha and a total belowground biomass of 0.22 t DM/ha. Livestock ingest daily 2.6 to 7.1 kg DM/TLU according to seasons and herbaceous biomass availability. Between 26.4% and 37.2% of the biomass is consumed during the night. At the landscape level, only 27% of total produced biomass is ingested by the animals in one year, the rest returns to soil or is burnt in bush fires.

Temporal variability of the GHG balance at the whole ecosystem level

Figure 1 shows the monthly variations of the full GHG balance for the studied landscape. The GHG balance is positive and varies between 9,996.2 t CO_2-eq/month and 80,632.1 t CO_2-eq/month during the wet season (from July to October). However, during the two dry seasons (cold dry season from November to February and warm dry season from March to June) the GHG balance is negative and varies between -55,769.4 t CO_2-eq/month and -6,992.7 t CO_2-eq/month. At the landscape level and over one full year the full GHG balance is –0.02 t C-eq/ha. This negative value for the GHG balance indicates that the GHG emissions are compensated by total carbon accumulation in the soil, trees and animals. Negative values were also found for temperate pastoral ecosystem (Soussana *et al.*, 2007). However this value is lower than the ones observed under temperate conditions because of lower carbon sequestration potentials in soils under semi-arid tropical conditions due to limited rainfalls and high temperatures (Kotir, 2011).

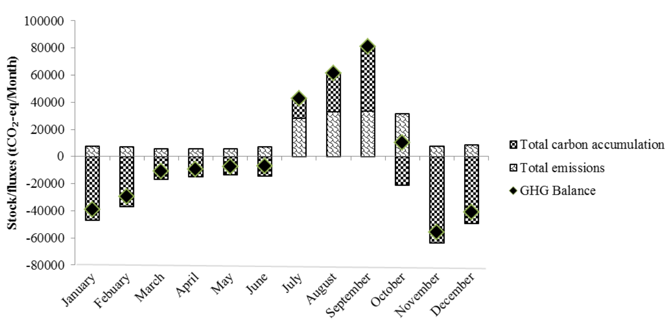

Figure 9. Temporal variability of the full GHG balance at the whole landscape level.

Conclusions and Implications

This study shows a strong temporal variability of the full GHG balance in a semi-arid sylvo-pastoral region. At the whole Widou borehole coverage area level, the yearly GHG balance appears slightly negative, indicating a more or less equilibrated state between the total GHG emissions and the total carbon accumulation in soils, tree and livestock. Transhumance plays a key role in this equilibrium because herders carefully adapt the livestock stocking rate to the available biomass.

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No Difference in Carbon Dioxide Emissions from Grazed and Non-Grazed Temperate Grassland Soils

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Key words: Greenhouse gases, soil microbes, rangelands, carbon emissions, carbon mineralization

Introduction

The emission of anthropogenic greenhouse gases (GHG) is driving global climate change. Rangeland soils have high potential to reduce GHG concentrations via soil carbon sequestration (Piñeiro et al., 2010). Due to the areal extent of rangelands, they may serve as a significant sink of GHG and help mitigate global climate change, provided appropriate management is taking place (Smith et al., 2008). The main drivers of GHG flux from soils are microorganisms (bacteria and fungi) that respire CO_2. The community composition of microorganisms changes over climatic gradients, but they are also sensitive to changes in their local environment (Steenwerth et al. 2002). Cattle grazing can alter the pedosphere by altering litter cover, and soil temperature and moisture. The goal of this project is to examine the impact of cattle grazing on CO_2 emissions from grazed and non-grazed rangelands across a broad precipitation gradient in the Canadian Prairies.

Materials and Methods

We established 15 study locations throughout the grasslands of Alberta, Canada to measure GHG emissions. Study sites were located along a climate gradient within 3 natural subregions of Alberta (Parkland, Mixedgrass Prairie and Foothils Fescue). Each site included a plot grazed by cattle and a non-grazed (cattle exclosure) plot. Exclosures were approximately 30 x 30 m, and at least 15 years old. In the spring of 2015, we installed 2 static gas chambers (15 x 17 x 66 cm) in each subplot and collected gas samples bi-weekly from May through July, then every 3 weeks until October. At each sampling time 4 gas samples were collected (0, 10, 20 and 30 min), which were used to calculate flux (Lambert and Frechette, 2005). GHG concentrations were measured by gas chromatography (CP-3800 GC, Varian). We used soil probes to measure soil temperature and moisture continuously in each subplot. Soil samples (0-5 cm) were collected three times (spring, summer and fall) to determine soil characteristics (e.g. pH, organic carbon and total nitrogen). Differences in CO_2 flux were tested with repeated measures analysis of variance in which treatment and region were fixed effects.

Results and Discussion

We observed that grazed sites tended to have less CO_2 emission, although the difference was not significant (Fig. 1; $F_{1,24} = 1.75$, $P = 0.19$) . We also observed that grazed plots had higher temperatures and soil moisture than non-grazed plots (data not shown). Thus, our results are somewhat unexpected as one would expect greater microbial activity under the warmer-wetter conditions in grazed plots, although the difference may be the result of altered plant respiration. CO_2 emissions were lower (Fig. 1; $F_{2,24} = 4.21$, $P = 0.027$) on average in the Mixedgrass Prairie (70.5 CO_2, ug m^{-2} s^{-1} ±24.9 SE) than in the Foothills Fescue (108.6 CO_2, ug m^{-2} s^{-1} ±38.4 SE) and Parkland (98.3 CO_2, ug m^{-2} s^{-1} ±34.8 SE) regions. The Mixedgrass Prairie receives significantly less precipitation than the others, which likely explains these patterns.

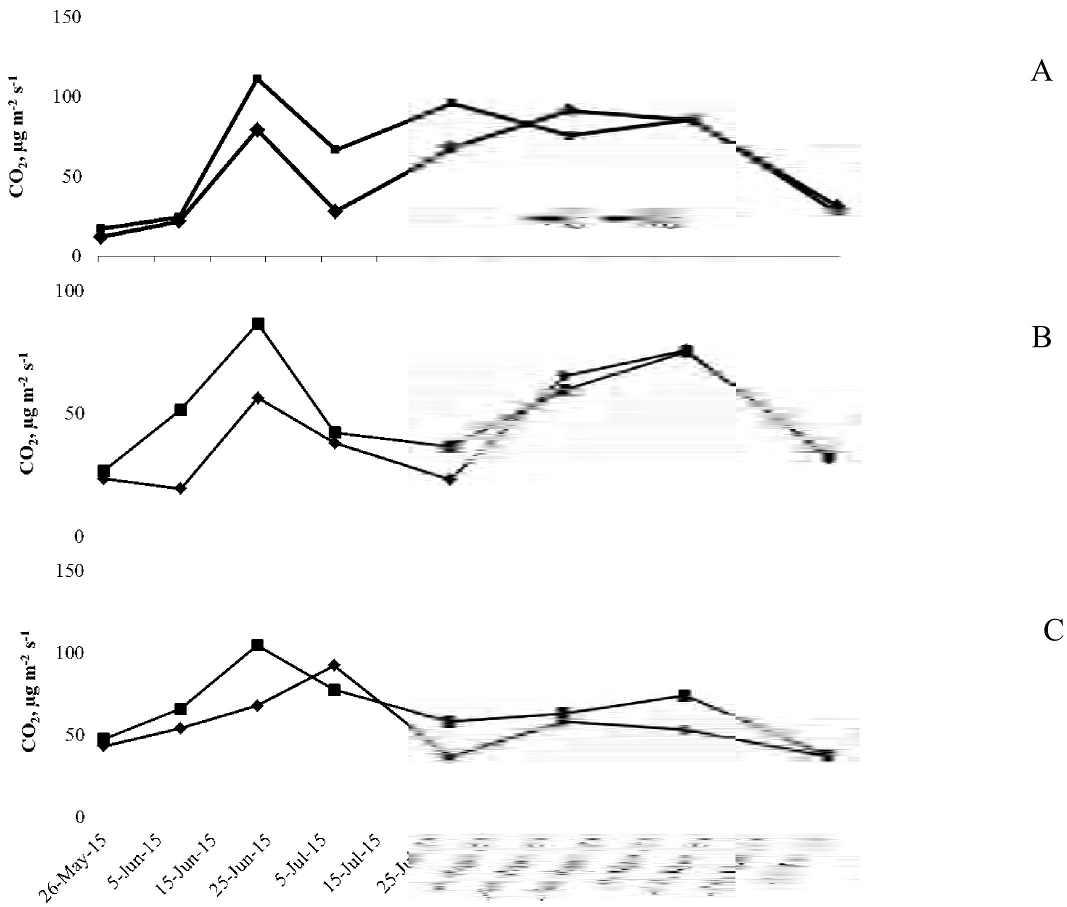

Figure 1. **CO_2 emissions (mean) during the growing season in grazed (G) and non-grazed (NG) treatments in each of three subregions:**
(A) Parkland, (B) Mixedgrass and (C) Foothills Fescue natural subregions.

Conclusion and Implication

The cattle industry has been criticized for its contribution to GHG emissions. However, our data suggest that grazing did not increase CO_2 emissions, and instead potential exists due to the widespread nature of beef production across the Canadian prairies for grazing to lower overall CO_2 emissions. Further work will include the examination of other GHG, specifically methane and nitrous dioxide, and to examine mechanisms for these patterns such as the composition of the microbial community.

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Soil Carbon Change in Different Pasture Types in SE Australia

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Key words: Soil carbon, Vetiver, Subtropical, Native, pastures

Introduction

Historically, soil organic carbon (SOC) has declined as a result of land clearing and agricultural management. Cultivation accelerates organic matter decomposition while soil erosion, vegetation clearing and removal of crop residue are known to result in long-term SOC loss (Shiferaw *et al.*, 2013). However, these carbon depleted soils offer an opportunity to store additional SOC to address climate change and promote sustainable land management, improving production and productivity (Lal, 2004). Alternative management practices that promote SOC storage are therefore being widely sought. One such approach is the use of tropical perennial grasses within the production system.

Perennial grasses are widely distributed in tropical and sub-tropical regions of the world and adapted to a wide range of climatic and environmental conditions (Lavania & Lavania, 2009). Grasses such as Vetiver (*Vetiveria/Chrysopogon Zizanioides)* produce large and complex root systems, which penetrate the soil vertically unlike many other grasses (Lavania & Lavania, 2009) giving it the significant potential to translocate carbon deep into the soil profile (Zimmermann *et al.*, 2012). Vetiver is a multipurpose grass and is widely used for conservation and rehabilitation across Asia and Africa (Singh *et al.*, 2011). Vetiver has therefore, been proposed as a potential candidate for long-term SOC storage (Lavania & Lavania, 2009). However, few empirical studies are available to indicate its SOC storage potential (Singh *et al.*, 2011). This study therefore tested the effect of Vetiver, other sub-tropical and native grasses on the quantity and distribution of SOC at a site in SE Australia.

Materials and Methods

Soil samples were collected from Gunnedah Resource Centre, in New South Wales located at 31.03 °S and 150.27 °E with an elevation of 270-340 m.a.s.l and Ferrosol (Australian Soil Classification, Isbell 2011) soil type (USDA equivalent Oxisols). At this site, pastures dominated by Queensland Blue Grass (*Dicanthium sericium*) are the common native grasslands. Into these native pastures, plots of Vetiver were established in 1993 and other perennial sub-tropical species (*Panicum coloratum L.*) in 2005. Undisturbed core soil samples were collected to a depth of 1.0m with 7 depth increments (0-10, 10-20, 20-30, 30-40, 40-50, 50-70, 70-100cm). Prior to analysis, samples were dried at 40^{o}C, crushed to pass through a 2mm then 200µm sieves. SOC *%* using bulk density, used to calculate Total Organic Carbon stock (TOC – Mgha^{-1}) while δ^{13}C was analyzed using Isotope Ratio Mass Spectrometry. The δ^{13}C signature of the soil, existing and "new" plant material (Vetiver=-11.59; Subtropical=-12.36 & Native$_{=}$-22) provides an indication of the source of carbon in the soil system. Data analysis was then performed using two-way ANOVA, following a generalized linear model procedure to examine the relationships of total carbon and its distribution in the profiles using R statistical software.

Result and Discussion

Analysis of variance detected both a "pasture type" and "depth" effect on SOC. A larger quantity of C was found under vetiver at all depths compared with subtropical pasture while vetiver and native pastures had similar TOC values (Fig. 1 left). Total carbon stored by vetiver, native and subtropical pastures was 123, 111 and 92 Mg ha^{-1} respectively. For all pasture types a decrease in TOC was observed with increasing soil depth. Vetiver would appear to be effective at storing a modest quantity of additional soil carbon in the soil profile compared with other pasture types.

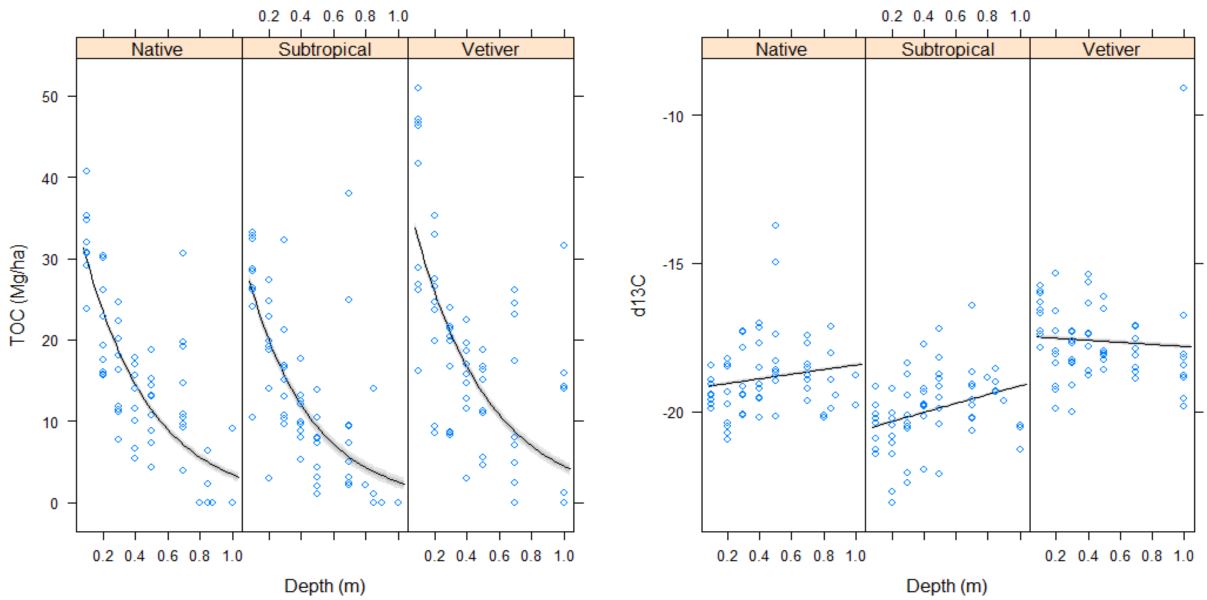

Figure 10. TOC in $Mgha^{-1}$ and Isotope ratios under vetiver, subtropical and native grasses.

Significant differences were observed in $\delta^{13}C$ between the vetiver, subtropical and native pastures (Fig. 1 right). Native and sub-tropical grasses had lower $\delta^{13}C$ values compared with vetiver through the whole soil profile and for both pasture types the $\delta^{13}C$ values increased with increasing soil depth. This is a commonly observed effect where increasing organic carbon decomposition with depth results in higher $\delta^{13}C$ values. For vetiver however, $\delta^{13}C$ values were higher throughout the soil profile, particularly in the surface soil layers, declining with increasing soil depth. This result suggests a significant, and ongoing, addition of organic matter with a higher $\delta^{13}C$ signature to the soil through the whole profile. The $\delta^{13}C$ values indicated the addition of new carbon by vetiver (40.8%) and subtropical pastures (19.54%) compared with native pasture and indicate a significant turnover of carbon under these pasture types even where the net accumulation of carbon was limited.

Conclusion and Implication

Due to its wide adaptability and extensive use, we believe vetiver has considerable potential for carbon sequestration, particularly on carbon depleted soils. Hence, the need to fully explore the potential of tropical perennial pasture species such as vetiver to influence land management decisions in tropical regions.

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Stock and Quality of Carbon in High Andean Wetlands

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Key words: wetlands, humic substances, condition, grazing

Introduction

High-altitude wetlands are very efficient ecosystems with respect to storing soil carbon (C), thus contributing significantly to mitigate the effects of climate change (Peña et al., 2009). Despite their importance, these ecosystems called "bofedales" are often disturbed by grazing and other factors (Salvador et al., 2014). The effect of grazing on the amount of C stored in rangelands is controversial because it may increase, decrease or have no effect on the content of organic matter (Milchunas and Lauenroth, 1993). Intensive grazing may decrease incorporation of plant residues in the soil and therefore the amount of C in the soil can be reduced. However, grazing can promote nutrient cycling through feces and urine which provides available soluble nitrogen to plants, while promoting soil organic matter mineralization (McNaughton et al., 1997). The aim of this study was to determine the grazing condition, soil-stored C and organic matter quality in bofedales to understand the effect of grazing on C stored in high Andean wetlands.

Materials and Methods

In this exploratory study, soil data regarding humic acids and C content were correlated with the grazing condition of bofedales. Six representative bofedales located in the southern and central Andes at altitudes ranging from 3800 to 4500 m.a.s.l. were evaluated (Fig. 1). The grazing condition of the bofedales was evaluated using Parker's procedure (1951) modified by Florez and Malpartida (1980), which considers the acceptability of plants, forage index, vegetation cover and vigor index. The percentage of organic matter was estimated using the Walkey and Black method (1934) whereas the C quality was assessed using the ratio of humic substances which are humic acid (HA), fulvic acid (FA) and humin (HU) by the Kononova methodology (1982).

Results and Discussion

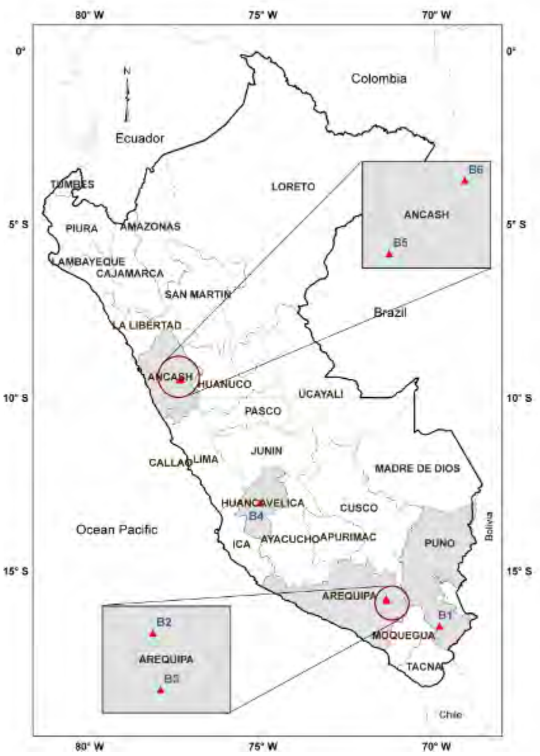
The main soil characteristic of bofedales was a soil profile with an organic matter surface layer followed by mineral layers of variable textures. The results indicate that good bofedales tend to have a lower amount of C stored in the soil than poor bofedales (Table 1). These results contrast with Medina-Roldan et al., (2008) who found the improvement of the ecosystems' condition increases the soil carbon reservoir. It is worth noting that the methodology used to asses grazing condition gives a weight score of 70% to desirable plants, thus bofedales of good condition contain great proportion of desirable plants. This might increase carrying capacity, resulting in decrease of C return to the soil and might increase mineralization rates (McNaughton et al., 1997), therefore a lower stock of C would be found in those bofedales.

Table 1. Grazing conditions of bofedales and stock C (t/ha).

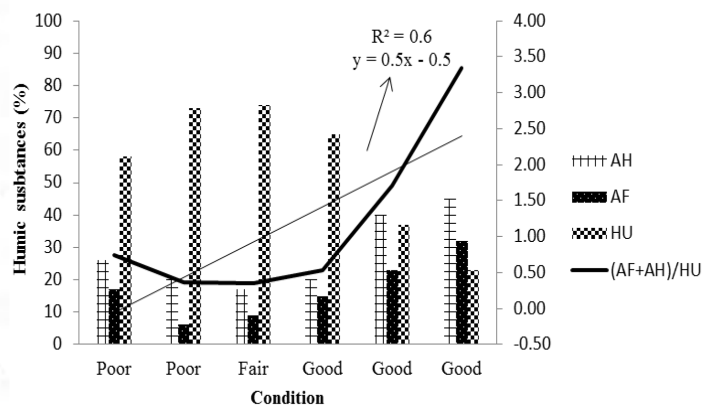
Region	Bofedal	Condition	Depth (cm)	C (%)	C ($t.ha^{-1}$)
Puno	B1	Good	60	1	33
Arequipa	B2	Good	70	5	47
Arequipa	B3	Good	80	7	78
Huancavelica	B4	Fair	100	6	157
Ancash	B5	Poor	50	15	185

Ancash	B6	Poor	100	12	223

Furthermore, the results revealed a positive correlation ($r^2 = 0.62$) between grazing condition and quality of organic matter, which means good bofedales had better organic material quality than poor bofedales (Figure 2). The latter have a higher amount of humins (AH + AF / HU <1), suggesting that C in the soils will remain stable for much longer, which helps to maintain the carbon stock (Canellas et al., 2009). The results also showed that bofedales with lower content of Chad better quality of organic matter and that bofedales with greater amount of C also had more stable C.



◄ **Figure 1. Map of Peru showing administrative regions. The regions mentioned in this article are identified by triangle (Δ).**



▲ **Figure 2. Content of humic substances (%) and quality of organic matter (AH+AF/HU).**

Conclusions

We found that bofedales in better conditions for grazing also have a high organic matter quality but a low stock of C. We recommend to extend the study to a larger number of mountain wetlands with different conditions for grazing and analyze the flux of C in this type of ecosystem.

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2.3 Water Supply and quality

Livestock and Fire Management Influence Fundamental Supporting and Regulating Ecosystem Services of Grassland Ecosystems: The Interacting Roles of Species, Vegetation Structure and Rainfall Intensity on the Redistribution of Water

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Key words: grasslands, Mexico, ecohydrology, disturbance regime, rain simulation

Introduction

Mexico's drylands cover over 50 percent of the terrestrial surface and consist of the semiarid grassland and desert scrub ecosystem types. Of these, the grassland biome is the most threatened biome in Mexico when considering its extension, functional integrity and role as life support system for a large part of the rural population. The main causes include massive conversion into rainfed and irrigated agricultural land, introduction of exotic forage species, inadequate stocking rates of livestock or alterations of the natural disturbance regime under which these grassland ecosystems originally evolved. Resulting changes in species composition, shifts in abundance patters, and an overall reduction in vegetation cover have not only reduced the productivity of these grasslands but also undermined the provision of fundamental supporting and regulating services of these ecosystems (Augustine et al., 2008). In dryland ecosystems, the provision of almost all fundamental supporting and regulating services are directly coupled to ecohydrological functioning. Hence, we asked the following question: how have changes in the structure and functioning of semiarid grasslands in Mexico associated with different management types put the resilience in the provision of ecosystem goods and services at risk? While there exists a great diversity in grassland use and management types, little do we understand of how resulting shifts in structural changes (vegetation composition, cover, microtopography) influence ecohydrological processes such as infiltration, run-off and water retention.

Materials and Methods

We compared 14 different land use and management types of semiarid grasslands in the physiographic province of Ojuelos, Jalisco, in Central Mexico, and in particular how different intensities of grazing and prescribed fire influenced species abundance, ground cover and run-off patterns in 75 confined run-off plots (2-3 m). Between June 2011 and May 2014, we recorded each rainfall event in a network of 7 pluviometers situated maximum 8 km apart. After each rainfall event we measured volumetric water run-off, and monitored weekly soil water content at 15 and 30 cm depth. We also determined root biomass, soil organic matter, soil compaction, vegetation cover, number, area and organization of vegetation patches in each run-off plot. We compared these variables i) in grasslands with different grazing histories (continuous, rotational, seasonal, 30 and 10-yrs grazing exclosures), ii) under the influence of an introduced grass species and iii) the effect of prescribed fire on microsite characteristics of *Bouteloua gracilis* and *Muhlenbergia rigida*. In addition, we set up 20 1x1m plots to apply rainfall simulations and examine how infiltration and hydraulic conductivity differed in microsites of *Bouteloua gracilis* and *Muhlenbergia rigida* under high and low rainfall intensities considering biotic and abiotic surface characteristics associated with and without prescribed fire. We applied stepwise regression to identify key biotic and abiotic factors explaining differences in ecohydrological processes.

Results and Discussion

Comparing the number and size of individual rainfall events, we discovered a surprisingly high spatiotemporal distribution both within and among years. Over 50% of all rainfall events were smaller than 5.0 mm and September was the month with the highest frequency of rainfall events. Less than 50% of all rainfalls occurred simultaneously in all sites. When considering different grazing treatments, both 30 and 10 year exclosures were the treatments with the lowest run-off volume resulting on average with 10% greater soil moisture content than sites with continuous or seasonal grazing. Soil cover by native and exotic grass species did not influence runoff volume or soil moisture content. Finally, when considering grazing and fire, runoff volume was significantly greater on sites with prescribed fire. Overall, vegetation cover, plant patch size, distribution and number as well as vertical and horizontal root biomass distribution explained these differential run-off patterns. In case of the rainfall simulations, percentage runoff was significantly influenced by rain intensity, species and fire (P=0.0003); high rain intensities in burned plots triggered greater runoff than in unburned plots (P<0.05), however this response was more pronounced in *Bouteloua gracilis* than in *Muhlenbergia rigida* microsites. At low rain intensities, fire treatment enhanced runoff only in *Bouteloua gracilis* plots. Hydraulic conductivity was higher in *Muhlenbergia rigida* microsites independently of fire treatments (P<0.05), and in associated microsites with bare soil it was lower than in the presence of vegetation.

Conclusions and Implications

The two grass species significantly influence ecohydrological processes of these grasslands both at the tussock level considering their inherent growth characteristics and at the community/ecosystem level, because of their influence on basal and soil cover, microtopography and thus heterogeneous distribution characterizing these grasslands.

Semiarid grasslands under continuous grazing pressure cause substantial water loss (Pierson et al., 2008) directly affecting the long-term provisioning of supporting and regulating ecosystem services (Huber-Sannwald et al., 2012). Reintroducing fire as an inherent disturbance agent in grassland ecosystem may stimulate primary productivity (Scheintaub et al., 2009), however with the trade-off of enhancing water loss.

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Estimating Rangeland Runoff, Soil Erosion, and Salt Mobility and Transport Processes

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Key words: Rangeland Hydrology and Erosion Model, runoff, soil erosion, salt transport

Introduction

The estimated annual cost of damage caused by soil erosion and excessive sediment in surface waters within the U.S. is approximately $6 billion to $16 billion. Over 55% of sediment and salts entering the Colorado River are derived from accelerated soil erosion from federal rangelands with damages estimated to be $385 million per year to water users. About 55% of the loading, however, comes from natural, non-irrigated sources on rangelands. This suggests a significant potential to reduce dissolved-solids loading to the Colorado River through land- and water-management activities on rangelands. Research on the topic of dissolved-solids loading to streams from rangelands is needed for identifying management practices that could reduce yields to the Colorado River. Specifically, there is a need to improve the understanding of sources and transport mechanisms of dissolved solids in rangelands and develop methods to estimate dissolved solids.

Materials and Methods

Rainfall simulation was used to quantify the hydrologic, erosion, and salt mobilization and transport processes on 2 ecological sites in central Utah, U.S. To quantify the hydrologic response we used a Walnut Gulch rainfall simulator (2 m wide x 6 m long). A single rainfall intensity was applied to each plot as either a 2yr (44 mm/hr), 10yr (80 mm/hr), 25yr (104 mm/hr), or 50yr (136 mm/hr) rainfall return rate on dry soil for approximately 45 min. At each site 3 replications of each of the rainfall intensities were sampled for a total of 12 plots. Runoff and sediment samples were collected every 2 min. in 1 l bottles, dried and weighed. Canopy and ground cover were measured with line-point intercept.

The rainfall simulation data was used to evaluate the ability of the Rangeland Hydrology and Erosion Model (RHEM) to predict runoff and sediment yield from saline rangelands. RHEM was designed to require minimal input that is readily available for most rangeland ecological sites: soil texture; slope; plant life-form; canopy and ground cover; and precipitation (Nearing et al. 2011). RHEM estimates runoff, soil erosion, and sediment delivery rates and volumes at the spatial scale of the hillslope and the temporal scale of a single rainfall event. The study was conducted in the Price River Basin in central Utah, U.S. on 2 different ecological sites. Soils were derived from Mancos shale and are naturally saline, sodic and highly erosive. Average site characteristics are presented in Table 1.

Table 1. Average site vegetation and soil characteristics.

Site	Price, Utah	Ferron, Utah
Ecological site	Desert loamy clay (shadscale)	Desert shallow clay (mat saltbush)
Canopy cover %	8.4 %	21.7 %
Bare Soil %	89.3 %	74.7 %
Soil Series	Persayo loam	Chipeta-Badland complex
Surface texture	Silt Loam	Silt Loam
Slope %	6.3 %	18.9 %

Results and Discussion

A governing principle of land management is that changes in land cover result in changes in watershed condition and response. Land management practices influence runoff and soil erosion on rangelands because they affect plant distribution, biological diversity, canopy and ground cover, and soil properties. Vegetation is the primary factor controllable by human activity that influences the spatial and temporal variability of surface runoff and soil erosion on rangelands. The RHEM model did an excellent job in predicting runoff at the two sites (R^2 0.90) over all rainfall intensities applied (Fig. 1). RHEM predicted sediment yield (R^2 0.58) reasonably well (Fig. 2) with no significant bias in the predicted sediment yield. For saline and sodic sites, such as these, the soils are highly dispersive and the RHEM model slightly under predicted sediment yield. New parameterization equations designed specifically for saline and sodic soils should improve sediment yield predictions. There was a very strong correlation (R^2 0.84) between observed sediment yield and observed total dissolved solids (Fig. 3) at these two sites.

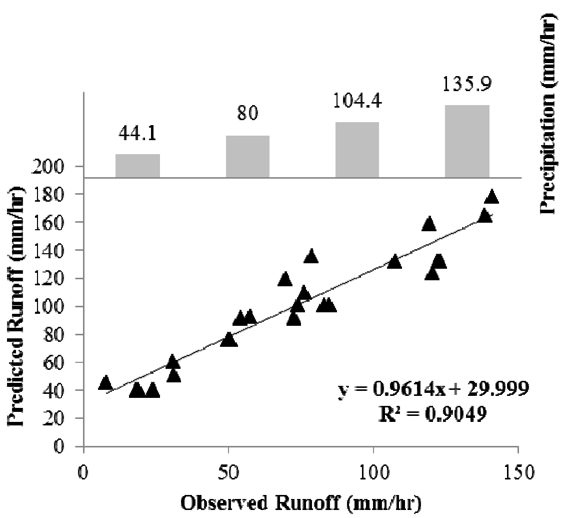

Figure 1. Observed vs. RHEM predicted runoff (mm/hr).

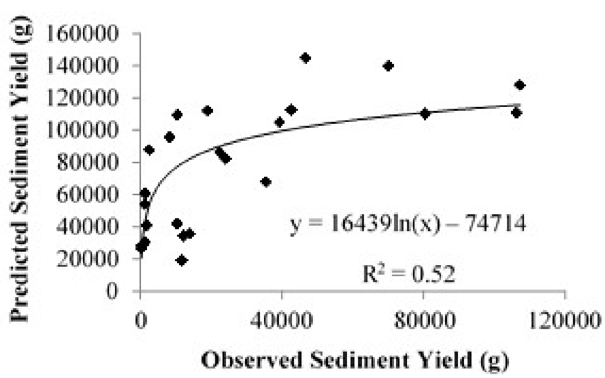

Figure 2. Observed vs. RHEM predicted sediment yield (g).

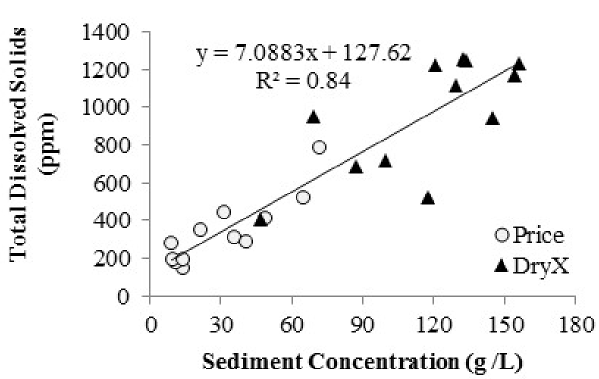

Figure 3. Sediment concentration vs. total dissolved solids (ppm).

Conclusions and Implications

Further work will involve additional rainfall simulations on saline and sodic rangelands to determine if these results are consistent and when or if soil erodibility parameters need to be altered. Updates to RHEM will include options to predict total dissolved solids in the future. Hydrologic response (runoff rate and sediment yield) at the hillslope scale can be used quantify and predict salt mobility and transport as a function of rainfall intensity to estimate total dissolved solids in surface runoff on rangelands.

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Promoting Resilience by Influencing Water Infrastructure Development in Community Managed Rangelands of Northern Kenya

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Key words: Rangelands, pastoralism, resilience, community validation

Introduction

Mobile pastoralism provides a highly efficient way of managing the unpredictable nature of drylands and forms the most viable form of production and land use in such regions. In Kenya, official estimates suggest that the livestock contribution to agricultural GDP was only slightly less than that from crops and horticulture, about $4.54 billion US dollars for livestock in 2009 versus $5.25 billion US dollars for arable agriculture (ICPALD, 2013). Despite its contribution to national economy, pastoralism is under-valued, neglected when it comes to national or regional decision-making, and marginalized.

The northern arid and semi-arid counties of Kenya are home to significant pastoral populations who make their living out of livestock keeping. Changes to land use patterns, often due to inappropriate development policies, population size, and the erosion of traditional management systems, have affected the resilience of these communities to the effects of climate change.

Responses to these problems, in the form of emergency water development, have in many instances inadvertently worsened the situation. Inappropriately sited permanent water points such as boreholes have encouraged settlement, broken down complex grazing patterns and resulted in degradation of the pasture and water resources. A heavy focus on hardware and technical delivery has also often been at the expense of building the institutional capacities and skills of local people to govern new water facilities, and manage relationships with the dynamic set of multiple users who may periodically access this resource. To rectify inappropriate development of water infrastructure in community managed rangelands of Kenya IUCN initiated “Water for Livestock in Isiolo and Garissa Counties, Kenya - Enhancing water resource and rangeland management community capacity through training and strategic water development”. The overall objective of the project was to improve livelihoods and resilience against drought for targeted communities in Northern Kenya. Specifically, the project interventions sought to:

- Improve access to water for livestock across Isiolo and Garissa Counties in ways that promote more sustainable management of rangeland resources, and as such strengthen the resilience of local communities in times of drought and climate variability;
- Strengthen the capacity of local institutions – both state and traditional – to understand and implement water and range management in the drylands, and build ownership for the sustainable governance and maintenance of water infrastructure;
- Document and share overall learning and lessons on project approaches with a wider audience involved in water infrastructure development and natural resource management (NRM).

The project built on IUCN’s previous work on natural resource governance in Isiolo and Garissa counties. Through this work, IUCN sought to build the capacity of local institutions, communities and local government authorities for local-level planning and management of grazing resources. This included utilizing participatory mapping methods to develop community resource maps which were the precursor to the development of participatory rangeland plans.

The project worked towards the overarching goal of building resilience of the pastoralist communities through sustainable management of rangeland resources and improved natural resource governance in the Northern Kenya, specifically target communities in Isiolo and Garissa Counties through the following strategies:

Materials and Methods

Table 1. Project approach.

What	Why?
Strategic water infrastructure development	Ensure appropriate location of the water infrastructure in rangelands to allow efficient and balanced utilization of pasture and water without environmental degradation. Community validation entrenched into planning and water development
Multi-stakeholder dialogues	Convened county dialogues to discuss ways of attaining effective coordination and improve governance in water and rangeland sector in Isiolo and Garissa Counties by engaging relevant stakeholders to explore mechanisms of fostering cooperation and capitalize on existing and emerging opportunities
Learning from experience: learning event	To share lessons and discuss pertinent issues arising from the project, learning event was convened to critically examine the project successes and failures in the spirit of learning. The learning event also aims to ensure that next phase of the project builds on the knowledge generated during the first phase of the project.

Results and Discussion

A number of critical issues that require understanding and reflection were identified during project implementation. A lot of these issues and views revolved around the kind of water infrastructure technology deployed in the project sites. These issues could form the basis of a checklist for use as an assessment tool for appropriate water infrastructure technology to be used in future phases of this project and other similar initiatives.

To assess the suitability of project interventions to the project sites three elements were taken into consideration: context, validation and institutions. Attention to each of these three elements is critical to the sustainability of the project interventions. Operating within the project site context allows for interventions to be moulded to community dynamics and helps to bring community knowledge and views into the decision-making realm. Validation becomes the equivalent of 'free, prior and informed consent' a principle that is increasing in importance and acceptance in development processes.

Conclusions and Implications

Engaging institutions supports the strong rules that are required to achieve effective use of water and range resources in a manner that enhances community resilience. Strong rules automatically imply strong and coordinated institutions.

The main lesson from the project is that the 'Water-Pasture balance' is critical for the resilience of rangeland communities. However, too much water for too long can lead to population increases, permanent settlement, conflict and degradation. There is also a need to understand and build on traditional grazing patterns as managed by traditional institutions and greater importance needs to be given to the governance and ecological considerations of range management, compared to a focus on individual water technologies.

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Strategic Supplementation to Manage Movement of Beef Cows on Hills

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Key words: Beef cows, behaviour, camping, hill country.

Introduction

New Zealand agricultural land has been intensified over recent decades, and there has been a corresponding decline in water quality, particularly through increases in nitrogen, phosphorus and sediment contamination of waterways. Previous research has shown that nutrient loss tends to occur from only small areas of hill country farms where two factors are present; a nutrient source and water movement (McDowell & Srinivasan, 2009). These areas are known as critical source areas. Cattle should be discouraged from congregating in these critical source areas, especially during storm events.

Extensively grazing cattle tend to select camping areas where they congregate to rest and ruminate for periods of the day. These camping areas accumulate a disproportionate amount of urine and faecal matter, and if surface runoff occurs, become critical source areas. It would likely result in improved water quality if these camping areas were located on well-drained soil types where there was little surface runoff. This experiment aimed to use strategic supplementation of beef cows during winter to influence the areas they selected for camping.

Materials and Methods

Thirty-two mixed-aged, pregnant Angus cows were selected for this experiment. The experiment was conducted for 43 d during winter 2015 at Massey University's Tuapaka farm near Palmerston North, New Zealand. The cows were grazed in two replicates of 16 cows, in adjacent 4.9 ha hill country paddocks. Beginning on day 15, cows were supplemented with 2 kg DM/cow/d of hay, which was fed at the same time and location each day. The feeding location was selected so as to be different to the preferred camping area within the paddock prior to supplementation.

A subgroup of cows (n=8 per replicate) were fitted with a neck-collar mounted Global Positioning System (GPS) from day 8 to 11 (pre-supplementation) and from day 39 to 43 (during supplementation). The GPS units were custom-made and reported the cow's position every time she moved ≥4 m or every 1 minute if she did not move during that period (Martin et al., 2015). The GPS data was used to derive total distance walked per day, and a distribution map using kernel density estimate.

Results and Discussion

Cows walked on average 3.52 ± 0.06 km/d prior to supplementation and 3.53 ± 0.06 km/d when supplementation was provided (P=0.92). The daily distance covered was similar to previous reports of 2.73 km/d and 3.36 km/da for un-supplemented cows in 8.04–12.75 ha paddocks on similar hills (Martin et al., 2015).

The distribution maps both before and after supplementation illustrated the preference of cows to camp on ridgelines, in the flatter areas (Fig. 1). Both paddocks were bisected by a valley, and prior to supplementation, cows had camping areas on both sides of that valley. Supplements were offered on different sides of the bisecting valley in each replicate. In the first replicate, where supplementation occurred on the eastern hillside, cows maintained a popular campsite on the western hillside, whereas in the second replicate, where supplementation was offered on the western hillside, cows abandoned their camp on the eastern hillside. The prevailing wind direction in these paddocks is such that the western hillside is likely to be more sheltered.

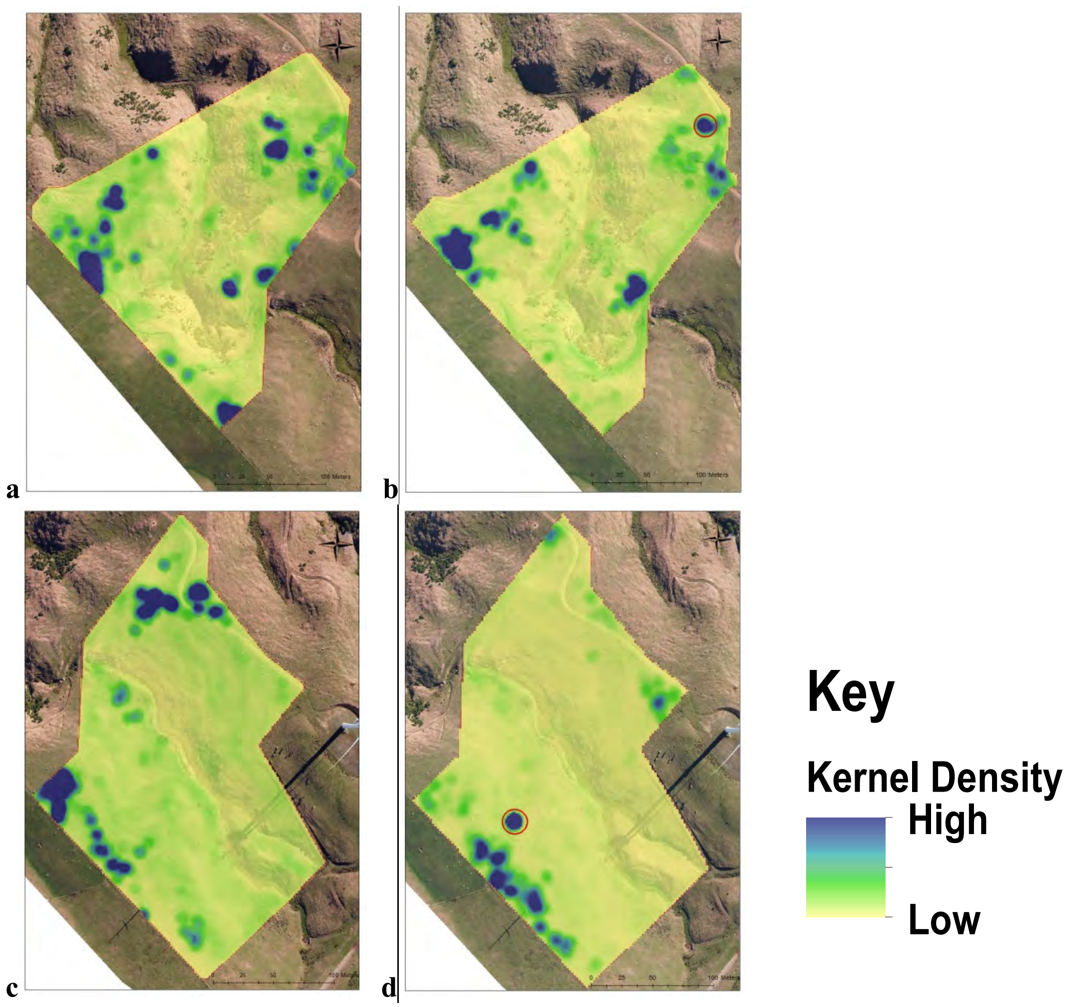

Figure 1. Distribution map showing the kernel density of location points of 2 replicate paddocks (a, b vs c, d) of 8 cows during a 4-d period prior to supplementation (a, c) and a 5-d period during supplementation (b, d). Supplementation was provided at the points marked with the red circle in b and d.

Conclusions and Implications

This research demonstrated that the camping behaviour of cows, and therefore, the high risk areas for nutrient runoff, can be influenced by the location at which supplements are offered. Further research is needed to determine the predictability and repeatability of these effects. Farmers should consider the impact on nutrient runoff when selecting supplementation sites.

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Integrated Lentic Riparian Grazing Management

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Key words: Riparian functions, risk assessment, objectives, monitoring, adaptive management

Introduction

Managing lentic riparian areas for functionality is a legal, policy, sustainability, wildlife & common sense requirement. Yet lentic work has been neglected without an effective integrated riparian management process (IRMP) such as Dickard et al. (2015) described for lotic riparian areas.

Methods

Step 1- Assess lentic riparian area proper functioning condition (PFC) (Prichard et al. 2003).
With areas in PFC, stabilizing plants capture sediment, dissipate or resist erosive energies, and accumulate organic matter to sustain the sponge for water to nourish stabilizing plants. Prior to PFC assessment, an interdisciplinary team reviews information and delineates and stratifies riparian areas using remote sensing. They stratify and randomly sample, if needed, using logical grouping based on similarities such as geomorphology, hydrology, vegetation, size, apparent condition, or classification (e.g. Weixelman et al. 2011). Potential, functions without human interference understood with the aid of soils (Lewis et al. 2003), is the foundation for site specific PFC assessment. Twenty hydrology, vegetation, or geomorphology assessment items can be validated with measurements, if needed, so the ID team can identify risks (e.g. Figure 1) to physical functioning (Prichard et al., 2003).

Figure 1. In grazed riparian areas, common "no" items putting lentic riparian areas at risk are illustrated in these photos: Smaller and not enlarging; Flow patterns altered; Low plant vigor; Inadequate stabilizing vegetation; Hummocking; and Out of balance erosion vs. deposition.

Step 2 - Identify resource values, or types of habitat.
Livestock production often depends on riparian vegetation to extend periods and amounts of nutritious green forage. Endangered, threatened, or sensitive species at springs depend on specific aquatic or riparian habitats.

Step 3 - Prioritize riparian areas for management, restoration, or monitoring using steps 1 and 2.
Prioritize riparian areas that function at risk. Add valuable areas recognized in step 2. Priority areas need to improve with better management before crossing an ecological threshold and losing their values.

Step 4 - Identify issues, and establish goals, and objectives for key areas.

Focus achievable objectives by considering potential and issues from steps 1-3 (specific riparian functions in need of recovery or restoration of resource values). Riparian vegetation usually drives recovery and objectives. It slows runoff to trap sediment and expand zones of wetness, dissipates or resists erosive energies to stabilize soil, and re-builds the organic sponge for water that nourishes stabilizing, forage, and habitat plants.

Step 5 - Design and implement management and restoration actions.

Many strategies that apply grazing management principles are effective for riparian recovery (Swanson et al., 2015). Principles are:

1. Strengthen important forage plants with only short periods of use OR moderate grazing intensity during the growing season.
2. Provide sufficient growing season recovery before next use.
3. Graze at a different time from one year to the next.

Step 6 - Monitor and analyze the effectiveness of actions by focusing on objectives addressing threats to riparian functions and targeted resource values.

For many strategies in Swanson et al. (2015), the most useful short-term monitoring data will be dates of nonuse for recovery from grazing. Long-term monitoring, photography and species composition or % bare ground should be focused where erosion is most likely, along the sloping curved greenline where elevation is lowest and flowing water deepest. Here, strong roots of riparian stabilizers (usually wetland obligates) must prevent erosion and capture sediment. Cross section(s) transect(s) can document distribution of wetland species and bare ground. Surveying elevation along transects tracks topography in relation to wetland plants versus erosion risk.

Step 7 - Implement adaptive actions.

Riparian management must be adjusted with monitoring. Monitoring short-term conformance with the plan, annual impacts of implemented management, and unplanned events like weather and fire helps interpret long-term resource changes such as vegetation, to determine progress toward resource objectives. Cooperative analysis guides adjustment of management.

Results and Discussion

In the Elko Bureau of Land Management (BLM) District, remarkable success has been observed for several streams (Swanson et al., 2015). About half of the 3,500 lentic riparian areas had been PFC assessed by 2012 (Personal Comm., 2013, Pat Coffin, Elko BLM fish biologist, retired) and ¾ of the lentic hectares were functioning properly or improving. However, ¾ of the riparian areas (mostly small, but potentially critical to local wildlife) were functioning at risk with a static or downward trend or no longer functioned (e.g. Figure 1). Long grazing periods was the most common problem.

Conclusions and Implications

Past riparian management focused on large and lotic areas. These foundations enable integrated lentic riparian management. The need for better management is greatest where riparian conditions risk loss of functions. Strategies developed for grazing management of lotic riparian areas can be applied with monitoring focused on the driving variables for lentic riparian recovery.

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Collaboration on the Mokelumne Watershed to Assure Water Quality and Preserve Working Landscapes

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Key words: Water quality; grazing; working landscapes

Introduction

East Bay Municipal Utility District (EBMUD) owns the Mokelumne Watershed surrounding Pardee and Camanche Reservoirs in the central foothills of California with a long history of cattle grazing. With new policies from the United States Environmental Protection Agency (EPA) to monitor *Cryptosporidium* in drinking water supplies, EBMUD took actions to help ensure drinking water safety. Now EBMUD is partnering with the University of California Cooperative Extension (UCCE) and ranchers to bring together science (UC research), policy (EBMUD and EPA), and management (ranchers and EBMUD) to find sustainable management practices to protect water quality and maintain a working landscape.

While maintaining a working landscape is an important goal of the agency, as a water provider to over 1.3 million customers in the Bay Area, providing safe drinking water is the utmost goal. With proper grazing and land management, the agency recognizes that safe water quality is attainable with livestock grazing. The agency also recognizes that grazing provides a tool to manage for many of its other goals including fuels management, species diversity, economic viability of the area, and historic and cultural resources.

UCCE provides the science behind many range management practices that can be implemented to obtain the goals of EBMUD through livestock grazing. UCCE research has demonstrated the compatibility of livestock grazing and safe drinking water over the years (Tate et. al, 2000). After ensuring the overarching goal can be met, UC research and information has been used to establish a monitoring program to meet the other goals and create a feedback loop to drive discussions between staff and ranchers concerning the rangelands.

The collaboration between EBMUD, UCCE, and ranchers has completed the second year of a five year partnership. A new range monitoring protocol has been developed involving all stakeholders and was implemented fully in 2015. Science will continue to be an integral component, with research conducted to answer management questions, ensuring that multiple goals are being met.

Materials and Methods

During the 2014 forage year, current and proposed monitoring protocols were field tested. Discussion was had with all involved stakeholders and a final monitoring protocol was agreed upon by all and fully implemented in 2015. Residual Dry Matter (RDM) mapping was determined to be the best management tool to quickly capture a snapshot of range health across the watershed. In addition to mapping RDM, undesired weeds and native perennials are mapped.

RDM is a significant tool in annual rangeland management as it's an important constituent in protecting soil from erosion, improving soil fertility, structure and infiltration rate, and in providing beneficial surface conditions for plant growth. Traditionally, RDM was taken from discrete locations in certain pastures. Data was determined by clipping forage from a number of 1 foot square plots and calculated to pounds per acre. For small and/or uniform pastures this type of data collection can be worthwhile. However for large variable pastures, this type of data collection is often not representative of the landscape. To better access RDM at the landscape scale, UCCE has introduced a new concept of RDM pasture mapping. Pasture mapping can be done quickly with a pair of observers and provides broader data for landscape management decisions. Observers first train their eyes to be able to recognize differences between RDM levels across the landscape and then able to visually quantify the RDM in lbs/acre. As part of the project UCCE developed a guide to train ranches and staff on how to visually estimate RDM. The guide consists of multiple photos of different weight classes as well as associated attributes. Once a team of observer has trained their eyes using the handout, they are then given an aerial map of the pasture and pens and are asked to draw polygons, noting whether the RDM levels are Above, Below, or on Target with the established standards. Digitized RDM pasture maps are then created to look for livestock distribution patterns and methods for improving utilization. Mapping weed populations allows land managers to prioritize efforts to control weeds at "high value sites" and to determine if weed presence/absence is correlated with forage utilization.

Results and Discussion

The immediate results of having the RDM pasture maps has been extremely useful. The maps have become the main tool for discussing land management between ranchers and the agency. The maps have become a guiding document that both parties can use to visually see what is happening on the landscape. In general, most pastures have been mapped at the "above" target RDM level, and tend to have high levels of invasive grasses. The maps are then used in discussions as to how to improve livestock distribution (i.e. cross fencing, water troughs, supplements, etc.) to better utilize the forage and meet goals.

Conclusions and Implications

A true collaborative process where each party has a stake in the process and feels that needs and concerns are being heard and understood creates a stronger overall rangeland management program for EBMUD. The prior model centered around EBMUD conducting monitoring that was never shared with ranchers, and ranchers never sure why changes were being asked in their grazing program. Ranchers now understand what the goals are for each of the pastures they manage and how their management can effect reaching each goal. Ranchers have also been given more freedom to reach different goals using livestock grazing as they see fit, giving ownership and receiving buy-in from the ranchers. This model can work well for other multi-stakeholder rangeland groups. Working from a common goals that are established together, having a transparent process where everyone is welcome to voice opinions and comments.

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Leaching of Nitrate from Grassland Field in Ireland

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Abstract
Grassland devoted to 90% of agricultural land in Ireland. Soil water chemical analysis result shows that there was considerable variation in nitrate concentrations from station to station, and between samples obtained by Teflon and ceramic water samplers in the same station. There was a clear tendency for concentrations to decrease with depth for Teflon samples, but that trend was not so consistent in ceramic cup samples. The result shows that the leaching of NO_3 is very high. Although no sampling was carried out below the root zone but it must be assumed that the high concentrations measured would constitute a threat to groundwater resources and high concentration of NO_3 in the well due to leaching of nitrate from root zone.

Key words: Grassland, leaching of nitrate, nitrate concentration.

Introduction

Grassland devoted to 90% of agricultural land in Ireland, almost all fertilizer and animal manures is surface applied, with little incorporation through the soil. This means that most fertilizer and manure tends to accumulate in the top few centimetres of soil, so that this layer can become saturated or nearly saturated with organic compounds specific nitrate- During rainfall events, water that runs over or infiltrates through this enriched surface soil can carry significant amounts of nitrate with it. This, in turn, can enrich surface water and contribute to eutrophication (Tunney *et al*., 2000). A chemical analysis of water samples from a ground water well in Skeagh yard nearby the Hill Field in the UCD Research Farm showed high nitrate concentration of 55 mg NO_3/L which exceeded the EU drinking water standards (Hart, pers. commun., 2006). The Hill Field at the UCD Research Farm was chosen as being representative of good versatile land, with undulating topography, on which moderate to intensive farming is practised in the drier rainfall areas of Ireland. Historically, the field was included in the tillage rotation of the farm but it has been in permanent grass for the last 25 years. The field is roughly square in shape, and occupies an area of approximately 4.5 ha with elevation ranging from 71 to 76 m. over sea level. Soil solution sampler were installed to obtain soil water from different depths to flow change in nitrate concentration.

Material and Methods

Field Management

The Hill Field is normally grazed by sheep and young cattle from August to December, and from February to April each year. One cut of silage is taken between the middle and the end of May. Chemical fertilizer in the form of urea is applied at a rate of 60 kg N ha^{-1} before grazing commences in the spring and again at a rate of 180 kg N ha^{-1} when the forage is managed for silage. After silage cutting, animal slurry (a mixture from cattle and swine) is applied at a rate of 27 m^3 ha^{-1} along with calcium ammonium nitrate (CAN) at a rate of 100 kg N ha^{-1}. No P or K chemical fertilizer, in addition to that applied in slurry, has been used for the last 5 years, but the field has received occasional, but un quantified, additional applications of slurry when conditions demanded outside the grazing periods. All slurry applications were applied by tractor drawn vacuum tanker.

Survey, Sampling and Nitrate Analysis

The Hill Field was surveyed using standard GPS techniques with the captured data processed cartographically by AutoCAD l4. Five monitoring stations were set up in the HillField at meter contour intervals. Suction lysimeters (Prenart Teflon and ceramic soil water samplers) were installed in the five stations at depths of 25, 65 and 85 cm soil water samples collected when their volumes were large enough to permit analysis. All water samples were filtered through 0.45-µM Millipore fi1ter paper immediately after collection. Nitrate were analyzed by ion chromatography (IC), using anion exchange column and conductivity detection.

Results and Discussion

Nitrate NO_3 concentrations were very high in soil water samples and average concentration of NO_3 in soil water was greater than the Maximum Admissible Concentration. These values appear to confirm the views of Stevens *et al*. (1999). The results also show that there was considerable variation in nitrate concentrations from station to station. There was a clear tendency for concentrations to decrease with depth for Teflon samples, but that trend was not so consistent in ceramic cup samples (Table 1). It is possible that these differences were simply due to soil heterogeneity. Warrick and Nielsen (1980), for example, reported that the nutrient content of soil can vary by orders of magnitude from meter to meter. The mean NO_3 concentrations in Teflon and ceramic s/w samples were very high, with concentrations in Teflon s/w samples ranging from 51 - 903 µg ml^{-1} at 25 cm depth, 4 - 576 µg ml^{-1} at 65 cm depth, and from 6 - 675 µg ml^{-1} at 85 cm depth. Even allowing for differences in installation depths, nitrate concentrations in ceramic s/w samples tended to be greater than those in Teflon cup samples. Ceramic s/w samples at the 30 cm depth had the highest range of NO_3 concentrations (64 - 1954 µg ml^{-1}), while at 50 cm depth the range was 136 688 µg ml^{-1}, compared with 26 - 1285 µg ml^{-1} at 70 cm depth. Concentration fluctuations throughout the monitoring period are shown in Fig 1.

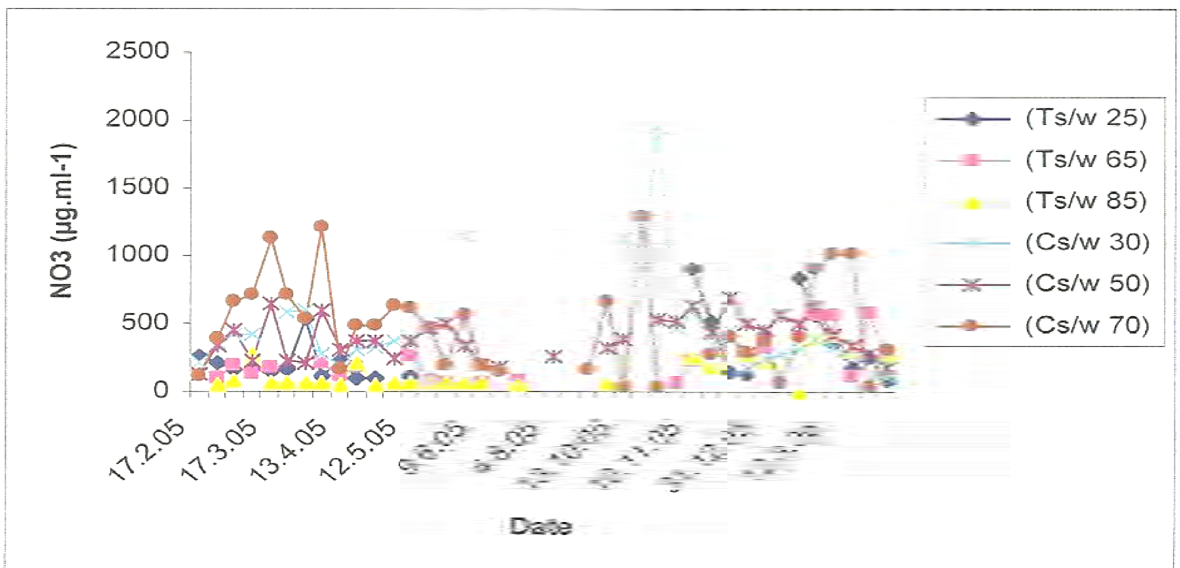

Figure 1. Mean NO_3 in Teflon and Ceramic cup samples during the monitoring period.

The NO_3 concentration varied even from one station to another. The highest variation occurred with Teflon and ceramic cup samples at different depths, and even at the one depth in the same station. Differences were apparent even between the shallowest Teflon and ceramic samplers that were inserted at almost the same depth. The highest NO_3 concentrations were recorded in a ceramic cup samples collected from Station 3, where NO_3 concentrations were higher than in other stations, and even higher than in Teflon cup samples (Table 1).

Table 1. Mean NO_3 concentrations ($\mu g.ml^{-1}$) in Teflone and ceramic soil water samples Hill Field.

Sampler type	Depth (cm)	Station S1	S2	S3	S4	S5
Teflon s/w	25	140	271	150	202	351
	65	235	-	202	241	178
	85	127	-	245	390	113
Ceramic s/w	30	194	-	595	-	203
	50	163	-	659	-	406
	70	157	-	1008	-	443

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Hydrologic Response to Restoration in Rangelands of Northern Mexico

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Key words: Arid landscape, hydrology, restoration, monitoring, Chihuahuan Desert

Introduction

Managing degraded rangelands to bring them to a more productive state requires a good understanding of the impacts that conservation efforts may have on local biotic and abiotic conditions. Properly conducted soil and water conservation practices can be beneficial to capture precipitation and store moisture for longer periods. In turn, this increase in moisture residence time can be beneficial for plant production, it can help recharge the soil profile, and in some cases, it can contribute to subsurface flow and groundwater recharge.

Materials and Methods

Since 2012, a series of conservation practices including land imprinting, grade control structures, small basins, and planting of native shrubland species (*Atriplex canescens*) and (*Prosopis glandulosa*) have been conducted in a 500 ha watershed in a rangeland location in the Chihuahuan Desert, in northern Mexico. In March of 2014, we began our collaborative research work to investigate plant-soil-water relationships following these restoration efforts.

We have instrumented the site to monitor rainfall, soil moisture, soil temperature, and shallow groundwater fluctuations. Also, vegetation variables such as canopy cover, species frequency, and planted shrub-growth response are being evaluated in treated and untreated areas.

Results and Discussion

Preliminary results show that average annual precipitation at the study site was 293 mm. Results provided valuable information regarding precipitation effects on soil moisture response at shallow (20 cm) and deeper (50 and 80 cm) depths. A greater soil moisture response, and variability, was observed by sensors located at 20 cm depth when compared to deeper probes. Shallow probes responded relatively rapid to specific precipitation events, particularly during the monsoon season. Soil moisture content at the 50-cm depth tends to increase during the winter season. An increase in soil moisture level observed during the winter season in all probes was attributed to decreased plant water uptake during dormancy. In general, similar soil temperature values were observed in under-canopy locations. Higher soil temperature values were observed in inter-canopy locations when compared to under-canopy sites. The difference in soil temperature between under-canopy and inter-canopy locations was more evident in the summer season.

Conclusions and Implications

Significant improvements regarding soil, water, and biodiversity indicators have been observed in response to conservation practices implemented. Study results provide valuable information towards understanding ecohydrologic response following land conservation practices in arid environments.

Effects of Rehabilitating Degraded Rangelands on Pastures and Water Quality

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Key words: Deep-ripping, blade ploughing, sediment runoff, nitrogen loss, phosphorus loss

Introduction

The Fitzroy River catchment of 14.3M ha in the Queensland rangelands is used for beef cattle production and has bare, eroded D-condition areas caused by episodic climatic events with continuous grazing. These bare patches continue to expand under continuous grazing, reducing grazing value of the pastures, and increasing erosion, causing sediment and nutrient losses. The result is poor quality of runoff water which causes deleterious down-stream effects on the Great Barrier Reef. Cattle producers have tried rehabilitation methods for over three decades with limited success. This paper describes rehabilitation methods in this catchment using two aggressive mechanical surface disturbance methods, with introduced pasture species seeding, and different grazing management strategies.

Materials and Method

Two rangeland sites with different mechanical rehabilitation methods and grazing management strategies were monitored for pastures and water quality on two commercial cattle propertes in the Fitzroy River catchment between 2011 and 2014 (Hall, 2014). Sites had been cleared of trees in the 1960's and sown to buffel grass (*Cenchrus ciliaris*) pastures. Under continuous grazing, nitrogen run-down and periodic droughts, extensive bare and eroded patches as large as 10 ha in size had developed and were continuing to expand. Runoff losses were measured by rainfall simulation in winter of 2012.

Site 1. Deep-ripping of loam soil

Two 85-ha paddocks with eroded, scalded patches in a rotation stocking method in cleared brigalow (*Acacia harpophilla*) were compared. Bare areas were deep-ripped and seeded with exotic pasture species in the rehabilitation treatment in 2003, and the control was untreated. Controlled management, using light grazing pressure and multiple long rest periods, was practiced annually during the first four years to 2007, and multiple short grazing periods continuing annually to 2014. Over the first four years the grazing pressure in the rehabilitation paddock was lower, and grazing times were shorter and less frequent, than in the control paddock, while both treatments had similar total stock grazing days between 2008 and 2014.

Site 2. Blade plough of clay soil

A 1000-ha paddock of cleared brigalow and *Eucalyptus* species woodland had extensive bare, eroded patches. In 2009, the rehabilitation method was to blade plough 95% of the paddock, leaving untreated strips as a control. The whole area was seeded with an exotic perennial grass and legume pasture. There was only light grazing the first year after the new pasture had produced seed. In subsequent years to 2014, there was conservative continuous grazing after an early summer complete rest period, and grazing pressure and timing allowed the pasture to seed annually.

Results and Discussion

Pastures

By autumn 2012, both rehabilitation methods produced dense productive pastures of perennial sown grasses with high total ground cover. The pastures responded to rainfall between years to 2014 (Table 1). The eroded control treatments at both sites produced negligible pasture or ground cover. The deep-ripping loam site was 50% rehabilitated after four below-average rainfall years, while the blade ploughed clay site achieved this cover with above-average rainfall within one year.

Table 1. Species composition (functional group % of herbage mass), total pasture herbage mass (kg ha^{-1}), and ground cover (%) after rehabilitation by deep-ripping and blade ploughing*.

Species group	Deep-ripping – loam soil			Blade plough – clay soil		
	2012	2013	2014	2012	2013	2014
Perennial native grass (%)	0.8	0.0	0.0	2.6	14.1	8.6
Perennial sown grass (%)	85.5	96.7	92.7	85.5	81.1	78.9
Sown legume (%)	5.2	1.3	5.1	4.1	4.5	10.5
Annual grass (%)	8.3	0.0	0.0	5.4	0.0	0.0
Herbage mass (kg ha^{-1})	5720	2320	3950	3830	4140	3580
Ground cover (%)	86	80	82	71	82	84

* Control treatments consistently had <100 kg ha^{-1} herbage mass and <0.5% ground cover.

Water quality

Rehabilitation increased water infiltration by 11.3 and 1.6 times on the loam and clay soils respectively. Runoff water quality was significantly improved by both rehabilitation methods with the exotic sown pastures, and the grazing strategies implemented on the two soil types (Fig. 1). Control losses were: sediment 9.8 times, N 8.8 times and P 15.7 times that of rehabilitated treatments.

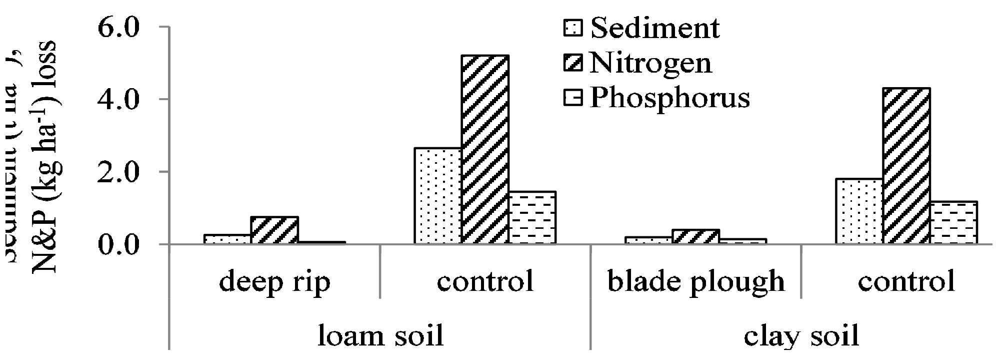

Figure 1. Runoff sediment (t ha^{-1}), total nitrogen (kg ha^{-1}), and phosphorus (kg ha^{-1}) losses in rehabilitated and nil disturbed loam and clay soil sites (one simulated rainfall event, winter 2012).

Conclusions and Implications

The results demonstrate: there are two successful commercial rehabilitation methods for major soil types of these rangelands; the potential for sown pasture production and ground cover; that water infiltration increases; runoff water quality is improved; and the necessity for conservative planned grazing management for many years. Bare eroded areas of these rangelands can be rehabilitated by aggressive disturbance methods of deep-ripping and blade ploughing, followed by seeding with well-adapted pastures, and long-term grazing management, which includes summer rest periods. Water quality flowing off these rangelands to the Great Barrier Reef will be improved.

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Nutrient Loss in Snowmelt Runoff from Cattle Winter Bale-Grazing Sites

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Key words: ammonium, nitrate, phosphorus, crested wheatgrass, Russian wild rye

Introduction

The feeding of bales of dry hay or straw over the winter to beef cattle spatially dispersed over annual cropland or pastures (i.e. bale-grazing) has become common practice on the Canadian Prairies, replacing confined winter feeding in drylot pens, and has been promoted as a beneficial management practice. In addition to saving producers the cost of spreading manure, it is assumed that the direct deposit of urine and feces will enhance soil fertility significantly. However, this practice also increases the risk of nutrient loss during spring snowmelt runoff while soils are still frozen, which is the main source of runoff on the Prairies. The objective of this research project was to determine the effects of in-field winter bale grazing on soil fertility and on nutrient loss in snowmelt runoff. This presentation will focus on the runoff data.

Materials and Methods

A four-year study was conducted in Swift Current, Saskatchewan, to using 350 m^2 micro-watersheds (MWs) established in Russian wild rye and crested wheat grass pastures. These pastures were bale-grazed in alternate years, each for two years total (from 2009 to 2010), and were compared to controls with no bale-grazing or with fall-spread, unincorporated manure. There were three replicate MWs for each bale-grazing treatment and two replicates for each control, for a total of 12 MWs Runoff samples (1 L) were manually collected every two hours daily (as available) during each annual snowmelt event from flumes at the bottom of each MW. Flow rate was also determined when samples were collected.

Runoff samples were also collected in 2013 to assess residual nutrient loss. Runoff samples were returned to the lab and were filtered through 0.7 µm glass-fibre filters within 12 hours of collection. The filters were dried, ground and analyzed for total and organic particulate carbon (C), total particulate nitrogen (N) and total particulate phosphorus (P). The filtrate (designated the "dissolved" fraction), was analyzed for pH, molybdate reactive P (MRP), ammonium (NH_4-N) and nitrate (NO_3-N) by colorimetric analysis, total dissolved organic C and total dissolved N by combustion, and total dissolved P, aluminum (Al), calcium (Ca), iron (Fe), manganese (Mn), magnesium (Mg), sodium (Na) and potassium (K) by inductively coupled plasma optical absorbance spectroscopy (ICP-OAS). All concentrations were flow-weighted. A subset of dissolved and particulate samples from one day of each runoff event per year were analyzed by ^{31}P nuclear magnetic resonance spectroscopy (P-NMR), to characterize the specific P forms transported in runoff. This presentation will focus on MRP, NH_4-N, NO_3-N and P forms by NMR.

Results and Discussion

The number of runoff events per year and average runoff volume, varied greatly from one year to the next (Table 1). This in turn influenced nutrient loss in runoff. Dissolved MRP ranged from 0.5 to 7 mg L^{-1}, with no clear patterns related to the year of bale-grazing (Fig. 1 left). Particulate P ranged from 0.2 to 2.8 mg L^{-1}, and generally higher in the years with bale-grazing (results not shown here). Loss of MRP in runoff from fall-spread manure was often as high as for bale-grazing, but particulate P losses were lower. Particulate P contained a variety of P forms, including organic P forms of microbial origin. Dissolved P was predominantly inorganic phosphate. Losses of NH_4-N were always higher from sites in the year they were bale-grazed (Fig. 1, right), and were as high as 100 mg L^{-1} in bale-grazed years. Concentrations of NO_3-N in runoff were generally higher in the year after bale-grazing, and did not exceed 4 mg L^{-1} (results not shown here).

Table 1. Runoff dates, average runoff volume per micro-watershed and total runoff per year.

Year	Dates	Average Runoff Volume per MW (L)	Total Runoff per Year (L)
2009	March 3-4, 14-16	1814	10883
2010	March 4-8	1996	23948
2011	Feb. 15		
	March 14-16, 18-19, 29-31	5643	67722
	April 5		
2012	March 9-10	2462	29543
2013	March 29-30	5865	70377

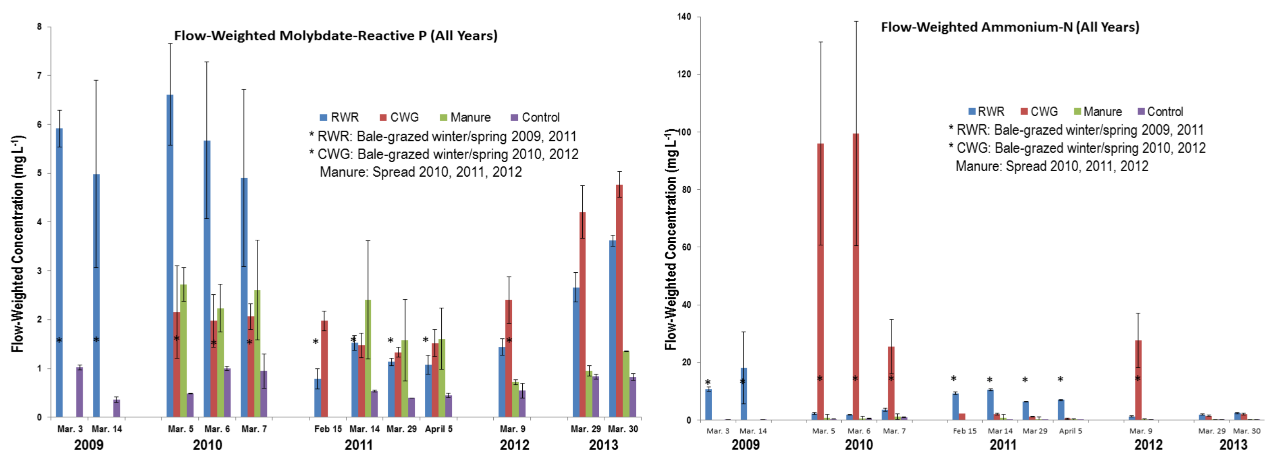

Figure 1. Flow-weighted molybdate-reactive P (MRP, left) and NH_4-N (right) in runoff.

Conclusions and Implications

Snowmelt is the main source of runoff on the Canadian Prairies. In-field winter bale-grazing leaves nutrients from manure and from the bales themselves on top of snow when the ground is frozen. As such, the potential for nutrients to be lost during snowmelt is high, and in concentrations far exceeding water quality guidelines. Managers using this practice should select fields very carefully, to minimize the transport of nutrients into nearby water bodies.

2.4 Wildlife habitat for endangered species

Bovids, Bugs and Birds: Livestock Avermectins – A Threat to Grassland Birds?

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Key words: Cattle, dung-pats, arthropods, grassland birds, avermectins

Introduction

Across the Great Plains, grassland birds are experiencing unprecedented population declines. Two novel threats are herein proposed: 1) the cessation of early spring (mid-March to late-April) grazing of grasslands by cattle and 2) the introduction, in the early 1980's, of avermectins to control parasites of cattle and their subsequent widespread use across the ranges of grassland birds.

Each of the 12 bird species investigated here have a diet dominated by invertebrates. Avermectins have been shown to significantly reduce the diversity and abundance of coprophilous invertebrates for periods of up to three months after application. When this is combined with the absence of cattle dung during early spring, it can have profound impacts upon invertebrate prey abundance for insectivorous birds, and hence productivity and survival of grassland birds and their young.

Materials and Methods

I conducted a literature review (908 papers) to identify potential linkages between cattle grazing (temporally and spatially), the timing of avermectin applications for the control of cattle invertebrate pests, the effects of avermectins on non-target species, and invertebrate prey requirements of grassland birds.

Results and Discussion

Grassland insectivorous birds are experiencing unprecedented population declines. Following massive losses due to winter blizzards in the early 1900's, cattle producers switched from extensive year round grazing, to a pattern of rangeland grazing from mid-spring to fall, with a contraction to feed yards during the winter to reduce death loss and increase profits (MacLachlan 2006). This has created a grassland environment that is free of dung-pats during the period from late winter to mid-spring, with the effective removal of critical resources for coprophilous invertebrates emerging from diapause (Fig. 1), and a consequent decline in prey for grassland insectivores. Laurence (1954) found that the manure from one cow can be responsible for 90 kgs of coprophilous invertebrate biomass during the course of one year. Cattle producers have been plagued by invertebrate pest species for centuries, but not until the early 1980s was an effective treatment available (Lumaret et al. 2012). They showed that avermectins can eliminate >90% of coprophilous invertebrates for up to 3 months.

Conclusions and Implications

The development of avermectins and their widespread use in the early 1980s has caused a massive reduction in invertebrate biomass across the ranges of grassland insectivores. The combination of having no cattle dung pats in early spring with the use of avermectins is correlated with the declines of grassland birds.

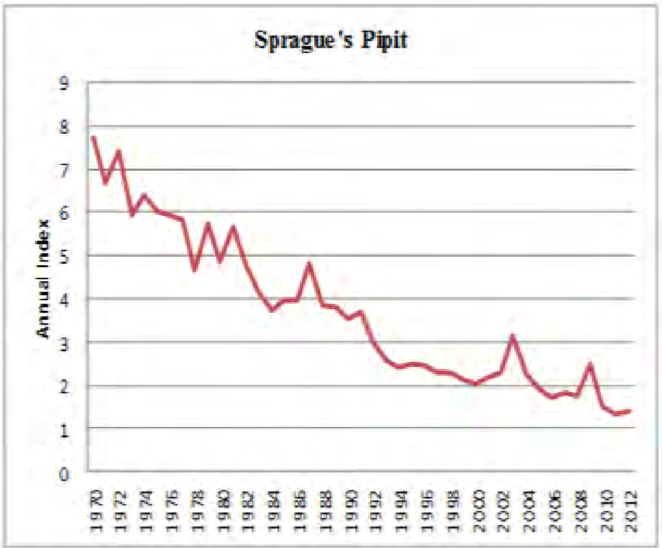

Figure 1. Population decline in of Sprague's pipit. Note the sharp drop in 1981. This is the year that avermectins were first widely used. Other grassland insectivorous birds such as McCown's longspur, Clay-colored sparrow and Common nighthawk also experienced the same trend (Environment Canada 2014).

Figure 2. The percent distribution of total dung beetles on a cattle ranch without anthelmintics (53% of total dung beetle capture), compared to that of a cattle ranch that employed anthelmintics (7%), and the edge between them (40%). Data from Whipple (2011). He found that with dung beetles present there were 95% fewer horn flies and up to 9 times fewer cattle parasites. Grazing by untreated bison may provide superior habitat to that grazed by cattle, since bison are on the landscape year-round.

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Native and Exotic Seed Grasses Preferences by Grassland Birds

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Key words: *Ammodramus*, buffelgrass, food selection, Lehmann lovegrass, natal grass

Introduction

Many species of new-world grassland birds are migratory and overwinter in the grasslands of northern Mexico; however, those populations are declining (Pool et al., 2014). Among the main threats to grassland bird winter habitat is the invasion of exotic grass species. Exotic grass invasions change structural characteristics of the vegetation and may reduce plant species richness and diversity, which could lead to a reduction in food availability for seed-eating birds. The most widespread invasive grass species in the Chihuahuan desert grasslands are natal grass (NG = *Melinis repens*), Lehmann lovegrass (LL = *Eragrostis lehmanniana*) and buffelgrass (BU = *Pennisetum ciliare*) (Ortega-Santos et al., 2013). Since invasive grass species tend to become dominant and reduce plant species richness and diversity, invasive grass species are a potential threat to granivorous grassland birds if birds are unable to exploit their seeds. The aim of this study was to compare the consumption of seeds by three grassland birds and to compare their preferences between the three main invasive grass species in northern Mexico and three native grasses.

Materials and Methods

Baird's (*Ammodramus bairdii*), Grasshopper (*A. savannarum*) and Savannah Sparrows (*Passerculus sandwichensis*) with similar body size were used to explore seed preferences; Baird's Sparrow (8 individuals), Grasshopper Sparrow (7 individuals) and Savannah Sparrow (7 individuals). Birds were captured on 15-16 November 2013 on a grassland area at Chihuahua, Mexico. Birds were housed in indoor facilities, provided vitamin enriched water *ad libitum*, and fed with commercial seeds for adaptation. Seeds of grass native species were blue grama (BG = *Bouteloua gracilis*), sideoats grama (SG = *Bouteloua curtipendula*), and green sprangletop (GS = *Leptochloa dubia*) and exotic species were natal grass, Lehmann lovegrass, and buffelgrass.

The experiment took place from 19 to 27 November 2013, after a 4 day adaptation period. Two tests were carried out: choice trial and nonchoice trial (Cueto et al., 2001). For the choice trail, the six seed species were presented simultaneously to the birds in individual feeders; 2 g of each seed during the first 3 days. The followings days, 4 to 9, only one of the six seed species, samples of 4 g, was presented during 1 h. Seeds were weighed before and after the trial to determine the amount consumed; handling time was recorded. Data from the choice trials was analyzed with a Dirichlet regression using the DirichletReg package in R 3.1.1. The data of the nonchoice trial was fitted to a linear mixed model including bird species or bill volume and seed species and their interactions as explanatory variables and consumption per seed species as the response variable.

Results and Discussion

Composition of consumed seeds in the choice trials evidently differed among species. Savannah Sparrows and Baird's Sparrows had preference for NG seeds over the other seeds whereas Grasshopper Sparrows preferred SG with a second preference for NG (Fig. 1). The model including bird species performed significantly better than the intercept-only model (Likelihood-ratio test, D = 91.37, df 12, $P < 0.001$), indicating that bird species is an important variable in explaining variation in seed selection. All these differences are in the expected direction with respect to bill size of the species. Consumption of seeds by bird species seems more uniform across seed species in the nonchoice trials (Fig. 2) than in the choice trials. The results show that when they had no other choice, birds seemed to be able to consume all seeds except for LL seeds and BU seeds.

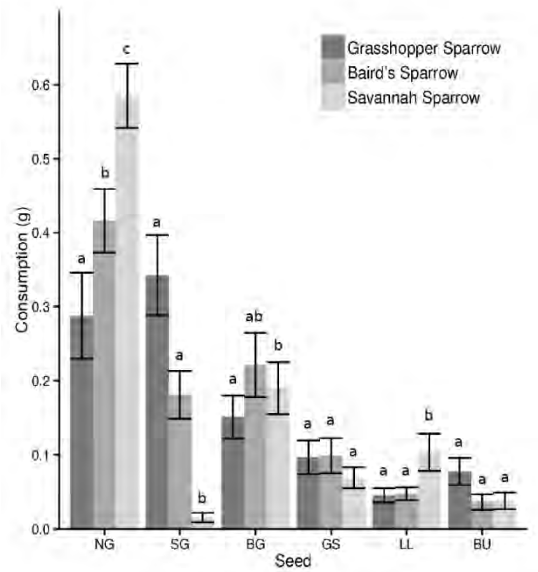

Figure 1. Consumption per seed and bird in the choice trail (P<0.05).

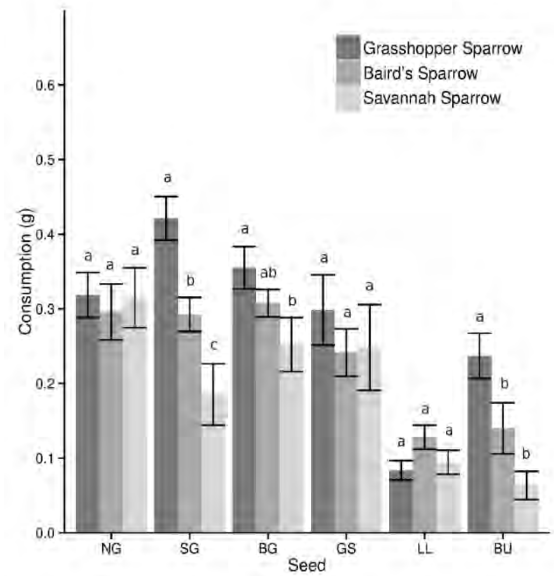

Figure 2. Consumption per seed and bird in the non-choice trail (P<0.05).

Conclusions and Implications

Invasions of NG and LL are expected to increase as a result of climate change, as both species are drought resistant and have a higher seed production capacity than native grasses under regular as well as extreme weather conditions (Melgoza-Castillo et al., 2014). These species often form monocultures, replacing native grasses, which may be detrimental to grassland birds. Therefore, it is important to educate private landowners on how to improve management practices to avoid extensive invasions as well as how to implement practices to actively control the spread of exotics. Since invasions of exotic grasses reduce the forage quality of pastures compared to blue grama grasslands (Melgoza-Castillo and Morales-Nieto, 2013) this will be in the interest of landowners as well. BU is often seeded and not considered invasive, although it has spread from ranches along roadsides. SAGARPA, Mexico´s federal agricultural agency, is currently promoting a program to seed BU in a potential area that extends to over 6 million hectares. Therefore, actions should be taken to discourage planting of exotic grasses, especially BU.

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Multiple Approaches to Habitat Conservation: Finding the Right Fit Encourages Producers to Manage for Species at Risk Habitat

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Introduction

The South of the Divide Conservation Action Program Inc. (SODCAP Inc.) is a non profit group created in July 2014 to implement a multi species at risk action plan in southwestern Saskatchewan, Canada. Along with one of their board members, the Saskatchewan Stock Growers Association (SSGA), SODCAP Inc. is investigating new and innovative programs that would effectively encourage producers to make species at risk a priority in their management decision making on their ranches.

Materials and Methods

Over the 2014-15 winter period, SODCAP Inc. interviewed 50 randomly selected producers who own or manage candidate critical habitat within the Milk River Watershed asking for feedback on how best to deliver species at risk programming in the area. A questionnaire looking for approximately 20 responses was developed to gain opinions and attitudes from participating producers on both existing and potential conservation programs and species at risk habitat. Interviews were done face to face and answers recorded. Producers were allowed to express their feelings and discuss how these types of programs would benefit their ranching operation. No formal statistical analysis was performed but commonalities were observed and key points noted from the discussions. A summary of the interviews was produced in an option analysis paper.

Results and Discussion

When asked what would be the most effective to encourage producers to make species at risk a priority in their management decision making, suggestions included results-based conservation agreements, cost sharing programs for ranch improvements as well as extension activities. The diversity of opinions and ideas derived from the interviews suggest that a 'one size fits all' approach would not work for ranchers in this area of the province. SODCAP Inc.'s goal is to develop a variety of approaches to meet the individual needs of their respective operations. Following the analysis of interviews and additional consultation with partners, six new programming options were selected for evaluation. They included:

Results-Based Conservation Agreements

Results based conservation agreements provide financial incentives to producers who meet or exceed habitat targets, at the site level, for a particular species at risk. Habitat targets have been described for four species at risk in southwest Saskatchewan. These habitat targets for species at risk are measureable and quantifiable, based on the current state of knowledge and within the ecological potential of the range site. In order to receive a payment, producers are required to achieve habitat targets that are greater than habitat that exists under normal agricultural practices that provide for basic forage and livestock needs. By being non prescriptive, these agreements acknowledge that each operation is unique and manages resources in different ways. In areas of critical habitat, they can make habitat management an important priority in the landowner's everyday decision making, along with typical herd health, livestock management and forage production considerations.

Habitat Management Agreements
Habitat management agreements allow for the development and implementation of a management plan based on species at risk requirements, range condition and health evaluations, producers' goals and available resources. Unlike results based conservation agreements, achievement of habitat targets is not a prerequisite for receiving funding. Payments made to the producer are based on the cost of implementing the management plan.

Term Conservation Agreements
Conservation easements in Saskatchewan have been in perpetuity and are for the most part, only 'no break, no drain' requirements. Currently producers in southwest Saskatchewan are not interested in signing conservation easements that are in perpetuity, however, approximately 30 percent of producers interviewed indicated that they would be willing to entertain signing a conservation agreement for a specific period of time. Furthermore, restrictions would have to exceed the 'no break, no drain' clauses to positively impact species at risk habitat.

Habitat Restoration
Lands that are currently cultivated and adjacent to critical habitat are being selected as potential sites for habitat restoration projects. The restoration projects will be designed to resemble habitat that reflects the potential of the given range site.

Grassbanking
A *"Grass Bank"* is a physical place where forage is made available to ranchers, at a reduced fee, in exchange for tangible conservation benefits being produced on participants' home ranches. The main goal of grass-banking is to have a community-based conservation plan that provides meaningful benefits for both the environment and participating ranchers.

Niche Product Branding
Beef can be branded as environmentally or ecologically-friendly and promoted to specialty markets. Consumers have chosen branded products over other products and are willing to pay a premium for them. This type of niche marketing takes a real sense of entrepreneurship and time must be invested into marketing.

Program and Economic Evaluation
An important component of SODCAP Inc.'s activities is an economic evaluation of the programming options noted above. This evaluation will (1) determine the economic implications for producers participating in the programs and (2) track the various costs and benefits of program participation and execution as they evolve over time. The economic evaluation is designed to provide SODCAP Inc. with near real time information regarding critical economic considerations regarding the programming options, which in turn will feedback into and inform future program implementation.

Conclusions and Implications

From 2016 through to 2020, SSGA and SODCAP Inc. will implement and evaluate these options on working ranches in southwest Saskatchewan with $2.58 million of funding from Environment Canada's Species at Risk Partnership on a Agricultural Landscape fund. Based on the outcomes, SSGA and SODCAP Inc. will provide a suite of recommendations on future programming for species at risk.

From Idle Back to Working: Evidence of Endangered Species Conservation Efforts Changing Rangeland Management Policy in the Western United States

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Key words: Grazing, endangered species, annual rangeland, policy

Introduction

Rangelands are a predominant land type in the western United States, comprising 31% of the total land area and supporting the area's most significant land use, livestock ranching. In past decades there was strong pressure from environmental interests to remove livestock grazing from public lands throughout the west. Although the efforts were led by radical groups such as Earth First!, with battle cries such as "No more moo by '92" and "Cow free by '93", the idea that grazed land was damaged land in the western US was popularized by some ecologists and the media. Through the 1980s and 1990s and into the early 2000s, efforts to conserve threatened and endangered (special status) species on western rangelands often meant removing livestock ranching. Research findings, demonstration results and failed conservation efforts in recent years with regards to endangered species has supported the continuation of livestock ranching and the reintroduction of grazing to some rangelands that were "protected" with grazing removal. At the landscape level, research has demonstrated that livestock ranching maintains extensive, open spaces by reducing land use conversion and fragmentation.. At the pasture level, proper livestock ranching has been shown to support biodiversity through grazing and associated rancher stewardship. Specifically, grazing reduces annual plant biomass, influences vegetation composition, and impacts vegetation structure as well as provides bare ground. The endangered bay checkerspot butterfly (*Euphydryas editha bayensis),* kit fox (*Vulpes macrotis mutica*), kangaroo rats (*Dipodomys stephensi),* burrowing owls (*Athene cunicularia*), tiger beetle (*Cicindela ohlone*), wildflowers, and numerous rare flora and fauna associated with vernal pools benefit from livestock managing vegetation. Grazing exclusion has resulted in extirpation of some populations of these species from "protected sites". Rancher stewardship includes development and maintenance of livestock water sources, pest management, debris clean-up, and forage improvement. Ponds developed for livestock water provide half of the available habitat for the endangered tiger salamander (*Ambystoma californiense)* in the San Francisco Bay Area. These results focus on California's annual rangeland, which is the habitat type where most of the special status species associated western rangelands are found.

Materials and Methods

Three lines of evidence regarding grazing rangelands and impacts on special status species were developed through review and analysis of the following: 1) current findings of the US Fish and Wildlife Service (USFWS) for special status species listed on the western US rangelands, 2) rangeland management strategies for 10 different public agencies (Federal, Regional, and Local) who manage rangeland and have acquired additional rangeland sites since 1990, and 3) management requirements for conservation easements fulfilling mitigation for listed rangeland species.

Results and Discussion

All three lines of evidence reveal that at least on California's annual rangelands, managed livestock grazing is valued for improving and maintaining habitat for a variety of special status species. In every case where the USFWS originally considered grazing or "overgrazing" a threat (n=12) it has been found that managed grazing has measurable benefits. In addition, managed livestock grazing has been determined to be essential in preventing further loss or decline of several threatened species. Rangeland management strategies for the 10 agencies evaluated revealed that all use grazing management for resource conservation with most recognizing benefits to specific listed species. Four of the agencies have recently re-introduced grazing to rangeland sites to support special status species habitat. Two of the agencies have removed grazing from new rangeland sites they acquired, but their decision to remove grazing was based on policy rather than any specific resource management objectives. These 2 agencies have also maintained grazing on other sites for specific special status species requirements. One agency has removed grazing from a rangeland site due to conflict with recreation. Conservation easements for special status species mitigation on rangeland are increasingly requiring managed grazing to maintain habitat.

Conclusions and Implications

Goals to maintain and improve habitat for special status species especially on California's annual grassland have provided clear and measurable objectives to evaluate rangeland management strategies, including the removal of livestock grazing. Extirpation of several species following grazing removal has been documented and has further built a case for the value of livestock ranching. Research findings and demonstration results have impacted USFWS listings, mitigation requirements and provided support for the continuation of grazing on public lands in western US. In 2005 environmental groups, agricultural organizations, and federal, state and local land management agencies drafted and signed the California Rangeland Resolution and initiated a coalition. The resolution, which has now been signed by 126 entities states that "rangelands, and the species that rely on these habitats, largely persist today due to the positive and experienced grazing and other land stewardship practices of ranchers that have owned and managed these lands." Despite the growing evidence that keeping rangelands working conserves open space and numerous special status species, when there is no specific objective to maintain or enhance habitat, policies of some public agencies may not fully support livestock ranching.

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Multi-Stakeholder Approach to Piloting a Conservation Offset Tool in Southeastern Alberta

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Key words: conservation offsets, mitigation hierarchy, spatial prioritization, AHP, GIS

Introduction

Disturbance or consumption of land by industries usually follow a mitigation hierarchy of avoidance, minimization of impact, restoration before they consider the use of an offset tool to offset the unavoidable loss of conservation, biodiversity, water or species of concern (OECD, 2014). Since the early part of the millennium the Business and Biodiversity Offsets Programme (BBOP) was formed between non-governmental organizations and industries to develop guidance and protocols for offsets, to be applied globally (BBOP, 2013). Offsetting can focus upon a single resource or species (e.g., water, Sage Grouse) or on a habitat or ecosystem (e.g., arid grassland, boreal upland forest). Industrial disturbances in Alberta include power transmission lines, wind generation towers, gravel excavations, oil and gas developments and strip mines.

The Alberta Land Stewardship Act (ALSA, 2009) was created to form an overarching policy framework to develop and direct land use planning across Alberta. It named four tools to achieve land use goals, one of which was conservation offsets. Subsequently, the national ministry of Environment recommended the exploration and use of conservation offsets to mitigate surface mining developments in Alberta (mine license approvals in 2012, 2013). Alberta Agriculture and Forestry were asked in 2012 by the Land Use Commissioner to develop a conservation offset pilot in southern Alberta.

Materials and Methods

The offset to be considered was to focus on conversion from annual cropping land use to native grasslands on private lands in the semiarid mixed grassland ecoregion of Southeastern Alberta. Nearly 80% of the endangered species in Alberta are residents of this ecoregion. The ecoregion has about 43% of native grassland cover remaining. The ‘receiving area’ was an 8860 km^2 largely contiguous block of grassland bounded by cultivated land. The ‘sending area’ was a large portion of the semiarid mixed grassland ecoregion in the South Saskatchewan River basin planning region that was about 29,000 km^2.

A comprehensive approach was taken from the beginning with a strategy to involve all stakeholders and to focus on “field experienced” personnel in order to develop a pragmatic system as well as a system that would have low transaction costs in order to provide value to buyers and sellers of the offsets.

A core team was assembled with representation/expertise from agriculture, native grasslands, wildlife biology, landscapes / soils. Core team members linked to others in biodiversity monitoring, oil and gas extractions, governance of lands, etc.

An industry stakeholder team was also assembled with representation from most impacted industries in the region of focus.

A group of farmers/ranchers from the region of focus was also identified for one-on-one and group consultation.

The offset pilot was designed to utilize a 'third party provider' to facilitate the offset development and transaction processes.

Meetings were held with each group and intersections of the groups depending upon the topic of focus. Research done by team members or consultants was brought back to the larger group or task team to be vetted. The Delphi technique was used in combination with an Analytical Hierarchal Process (AHP) to develop an Offset Suitability Index to prioritize targeted lands. Field truthing of the Index was done in 2013.

Results and Discussion

A decision was made at the beginning to use a bundled approach of habitat development (develop native grasslands) rather than a specific species focus in order to keep transaction costs down and create the largest ecosystem benefit.

The pilot developed a system of quantifying offset requirements across different types of disturbances using a multiple species conservation value as well as the grassland vegetation inventory (GVI) and range site type restoration factor. Conservation Offset Factors could be assigned to each parcel along with the area of disturbance to generate Habitat Acres. The work benefited by the wealth of inventory work done in the area as well as the foresight of long term monitoring along historic pipelines.

The Habitat Suitability Index was developed using the AHP + Delphi Technique + expertise and patience of GIS specialists, all addressing 17 layers of variables and weightings. A map of the entire region was generated showing the value for each parcel of land. The industry stakeholders were very interested in this result as it could be used for the first steps in the mitigation hierarchy.

A number of meetings were needed with the groups to overcome social and expertise biases and share viewpoints but the result was very effective work groups.

The pilot did stall when high level government support was not forthcoming and the industry stakeholders were reluctant to contribute further without recognition for early action and investments. The pilot did continue through the Alberta Conservation Association that served the role of designated aggregator with completion of a tracking system and testing of the offset process on a land parcel.

Connections were kept with other provinces, federal, USA and BBOP interested parties. Interim activities and results were shared with interested parties, government ministries and NGOs. All interim reports and information documents were placed on a website for access and transparency of the process (http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/sag14846).

Conclusions and Implications

The teams and engagement processes worked well. New tools were developed that all stakeholders played a role in developing, testing or both. An offset process was developed that works well for the range of stakeholders in Alberta as well as the existing data quality and coverages. Working with current data environments and finding inexpensive and effective solutions for gaps and deficiencies yielded an effective and pragmatic system that should have low to reasonable transaction costs.

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Effects of the Rapidly Changing Habitat of the Liben Lark

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Key words: Liben Lark, farmland, hotspot.

Introduction

The Liben Plain is part of the Borana rangelands that was once known for its high grazing potential in East Africa. The Borana pastoralists have been managing these rangelands with their traditional '*gadda*' system since the 15th Century (Coppock, 1994). The Liben Plain had rich biodiversity and was designated as one of the Important Bird Areas (IBAs) in Ethiopia mainly due to being the stronghold for the Liben Lark (*Heteromirafra archeri*). The Liben Lark is an endemic grassland bird species that was first discovered in 1968. Not much was known about the species until the 1990s but it wasn't until 2007 that a thorough survey was conducted in its habitat, after which it was found that the species was Critically Endangered and that it could even soon become one of mainland Africa's recent extinctions (Spottiswoode et al., 2009). One of the major threats to the species is habitat degradation that was caused by disruption of the '*gadda*' system mainly when the pastoralists started becoming sedentary and farming started increasing in the area. The main aim for this study was to monitor the land use changes in the area and the response of the Liben Lark to these changes.

Materials and Methods

The Liben Plain is an extensive area of flatland, 600 km south of Addis Ababa, found at 1,500 - 1,550masl. Several free satellite images were downloaded from the Global Visualization Viewer (GLOVIS) website. An area of about 400 km^2, surrounding the habitat of the Liben Lark, was selected in order to quantify the amount of land that was cultivated in the area since 1994 usingArcGIS Desktop version 10.2 (Price, 2014). Twenty line transects covering about 63 kms in the core area of the Liben Lark were used to conduct population surveys in 2007 and 2009 – 2013 (Bibby et al., 2000). GPS coordinates of the location of the individuals were mapped out in ArcMap. The kernel density tool in the spatial analyst toolbox was used to create hotspot maps of the Liben Lark population across the Liben Plain for the records in the different survey years as well as for all the years combined.

Results and Discussion

Farming on the black soils of the selected area started becoming visible in 1994 in an area of about 3 km^2. The farmlands had doubled by the year 2000 and covered an area of about 45 km^2 by 2009. The amount of black soil started becoming saturated after this time, which is when people started to slowly start farming on the red soils. This was exacerbated especially after large areas of grasslands on red soils were given to investors for mechanised farming. This led to the loss of access to grazing lands for the livestock owned by local people and hence the increase of pressure on the remaining grasslands. The areas of relatively good grassland were hence greatly diminished. Overall, 39.47 km^2 of red soil grassland and 53.79 km^2 of black soil grassland of the selected study area had been converted to crops by 2015.

According to the surveys conducted, 2007 was the year that the most number of Liben Larks were recorded. Four hotspot locations were identified in 2007. One of these locations was completely lost after 2011 due to conversion of almost all the areas of grasslands in that area to croplands. The total area covered by the hotspots in 2007 was 26.4 km^2. By the end of 2013, the hotspots had an area of only 10.7 km^2. The hotspot map for the bird records of all the years combined had an area of about 13 km^2 (Figure 1). This was mainly due to the exponential increase in conversion of grassland habitat suitable for the Liben Lark to farmlands during the survey times.

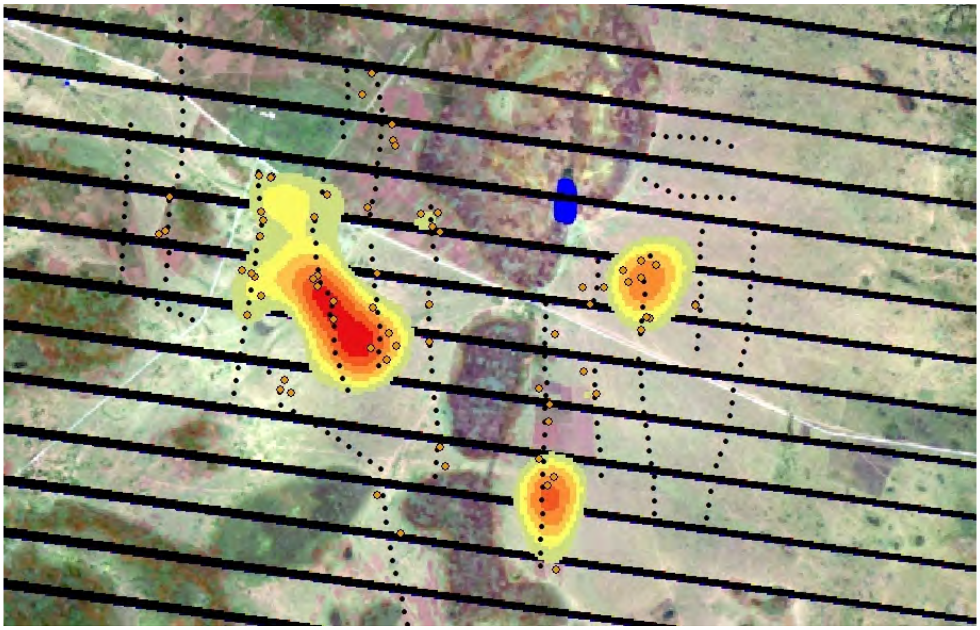

Figure 1. Number, location and extent of Liben Lark density hotspots and transect routes (black dots) across the Liben Plain for all the years combined over a satellite image of 2013.

Conclusions and Implications

According to the land-use data, farming has rapidly increased on the red soils especially after 2007. This has led to the further decrease in the population of the Liben Lark mainly due to habitat loss and degradation. The increased demand for land could lead to the conversion of the remaining grassland habitat into croplands within a few years' time. This will result in increasing the extinction risk of Liben Lark or even completely wipe out the species in a short time.

All these results also show that there is need for a strong conservation intervention in order to save the species from extinction as well as to preserve the pastoralist way of life of the Boranas. To be able to do this, there should be a well-regulated land management system in the area. Grassland habitat restoration should be done by building enclosures and clearing scrub encroached areas. Farming should be stopped and even reversed in the core habitats of the species in order to be able to make significant and long lasting changes.

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Grass Vegetation Dynamics of Vettangudi Wildlife Habitat Ponds, Southern India

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Key words: Vettangudi Birds Sanctuary, Temporary ponds, dry pond surface, vegetation diversity

Introduction

Temporary ponds are wetland habitats, generally covered by shallow water for a short span of time during the year. Globally, these type of rangelands cover relatively lesser land area; however, they are a very productive ecosystem (Prigent *et al.,* 2001). Habitat plays a vital role in the diversity pattern of plants and their aggregation (Lindberg and Erikson, 2004), upon which and-use pattern also impacts (Montero *et al*., 2013). In this study, we analyze the grass vegetation of Vettangudi bird sanctuary ponds.

Materials and Methods

The research was conducted in three temporary ponds - Periyakollukudipatty (PKPTY), Chinnakollukudipatty (CKPTY) and Vettangudipatty (VKPTY) located in Sivagangai District, Tamil Nadu, India, where a semi-arid eco-climate is prevalent. The experimental ponds fill with water during rainy season and remain dry during summer months. PKPTY pond serves as the Vettangudi Birds Sanctuary for several avian fauna, including migratory birds, and the pond water is also utilized for irrigation and domestic requirements to the communities that live on the banks of the pond. The CKPTY and VKPTY ponds have been used by the communities for domestic needs, cattle ranching and irrigation and both are closely situated (0.5 to 1 km) to PKPTY pond (Mahesh *et al.,* 2014).

Vegetation analysis was done separately for surface and bund regions. Listing of vegetation was done using all-out search method and identification was done using the standard monograph. In the bunds and desiccate surface areas of each site, twelve randomly laid 1 x 1 m quadrats were used and re-measured at regular intervals for twelve months, during 2014-2015. Only grass species were used to determine diversity indices with statistical analysis using Principal Component Analysis (PCA) computed using the SPSS programme (Version 16.0).

Results and Discussion

VKPTY pond was found to have more grass species, both on its desiccate surface and bund region, compared to the other two ponds. Sorenson's similarity values were found to be significantly different ($p<0.05$) between the ground surfaces of CKPTY/VKPTY ponds; this is due to the presence of more grass species in VKPTY. No significant ($p<0.05$) Sorenson index values were observed between the bund regions of the three pairs of ponds (Table 1).

In the case of PKPTY pond's surface vegetation analysis, negative value on the factor loading for the relative frequency of species diversity caused a weak loading of Importance Value Index (Fig. 1A). Since the individuals of the grass vegetation of VKPTY pond dry surface showing the weakest loading among all the analyzed factors, that factor cannot be considered as the determinant factor The analyzed components show strong factor loading on species and individuals and Shannon and Simson diversity indices for the surface vegetation of CKPTY pond; however moderate factor loading was observed for species abundance.

A clear proportionate weightage of factors from the PCA were observed between the number of individual grass species and the relative basal area of the grass tillers in the bund regions of the three experimental ponds (Fig. 1B). This feature is observed with a strong weightage on the number of plant individuals in the PKPTY caused the poor weightage on the basal area factor.

Conclusions and Implications

A marked variation was observed for the grass vegetation diversity index for the experimental ponds' surfaces and bunds. Present study results strongly support the study of Monteiro *et al*., (2011) emphasizing landscape pattern change plays a key role on vegetation cover and diversity and hence, the protection of ponds against grazing pressure and anthropogenic disturbances is essential to establish the ponds, as they support the avian population. Further study is necessary to relate habitat soil quality, altered due to biotic disturbances. Further could be related to the vegetation diversity.

Table 1. Grass vegetation occurred in the experimental ponds and Mean values of Sorenson's Similarity Co-efficient analyzed among the pairs of experimental ponds.

Experimental Pond	Grass species on the surface	Grass species on the bund	Surface region's Sorenson Similarity coefficient (Pair of ponds)	Bund region's Sorenson Similarity coefficient (Pair of ponds)
PKPTY	*Brachiaria mutica* *Chloris barbata* *Cyanodon beriberi* *Cynodon dactylon* *Sporopolus africanus*	*Cynodon dactylon* *Sporobolus africanus* *Typha angustifolia*	0.59[a] (PKPTY/CKPTY)	0.56[a] (PKPTY/CKPTY)
CKPTY	*Cynodon barbari* *Aristida setaceae* *Chloris barbata* *Cynodon dactylon* *Brachiaria mutica*	*Cyanodon barberi* *Cyanodon dactylon* *Sporobolus africanus*	0.75[b] (CKPTY/VKPTY)	0.72[a] (CKPTY/VKPTY)
VKPTY	*Apluda mutica* *Aristida hystrix* *Aristida setacea* *Brachiaria mutica* *Chloris barbata* *Cyanodon beriberi* *Cynodon dactylon* *Dactyloctenium aegyptium* *Sporopolus africanus*	*Apluda mutica* *Aristida setacea* *Cyanodon barberi* *Aristida hystrix*	0.67[ab] (PKPTY/VKPTY)	0.63[a] (PKPTY/VKPTY)

[ab] Values in the successive columns with same alphabets are not statistically significant ($P \leq 0.05$), based on Students-*t* test

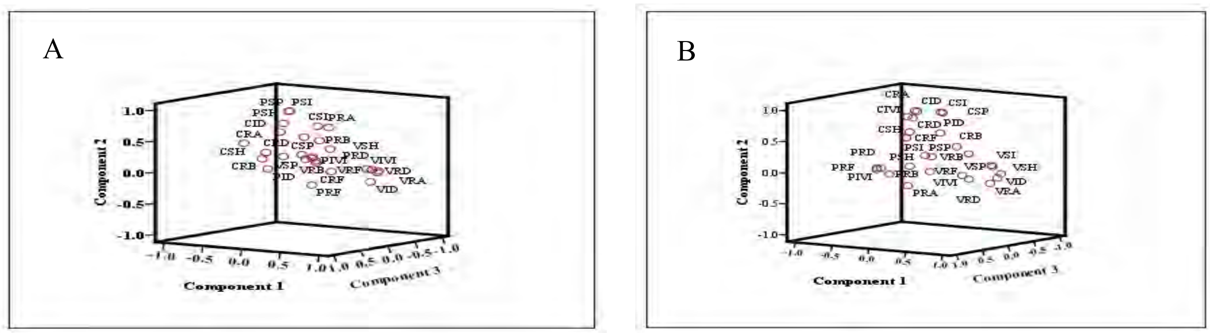

Figure 1. Rotated Component Matrix of Five-factor PCA Model, using varimax rotation for the grass vegetation analysis of pond surface A and bund B regions of experimental ponds.

Acknowledgements

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Diversity, Floristic Richness and Evenness of a Natural Grassland in Uruguay

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Key words: Natural grassland, richness, evenness, diversity

Introduction

Natural fields in Uruguay comprise 64% of the national surface. They are composed of highly species-rich communities and are able to undergo changes due to soil. The information about dominant vegetal formation is scarce, particularly in regards to papers that register floristic variation at landscape and regional scale (Altesor et al 2006). The aim of this paper is to analyze whether diversity, richness and evenness of the community were affected by the type of soil and the level of intervention.

Materials and Methods

This study was carried out on a natural grassland with grazing in Facultad de Agronomía, Uruguay, (32°23'57,37"S; 58°02'41,72"O), during November 2014. The study took 8 hectares with an experimental complete block design with four repetitions and four treatments: (N) natural grassland, (I) natural grassland improved with oversowing *Trifolium pratense* and *Lotus tenuis*, fertilized with 40kg. ha^{-1}.year of P_2O_5, and natural grassland at two levels of nitrogen fertilization: 120 and 60kg.ha^{-1}.year of N, and 40 kg.ha^{-1}.year of P_2O_5 (6;1). The dominant soils in the area are: Lithic Hapludoll (LH), Typic Natraquoll (TN), Argiaquic Argialboll (AA), Pachic Argiudoll (PA). The vegetation associated to each type of soil was assessed in 1m2 squares. The coverage of each species was registered, which resulted in 144 samples in total. The species of the Poaceae family were grouped according to functional types, defined as the combinations: life cycle, productive cycle and vegetal type. The data was analyzed with main-component technics.

Results and Discussion

The main coordinates explain 85% of the variation. Principal component 1 correlates positively with evenness and diversity, but negatively with richness. However, principal component 2 correlates negatively with evenness and positively with richness and diversity (Fig 1.) Both LH and TN feature certain physical attributes as these communities tend to appear in the middle of the graphic. However, the greatest richness and lowest evenness are on AA. The highest number of species -70- was found here. There is a gradient of higher richness, which is the highest in the improved grassland; intermediate in natural grassland, and the lowest in 120kg N.ha^{-1}.$year^{-1}$ fertilization. Richness declined as fertility increased across sites.

PAs tend to higher levels of evenness, as they are more fertile, deeper and well-structured soils that present minimal restrictions for vegetable growth, which reduces richness and increases both diversity and evenness.

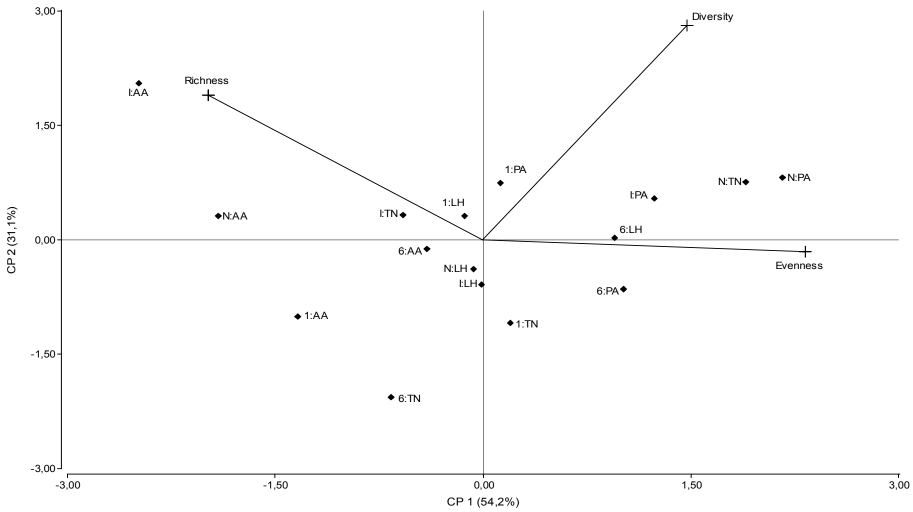

Figure 1. Diagram of ordination by principal coordinates, based on frequency of species under different treatments and soils in a natural grassland in Uruguay.

Conclusions and Implications

The soils with greater constraints feature higher richness, meanwhile the ones with less edaphic restrictions features higher evenness and diversity. Only in the AAs were different treatment effects observed.

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Seed Morphology and Anatomy of *Haloxylon ammodendron* Bge. C.A. Mey (Amaranthaceae Juss.)

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Key words: *Haloxylon ammodendron,* Saxaul forest, seed morphology, seed anatomy

Introduction

The genus *Haloxylon* L. belongs to the family Amaranthaceae Juss (APG II, 2003) comprised of 11 species world-wide (Chaoyan et al., 2012). But only one species, *Haloxylon ammodendron*is, is reported from Mongolia (Urgamal *et al.,* 2013). *H. ammodendron* is mainly distributing in the desert and semi-desert region of the southern Mongolia, protecting the fragile desert soils from wind erosion. The Mongolian Law on Forest protects the forest zones (7.9 million ha) including all Saxaul (*H. ammodendron*) forest (Batsukh, 2007). *H. ammodendron* served as livestock feed and firewood and was wildly used in Mongolia. Due to its over-exploitation the population of *H. ammodendron* has degenerated. In our study we investigated the seed morphology and anatomy of *H. ammodendron*. It is important to promote the basic understanding of quantitative population ecology of desert plants and the conservation practice of the desert and Saxaul forests ecosystem of Mongolia.

Materials and Methods

Samples were collected from natural Saxaul stands during 2012 and 2013. The morphology of mature seeds was observed with a light microscope, and the measurements made were based on 40-50 readings per specimen. The terminology of seed morphology follows Ganbaatar (2001) and Tserenbaljid (2013). For our anatomical/histological study, seeds were dehydrated through an *n*-butyl alcohol series, embedded in Paraplast and sectioned with a rotary microtome. Sections cut at 8-12 µm in thickness were stained with Heidenhain's hemotoxylin, safranin, and Fast green, and mounted with Entellan. Seed anatomy was observed with a light microscope (Olympus BX-50). The terminology of seed anatomy follows Boesewinkel and Bouman (1984).

Results and Discussion

The seed is spherical to ellipsoid and has a dorsal side pore and rib (Fig 1.a). Seed color is glossy to light brown. The seed surface shows smooth-fold form ornamentations on a wrinkled substrate (Fig 1.b). The size of mature seeds 1.8-2.5 (2.2±0.026) mm long, 1.5-2.4 (2±0.024) mm wide and 0.7-1.1 (1±0.014) mm thick (height).1000 seed weight–4g.

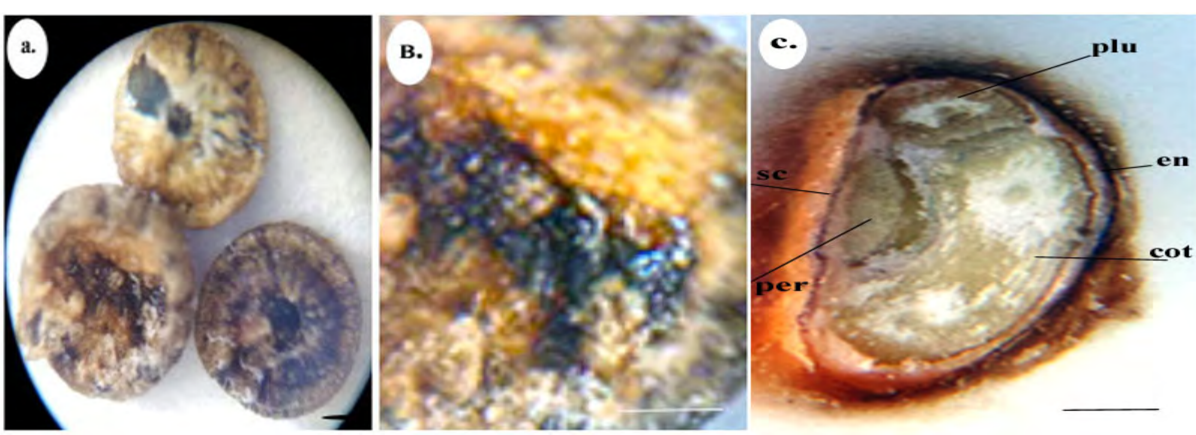

Figure 1. Seeds of *Haloxylon ammodendron.* a. Seed shape, b. Seed surface, c. Seed anatomy (sc-seed coat; plu-plumule; en-endosperm; cot-cotyledon; per-perisperm. Bars: 0.1 mm)

Seed anatomical type is perispermic (Fig 1 c). Perisperm is diploid maternal food storage tissue that originates from the nucellus. Mature seeds lack endosperm (Fig 1 c-en), therefore cotyledon photosynthesis is the major energy source (Fig 1. c-cot) that assimilates during young plant development.. The seed coat is very thin (Fig 1. c-sc). The embryo located on the peripheral side (Fig 1. c-plu). *H. ammodendron* is one of the well known sexually reproducing trees from Central Asia, Middle East Iran, North-West China and near eastern deserts. Nevertheless, few studies have been done on its embryological features, seed morphology, effects of seed germination and seedling growth, and seed yield model (Hong *et al.,* 2001; Tobe et al., 2004; Chaoyan et al., 2012). Scientists have studied germination characteristics of *H. ammodendron* (Tong & Han, 2008). According to their work, the average weight of 1000 seeds was 3.2 g, seed size is 2.1 mm. Our study shows the seed weight and size are relatively large. This difference would seem to the specific environmental conditions of the original seed collection site and the weather were collected the samples.

Conclusions

We studied the seed morphology and anatomy of *Haloxylon ammodendron*. The results of our study increases our knowledge on the seed science and restoration of ecology of *H. ammodendron.*

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The Structure of Coenopopulations of *Lagochilus vvedenskyi* (*Lamiaceae*) in Kyzylkum Desert

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Key words: Ontogenesis, ontogenetic structure, demography, coenopopulation spectra, Uzbekistan

Introduction

Unsustainable use of plant resources for human welfare has resulted in the loss of plant biodiversity worldwide. In parallel, the number of endangered species has increased. These developments have affected the flora of Uzbekistan, with the number of Red List plant species almost doubling in the last 30 years: from 163 to 1984 to 324 at present. Species from the genus *Lagochilus* belong to the most vulnerable plant species from the *Lamiaceae* Lindl. family. Out of existing 18 *Lagochilus* species in the flora of Uzbekistan, four are included in the Red Book of the Republic of Uzbekistan: *Lagochilus vvedenskyi, L. olgae, L. Proskorjakovii* and *L. inebrians* (Red Book of Uzbekistan, 2009). Species of the genus *Lagochilus* have a potentially high economic value. The leaves and flowers of the plant are widely used as medicinal raw material. The leaves contain alcohols, lagochilin (0.6-2%), essential oils (0.03%) and vitamin K. The majority of the genus' members contain narcotic, hemostatic, among other substances.

At present, populations of *Lagochilus* are highly affected by the influence of various natural and anthropogenic forces and, as a result, large reductions in the natural habitats of these species have been observed (Shomurodov et al., 2014). The reduction of the natural habitats of *Lagochilus* species urges the undertaking of detailed and in-depth ecological studies of these plants in order to develop better, science-based and practical measures for their conservation and restoration. The purpose of this work is to study the structure of a coenopopulation of *Lagochilus vvedenskyi* on low mountains of Kyzylkum desert.

Materials and Methods

Research was conducted during the growing seasons of 2011-2015 in three coenopopulations (CP) of *L. vvedenskyi* in vegetation communities of Kuldjuktau low mountains in the Kyzylkum desert (N 42° 33.459' E 63° 21.575' Elev. - 595 m). Descriptions of plant communities where the study of coenopopulations structure was conducted, made according to conventional geobotanical methods, can be found in Mirkin et al. (2000). Ontogenetic structure of populations is defined as the ratio, in populations of individuals, of different developmental states. In characterizing the population structure, we used the idea of the typical ontogenetic spectrum (Zaugolnova, 1994). Coenopopulations were characterized by the classifications of "delta-omega" (Zhivotovsky, 2001).

The structure of coenopopulation (CP) of *L. vvedenskyi* was studied in petrophytic and gravelly grey-brown soils. The first coenopopulation of *L. vvedenskyi* occurs in semi shrub plant community composed of mostly of *Artemisia diffusa, Artemisia turanica, Poa bulbosa,* and *Carex physodes*; the second CP occurred in a plant community with a mix of different semi shrub and perennial grass species including *Artemisia diffusa, Artemisia turanica, Salsola arbuscula, Scorsonera gageoides, Ferula foetida,* and *Alhagi pseudalhagi*; and the third CP in ephemeral-semi shrub community with *Artemisia diffusa, Ferula foetida, Tulipa lehmaniana, Delphinium camptocarpum,* and *Roemeria hybrida*.

Results and Discussion

L. vvedenskyi is a semi-shrub growing to approximately 10-15 cm height. It blossoms in June, and fruits in July-August. It is a narrowly local endemic of low mountains of Kyzylkum desert. Ontogenetic structure of coenopopulation of *L. vvedenskyi* has not been studied. According to the classifications of Zhivotovsky (2001), the studied coenopopulation of *L. vvedenskyi* is normal, based on demographic characteristics, but doesn't contain full members of all ontogenetic stages, except CP 1. Ontogenetic spectra of certain *L. vvedenskyi* coenopopulations are represented by the following types of ranges: centralized or mature individuals (CP 2 and CP 3) and left-directed or young individuals (CP 1). In the coenopopulations with centralized individuals (CP 2, CP 3) the peak belongs to middle-aged generative individuals that is connected with duration of the ontogenetic state (Fig. 1).

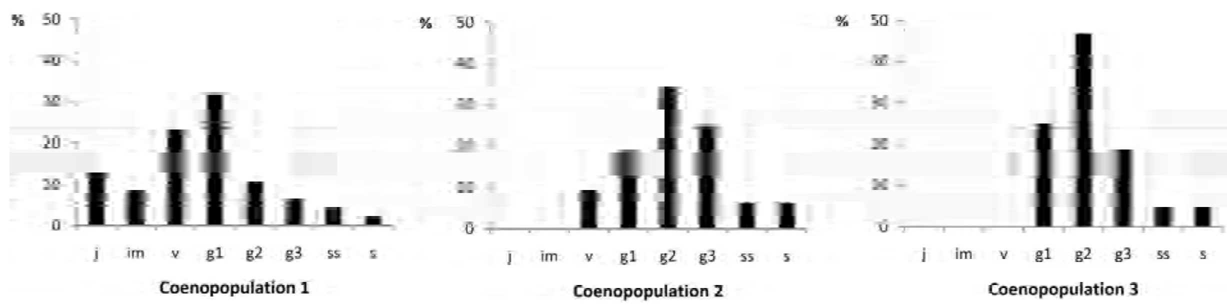

Figure 1. Developmental coenopopulations spectrum of *L.vvedenskyi.*
Note: *x-axes - developmental state; y-axes - distribution of individuals on developmental states in %*

The age-dependent assessment (Δ - the delta) and efficiency (ω - omega) of cenopopulation showed that CP 1 is young with high ratio of generative (48,89%) and predominantly pre-generative individuals (44,68%); CP 2 is mature (Δ = 0,55; ω =0,78), but approaching to senescence type. In the composition of this coenopopulation there is an accumulation of individuals of old generative state (25,0%). CP 3 is represented by early senescent stage (Δ = 0,52; ω =0,84); in this coenopopulation individuals of the generative period (g = 90,62%) is predominant (Fig. 1 and Fig. 2). We assume that the dynamic of coenopopulations is directly related to edaphic condition and grazing load in each site. The main reason of CP 1 being young is possibly connected to its pure rocky habitat with steep slopes where the impact of livestock is significantly limited. CP 2 and CP 3 are characterized by relatively high grazing disturbance that has resulted the coenopulations moving towards mature and senescent ontogenetic stages. Compared to CP 1, the soil condition of CP 3 is represented by dense soil particles, which, according to our estimation, is not favorable niche for distribution of *L. vvedenskyi.*

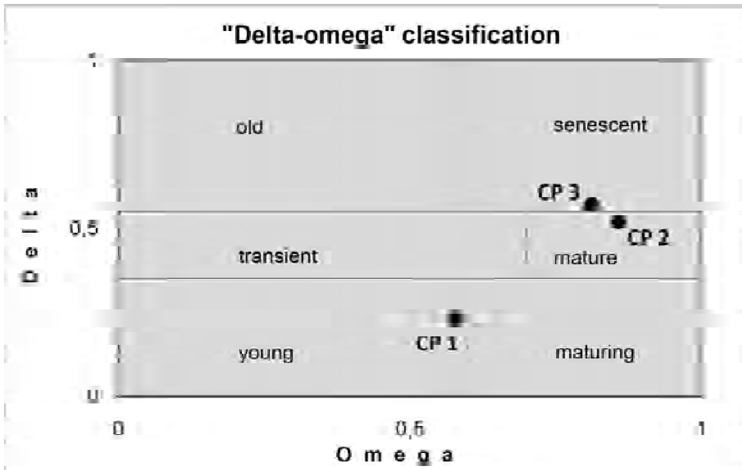

Figure 2. Coenopopulation types of *L.vvedenskyi* according to the classification of Zhivotovskiy (2001).

Conclusion

The studied coenopopulations in different environmental conditions showed that optimum ecological habitat for growth and development of *L. vvedenskyi* are petrophyte communities. Absence of young individuals in CP 2 and in CP 3 at the time of investigations is connected with the most notable anthropogenic pressure on vegetation cover (mining, overgrazing). Conducted studies indicates that coenopopulation of *L. vvedenskyi,* according to its demographic characteristics, belongs to normal, but doesn't contain full members of all ontogenetic stages, except for CP 1. Optimum conditions for distribution of individuals of *L. vvedenskyi* appeared to be the plant community dominated by *A. turanica* and *S. arbuscula* associated with perennial grass species. For these plant communities high ratio of pre-generative and generative fractions of plants is characteristic.

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Ecosystem Integrity Index: A New Tool for Ecosystem Services Evaluation in Livestock Production Systems

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Key words: biodiversity, sustainable production, livestock, grassland, rangeland.

Introduction

Animal production systems based on rangeland are very complex being its management closely related to the functioning of the ecosystem in which it is supported. For assessing the environmental impact of livestock management many variables need to be considered, making difficult and expensive to obtain a comprehensive overview of the ecosystem state and evolution. Therefore a qualitative and quantitative assessment tool was developed in order to evaluate the integrity of the ecosystem under productive use that may be applied in a simple and practical process. The aim of this study was to evaluate the performance of the index in real production systems that were part of a participatory research project.

Materials and Methods

A three years co-innovation project was carried out in seven livestock farms based on rangelands, located in the east zone of Uruguay. The main goal was to improve the productive results while, maintaining environmental status and contributing to social development (Aguerre *et al*, 2015).

In this framework, Ecosystem Integrity Index (EII) was applied as a 10 points scale index (from 0 to 5, 0.5 step) that includes four dimensions: vegetation structure, species presence, soil erosion evidence and state of streams including water, riparian zone and vegetation, assessing the status of the ecosystem relative to a natural (low intervention) condition. The develop of the EII had three phases: a) design of the structure and evaluation protocol, b) discussion with interdisciplinary panel of specialists and c) application in different situation. Values were determined for each paddock of the farm and a general value was calculated by prorating the area contribution of each paddock as showed in the equation 1.

(Eq1)

$$EII = \sum_{n=1}^{n} \frac{(St_i + Sp_i + So_i + Rz_i)\mathrm{PA}i}{4FA}$$

Where, St_i=score value of vegetation structure for paddock *i*, Sp_i=score value of species presence for paddock *i*, So_i=score value of soil for paddock *i*, Rz_i=score value of riparian zone for paddock *i*, PA_i= area of paddock *i* and FA= farm total area

Each farm was evaluated at the beginning of diagnostic process and was re-evaluated three years later. In addition to this, beef production was estimated for the three years before starting the project by using farmer's data and measured during the project implementation. Also biomass production, grassland structure and diversity, soil organic carbon, and birds assemblage were evaluated (Blumetto et al, 2014). In order to validate EII, Pearson correlation coefficients between EEI and other variables were obtained.

Results and Discussion

The environmental quality measured throw the EII stayed without substantial changes while productive results (beef kg /hectare/year) increased comparing the average of the three years before starting the project with the average of the three years of the project implementation (see table 1). This could indicate that low input technology applied can be an adequate option for the sustainability of this production system.

Table 1. Values of Ecosystem Integrity Index and beef production for the seven study cases.

Farm	A	B	C	D	E	F	G
EII (2012)	3.3	3.0	3.8	3.9	3.7	3.6	3.4
EII (2015)	3.5	3.2	3.7	3.9	4.0	3.7	3.6
EII difference	0.2	0.2	-0.2	-0.1	0.2	0.1	0.2
BP b 2012	78	80	30	63	59	101	127
BP 2012-2015	126	83	71	83	84	119	181
BP difference	48	3	41	20	25	18	54

EII (2012): Ecosystem Integrity Index obtained at the start of project; EII (2015): Ecosystem Integrity Index obtained at the end of project; BP b 2012: Beef production Kg/ha estimated average three years before project; BP b 2012: Beef production Kg/ha measured average for the three years of the project

In order to validate the EII as an evaluation tool for the functionality of the ecosystem, correlation with other variable were studied (table 2).

Table 2. Pearson Correlation Coefficient between Ecosystem Integrity Index and other variables.

Variable	Shannon Birds	Richness Birds	Shannon Grass	Richness Grass	C Org 0-3 cm depth	C Org 3-6 cm depth	Sward height (cm)	Biomass (kgDM/ha)	Stocking rate (LU/ha)
Pearson EII	0.77	0.81	0.82	0.76	0.74	0.57	0.07	0.12	-0.65
p	$1.8E^{-09}$	0.03	0.05	0.02	$1.7E^{-03}$	0.03	0.79	0.64	0.12

EII had positive correlation with species richness and diversity of grasses and birds. Both variables do not integrate directly the index, although some appreciations of herbaceous communities are included. Three of the index dimensions can be associated with bird diversity: vegetal diversity, vegetation structure and riparian zone status, which could explain this strong correlation. EII values had also positive correlation with organic carbon content of the soil in both 0 to 3 cm and 3 to 6 cm depth. Organic matter of the soil is considered strongly associated to productivity and soil health, and important support for many ecosystem services.

No correlation was found for average sward height and aerial biomass, which means the index result independent of characteristics that can change in very short time and are associated to management decisions. Although not significant, a tendency of negative correlation was found with stocking rate, which high values are widely associated to rangeland degradation (Angerer *et al*, 2016).

Conclusion

A practical and low cost tool (Ecosystem Integrity Index) have been developed and shown to be useful for evaluating several aspect of the ecosystem functionality. Additionally, EEI provides numeric values that can be useful for comparing different farm or paddock level, and also can be mapped in order to help to farmers in management decisions.

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Effects of Cattle on Bees in Alberta's Rangelands

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Key words: Pollinators, grazing, rangeland health, diversity, monitoring

Introduction

Rangelands are extensive ecosystems that include much of the terrestrial surface and provide valuable ecosystem goods and services. In particular, rangelands provide forage for cattle but they also support biodiversity, including communities of pollinators. Many insect pollinators nest in below-ground burrows, consequently undisturbed soils provide better habitat than those that are tilled. Insect pollinators support flowering crops through pollination and can travel considerable distance (<4 km) but they are also critical to the life cycle of most flowering plants within rangelands. Recent studies have shown that pollinators are threatened by climate change (Kerr et al. 2015) and threats (Goulson et al. 2015). It is also likely that cattle affect pollinators through alteration of the plant community. Unfortunately, there are few recent records of which bee species occur where, so it is difficult to assess changes in insect pollinator communities. Rangelands in Alberta are extensive, but exist in a patchwork agricultural landscape that includes annual crops, residential and industrial areas. The purpose of this study was to survey pollinator populations throughout Alberta's rangelands to create a baseline survey but also examine whether grazing impacts pollinator communities.

Materials and Methods

In 2014, we established 35 study sites in rangelands throughout Alberta's grassland regions. We surveyed each site for insect pollinators twice using bee-bowls and sweep netting. We counted the number of flowers along establish transects during each survey, measured plant cover at the peak of plant growth and assessed rangeland health (Adams 2009).

Results and Discussion

In 2014, we caught 23 genera of bees, which represent about 140 species including many rare species, across the different grassland regions of Alberta (Fig. 1A). Linear regression weakly predicted a relationship between rangeland health scores and bee abundance (Fig. 1B); which may be a result of more floral resources under moderately grazed conditions. Bee communities varied across the province, indicating that there are diverse community assemblages (Fig. 2).

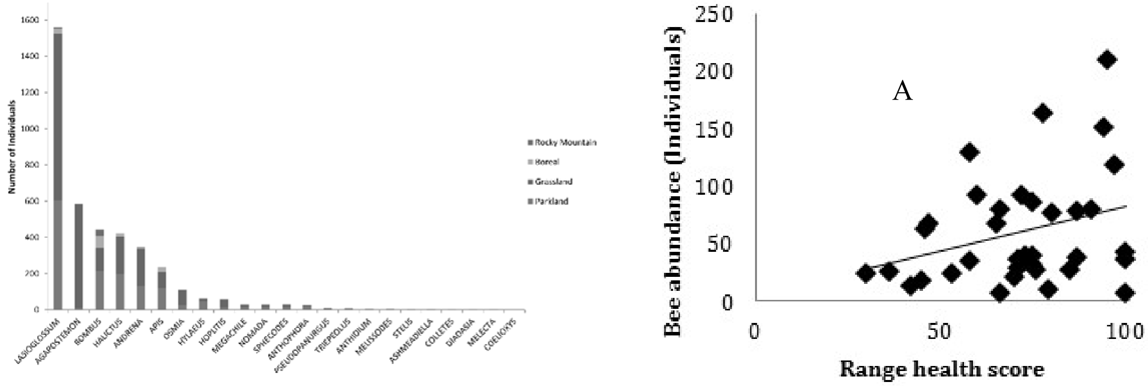

Figure 1. A) Abundance of bee genera captured in regions of Alberta in 2014. B) Rangeland health scores weakly predicted the number of bee species in 2014 (R^2 = 0.09, P= 0.07).

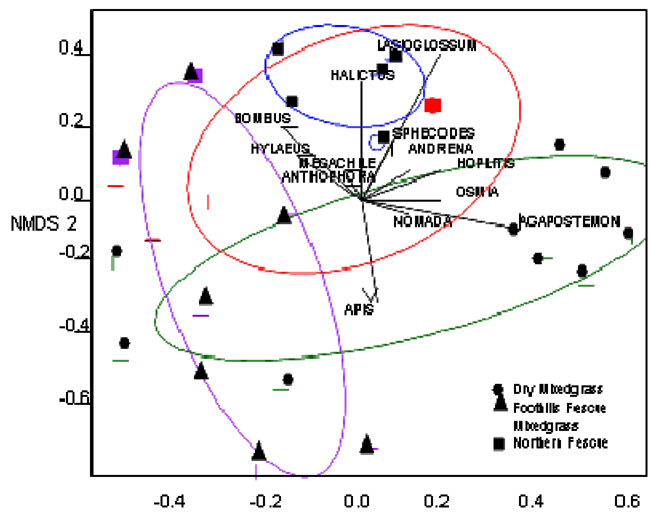

Figure 2. An NMDS ordination of bee communities at grassland study sites throughout Alberta. Points represent individual sites. Ellipses represent groups of similar sites based on bee community composition. Arrows indicate association of different bee taxa with different sites.

Conclusions

Rangelands are habitat to a diverse community of bees, our analysis also indicates that cattle affect bee abundance, which suggests that appropriate management could be used as a tool to improve habitat for bees. Further analysis, will examine the mechanisms linking cattle grazing to bee communities through the response of the plant community, and look at landscape patterns and whether increasing cover of annual crops affects pollinators.

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2.5 Aesthetic and Spiritual Value of Wildlands

Effect of the Different Plants on Community Stability for Slope Protection in Inner Mongolia, China

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Key words: Slope protection, slope-protecting vegetation, population density, community stability

Introduction

Physical measures using concrete were used in slope protection to protect the Zhuozi highway in Inner Mongolia. With time, cement has degraded and water erosion become problematic. Vegetation plantings were used to remedy the defects of the cement firmware (Liu, 1999; Wang, 2003). This study, based on five years' data of community and population densities, investigates factors affecting community stability in side-slope of highways.

Materials and Methods

Experimental area is located in the west of the Zhuozi mountain expressway, at N 40°56.147′, E 112°11.501′. Elevation averages 1270 m. The annual average temperature and precipitation are 3.3°C and 389 mm, respectively. The trial site was a cutting slope of mountain side for road repair on highway and the slope was up to 60 degree. The hydraulic powered spray-planting-turf technique (Wen, 2000) was used and six species of smooth brome (*Bromus inermis* Leyss) 30%, Mongolian wheatgrass (*Agropyrom mongolicum* Keng) 30%, alfalfa (*Medicago sativa* L) 20%, white sweetclover (*Melilotus albus* Desr.)10%, erect milkvetch (*Astragalus huangheensis* H.C.Fu.) 5% and korshinsk peashrub (*Caragana korshrinskii* Kom.) 5%, were mixed with adhesive materials and fertilizers.

Three sampling plots, on top, middle and bottom of slope, were randomly set in the research site. All the data were monitored in from the planting year 2003 till the year 2007 with three replicates. The population density decay rate and the population density ratio were calculated by population and community density. All data were analyzed by the MIXED procedure. Analysis of variance (ANOVA) and general linear model were performed with SAS (SAS Institute, 2013).

Results and Discussion

The population densities of grasses decreased in the fifth year, but the legumes decrease in the second year. Erect milkvetch and the korshinsk peashrub almost disappeared in the fourth year. Compared with the population density decay rate of different vegetation at the same year, the legume species were significant higher than grass species in the second and the third years, while the results were reverse in the fourth year. There were no differences in different species in the fifth year, indicating the community tended to be stable (Table 1).

The population density ratios of different species in first year were similar with mixed ratio of seeds before seeding, so the results shown that planting was very successful. In the whole community, the population densities ratio of grasses were increasing and legume were decreasing during the research period (Table 2).

The results were in agree with the results found by McNaughton (1988). The newly planted vegetation community developed to stable with the time past. In another words, the development of new community has three evolution stages, the niche pubertal stage, niche competition and ecological niche positioning

(Goodman, 1975). The time cost for each stage was different, which based on the vegetation species. The ecological site of the slope was worse than flat at the same area, especially the water. The degree of drought was increasing with the slope degree. So it was important for the

Table 1. The population density decay rate of different species in different years.

Specific	The annual attenuation rate（%）			
	The 1st-2nd years	The 2nd-3rd years	The 3rd-4th years	The 4th-5th years
Smooth Brome	2.0b*	2.0d	84.4a	46.2a
Mongolian Wheatgrass	2.6b	0.4d	88.8a	9.3a
Alfalfa	58.6a	70.5c	46.9b	43.7a
White Sweetclover	53.0a	82.8b	26.9b	57.3a
Erect Milkvetch	60.4a	93.3a	25.0b	66.7a
Korshinsk Peashrub	59.4a	76.7bc	27.8b	50.0a

*Different letters in a column indicate significant difference ($p < 0.05$).

Table 2. The dynamic of population density ratio of different species in different years.

Year	Population density rate（%）					
	Smooth Brome	Mongolian Wheatgrass	Alfalfa	White Sweetclover	Erect Milkvetch	Korshinsk Peashrub
1	33.4b*	34.2c	17.6a	12.4a	1.1a	1.2a
2	41.0ab	41.6bc	9.0b	7.3b	0.5b	0.6bc
3	46.9a	48.4ab	3.1c	1.5d	0.0d	0.2c
4	46.9a	34.8c	10.4b	6.7b	0.3c	0.8ab
5	36.0b	51.0a	8.2b	4.3c	0.0d	0.4bc

*Different letters in a column indicate significant difference ($p < 0.05$).

vegetation species choice in slope protection. In our results, the grasses were better than legume. The wheatgrass was the best species, because it's ecological niche compatibility with the smooth brome. Erect milkvetch was a short lived legume and disappeared soon after planting. Changes in vegetation caverage showed a decreasing trend in the five years. In the third year, the community appeared sparse and to the forth year, bare spots appeared. In the fifth year, coverage rate was less than 50%, with less than 30% in top, about 50% in the middle, and about 60% in the bottom section of the slope.

Conclusions and Implications

The results shown that, the contribution of community of Mongolian wheatgrass and the Smooth Brome were the greatest and more stable. The followed were alfalfa, white sweetclover and korshinsk peashrub. In spite of their population density ratios were decreased, they still played an indispensable role in biodiversity which was the most important element to support community stability. The erect milkvetch could not adapt to protect the slope because of the population declined earlier and seriously.

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The People of the Grasslands

3.1 Changes to pastoral Systems around the Globe

The Shift from Pastoral to Agro-Pastoral Livelihood: Current Challenges and Future Research Priorities

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Key words: Sedentarization, climate change, sustainable land management, policy reform.

Introduction

Nomadic pastoralism is a precarious lifestyle and a significant form of land use involving some form of mobility within extensive rangeland areas (WISP, 2007). Pastoralism provides 10% of the world's meat production and supports approximately 200 million households worldwide (FAO, 2001). A declining trend in pastoralism with a shift to sedentary agro-pastoral practices on smaller tracks of land and its major implications on rangeland management have been noted by the authors across many regions. This short overview reviews the major transformation from pastoral to agro pastoral production systems as a result of declining transhumance and its potential implications for rangeland management. The objective of this paper is to understand the current trends and highlight new areas for research to improve rangeland management as it is occurring on the ground.

Materials and Methods

A survey was conducted in South Asia on transhumance on 250 pastoralists. It was observed that transhumance is declining and there is a tendency for people with larger herds and lower educational levels continuing the practices at certain times of the year (Louhaichi et al., 2014). This trend has been observed in research activities in multiple locations. As a result, a review of the literature was conducted to understand the reasons for the reduction in transhumance and the resulting increase in agro pastoralism.

Results and Discussion

Extensive livestock production based on pastoral grazing systems has been in decline as a consequence of environmental, socio-economical and policy changes over the last five decades in many parts of the world. A number of factors contributed to the settlement of pastoralists, such as: urbanization, degradation of the natural resource base, drier conditions associated with climate change, and an attempt to reach markets with better prices and payment. Polices and services play another major role in settlement as policies tend to favor settlement through feed subsidies and making borders difficult to cross as well as allocate crop land in pastoral areas in many occasions. Major transformations in social structures and lifestyles prompted mass migrations from rural areas to cities for easier access to beneficial social services like healthcare and education among others. Development in agriculture services has improved agriculture livelihoods making crop production more profitable. Farming families as a result often prefer to be near these services as they diversify their earnings. While pastoralism is declining along with a decline in rural populations, livestock numbers are increasing (Figure 1).

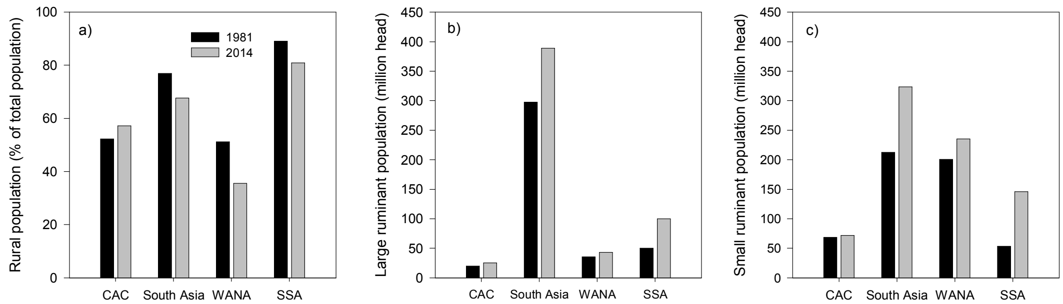

Figure 1. Evolution of rural population and livestock number (source World Bank and FAO stat).

Livestock production will respond to meet the rising meat consumption. In contrast, small ruminants are no longer considered to be the major suppliers of animal products in Turkey due to the large decreases in sheep and goat populations as partly associated with sedentarization (Gursoy 2006). Sedentarization of the small ruminant flocks in the form of agro pastoral production lead to inefficient use of rangeland grazing. This reduction in mobility resulted in overgrazing of rangeland areas with easier access and under grazing in remote areas. Underutilization of rangeland can cause problems not only of overgrazing in key locations but also serve as a security vacuum in remote harder to access areas (de Haan et al., 2014).

Conclusions and Implications

Policies and social services can be adjusted in a way that still promotes migratory pastoralism to utilize and reduce the security vacuum that these areas may pose. Currently governments often provide feed subsidies and land tenure incentives that cause pastoralists to stay near urban areas. Using this money for assessing carrying capacity and enforcement of grazing permits in underutilized areas can provide incentives to utilize harder to reach areas. Providing mobile services such as; school, veterinary, and health services makes it easier for pastoral people to continue their traditional lifestyle. Governments have often rewarded people who move to remote areas by giving them land once it has been cultivated for many years. This has led to degradation in some areas. Revisions of such policies with land planning can change negative impacts. Research on pastoral development is needed to reduce conflict and promote sustainable land management.

Acknowledgments

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New Way to Manage Grazing Livestock System in Degraded Grassland Based on System Economics

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Key Words: Grazing livestock system, ecological site, stocking rate, animal performance, economics

Abstract

Grasslands provide about half of the total feed for livestock production and support a large number of social and cultural ecosystem services around the world. Grazing livestock systems mostly depend on grasslands, but the production efficiency of this system is often very low. Improving the efficiency of grazing livestock systems while conserving grasslands is a great challenge. One large size on-farm experiment with traditional whole-year grazing and a lower stocking rate summer animal grazing plus three months of greenhouse feeding was carried out in grassland areas of northern China. Ecological sites were classified and their aboveground biomass was estimated with ground measurements and remote sensing technology. Models of balance of forage supply and animal requirements, and the optimization of grazing livestock system were used to understand the current situation of the grazing livestock system, and to find an improved way to manage grazing livestock system. Finally, we worked with a private company and some herders to upscale adoption of the results in a wider area. The results indicated that a lower stocking rate during summer grazing plus greenhouse feeding in winter is a suitable improved grazing livestock system in pastoral areas in northern China. This management system is innovative in that it both enhances livelihood outcomes and conserves the grazing lands. The key points for this new system are estimation of forage and feed supply and animal requirements, grazing livestock management improvement (such as the low stocking rate plus winter greenhouse feeding) assessed based on maximum net income, integration of Dorper sheep and improved management.

Introduction

Grasslands provide about half of the total feed for livestock production and support a large number of social and cultural ecosystem services around the world (Herrero 2013). Traditionally these grasslands have supported livestock grazing systems as distinct from those that intensively use forage and grain crops. However, as a result of limited forage resources and environmental constraints through much of the year, both inputs and production efficiency are often low. Often livestock herders have focused on maximising the number of animals they have and have learnt the skills needed for survival, but a consequence has been that overgrazing and grassland degradation is not uncommon. This is especially true where other factors lead to large increases in the human population and concurrent increases in reliance and use of grassland resources. The features of degraded grassland include significant shifts to less-desirable plant species, decreases in plant cover, and in some cases to desertification, reduced net primary production and reduced capacity of soils to sequester carbon, and increases in water and wind erosion and in greenhouse gas emissions from soil (Kemp 2013). At the same time an increasing world population is demanding more animal products while also expressing a desire to maintain natural ecosystems in a better state. These conflicting pressures and effects are very evident in northern and western China, where the herders / pastoralists are among the poorest groups in society. The Chinese central and local governments commenced discussions on restoring degraded grasslands in 1985, though large scale implementation of programmes only started in 2002 once the Grassland Law was in place. These programmes included resettlement of herders, forage reseeding, and grazing bans and fencing, all aimed at promoting grassland recovery. However, implementation of these measures has been expensive and with variable results, in part because these measures did not address herders' reliance on growing numbers of animals for livelihood improvement. Overstocking of the grasslands was still an underlying problem. Alternative strategies were needed.

In 2001 discussions started on a new project (Kemp and Michalk 2011) to analyse grazing livestock systems on farms in northern and western China and to use simple models to investigate potential changes in management practices. In addition, data were used from grazing experiments and other sources, where sufficient information could not be derived from farms. From those studies some system changes were initially tested. From 2007to 2015 a larger farm scale study was done aimed at enhancing herder household incomes in a way that also improved grassland conditions. The modelling had shown that reducing animal numbers should increase animal production per head and thus income per head, providing an economic incentive for lower stocking rates. A reduction in animal numbers could then deliver benefits for grassland rehabilitation. An important aim was to help shift the focus among herders and officials towards evaluating net household income from livestock, rather than gross income or maximising animal numbers.

Materials and Methods

Nine sites were selected from Jilin Province in eastern China to Xinjiang and Gansu Provinces in the west and southwest pastoral areas of China (Fig. 1). The grassland types varied from the higher rainfall meadow and meadow steppe, through typical steppe, alpine meadow, and mountain steppe, to the dry desert steppe. This paper mainly presents data from the desert steppe site at Siziwang Banner (250 mm annual precipitation) in Inner Mongolia, while also referring to extension results from other sites in northern China.

In each site, three households were selected as experimental farms (testing both stocking rate reduction and summer grazing with greenhouse feeding for three months) and another similar three households were selected as control farms (implementing traditional management, i.e. whole year grazing with some supplementary feed in winter). All households were mapped and classified to assess ecological sites and rangeland health (Fig. 2). Grazing land condition and forage supply from both natural grassland and tame pasture were estimated using field measurements, such as aboveground biomass and plant composition with 1×1 m quadrat and remote sensing. Data on grassland condition and all feed inputs (concentrates and grain) were monitored regularly. Household and livestock income and costs were surveyed each year.

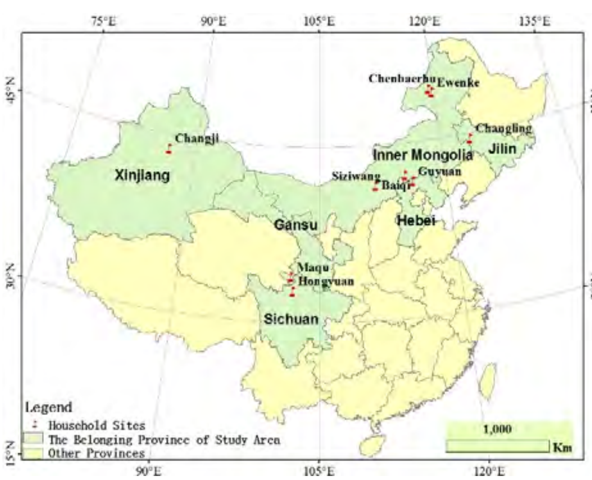

Figure 1. Grazing livestock sites in China.

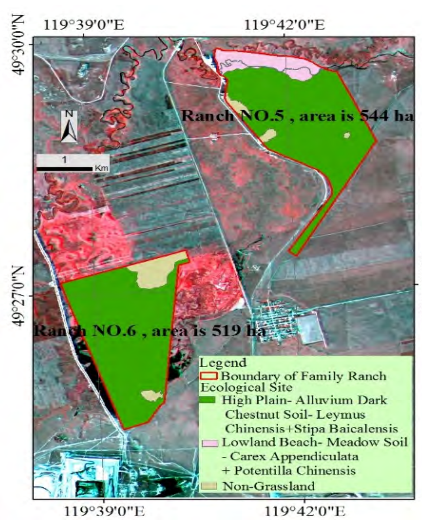

Figure 2. Remote sensed images of farms.

Semi-structured interviews were used to obtain data on the grassland and livestock production systems. Two models (Stage I, II) were used to test the balance between forage supply and livestock requirements, and to predict the effect of changing the grazing livestock system (Han *et al*. 2011). The data used in the models were based on household surveys and results from grazing and other experiments. The Stage I model, calibrated with farm data, analysed the metabolizable energy (ME) balance between feed supply and demand for all animal types and classes on the farm on a monthly basis under steady-state conditions, and was used to investigate scenarios for a range of potential grazing livestock options. The Stage II model is a steady-state linear program optimising model used to predict the optimal combination of factors that would enhance household income while changing stocking rate and other factors, including lambing times, livestock infrastructure change (conventional or greenhouse sheds) and livestock feeding strategies.

The farm demonstrations were done in collaboration with local government and a private company, Sainuo Sheep Company. The local government provided support for the herder association to adopt new technology and subsidised cross-breeding of Dorper (meat breed) with local Mongolian fat-tail sheep. The cross bred with Dorper sheep has faster growth characteristics compared to local Mongolian fat-tail sheep after lambing. Usually, Mongolian fat-tail lambs need 6 months before they are ready for sale, but cross-bred lambs need only 4 months to marketing. Therefore, when herders use the cross-bred sheep grazing pressures will be reduced and feed demand is reduced. The private company promoted and marketed sheep products from 2009, paying herders a premium per kg for larger animals and hence more meat per head. Changes in stocking rate and livestock summer grazing with greenhouse feeding in stalls for three months were combined with market changes.

Results and Discussion

There are plain-light chernozem soil-*Leymus chinensis* and plain-light chernozem soil- *Phragmites australis* ecological sites in the meadow households in Jilin, where cattle grazing is common; high plain-alluvium dark chestnut soil-*Leymus chinensis*+*Stipa baicalensis* and lowland beach-meadow soil-*Carex appendiculata*+*Potentilla chinensis* sites in meadow steppe households in Inner Mongolia with cattle and sheep grazing; high plain-sandy chestnut soil-*Stipa krylovii*+*Cleistogenes squarrosa* and high plain-meadow soil-lowland saline meadow sites in typical steppe households in Inner Mongolia and Hebei Province with sheep and cattle grazing; brown and light chestnut soil-*Stipa breviflora*+*Cleistogenes songorica* sites in desert steppe households with sheep grazing; mountain-chernozem soil-*Poa pretense*+*Achnatherum inebrians*, mountain-brown calcic soil-*Stipa caucasica*+*Seriphidium borotalalense*, mountain-chestnut soil-*Festuca ovina*+*Seriphidium borotalalense* and mountain-grey desert soil-*Petrosimonia sibirica*+*Ceratocarpus arenarius*+*Seriphidium transillense* sites in Xinjiang households with sheep and goat grazing; plateau-meadow soil-*Kobresia humilis*+*Potentilla anserinal* and plateau-meadow marsh soil-*Kobresia humilis*+*Potentilla anserinal* sites in alpine meadow in Gansu Province with Tibetan sheep grazing; and alpine meadow soil-*Festuca ovina*+*Carex* sp., subalpine swamp soil-*Carex* sp., subalpine alluvium dark chestnut soil –*Carex muliensis* sites in Sichuan Province with yak grazing. All households apply a traditional whole-year grazing system with some supplementary feed in the cool season for female livestock.

The new management systems tested resulted in an average 46% reduction of stocking rate during summer grazing with winter greenhouse feeding for three months, while net household income increased substantially in the desert steppe site during 2010-2013 (Table 1). Net income per sheep and per ha in experimental farms was 2 and 1.5 times, respectively, that of the control farms. Experiment farms were larger, but often that leads to a lower net income per head or per ha (Kemp, unpublished data) rather than more as in this case. This effect may be due to the total number of sheep being only about one-third more in the experimental farms and thus more readily managed by a household.

Table 1. Sheep numbers and net income in experimental and control farms in the desert steppe site after four years of implementing a new management system (Han *et al*. 2013)

Farms	Area (ha)	Adult sheep number	Stocking rate (sheep unit/ha)	Cost of supplement (Yuan/household)	Net income (Yuan/household)
Control	406.4±54.2[b]	285±28[b]	0.61±0.05[a]	51,181±14,576[a]	94,715±15,543[b]
Experiment	785.1±145.0[a]	393±58[a]	0.47±0.06[b]	56,007±14,949[a]	278,442±57,348[a]

When the new way of grazing livestock was applied in Jilin, Hebei, Sichuan, Gansu and Xinjiang in northern China from 2013 to 2015, the results were similar to those shown in Table 2. There was no difference in stocking rate between experimental and control farms, but the net income of experiment farms increased by 48.6% in three years. This is due to changing the whole-year grazing with some supplementary feed in the cool season to a slightly lower stocking rate during summer grazing, and greenhouse feeding in the cool season (three months). However, the results showed that after three years there was no significant change in stocking rate, suggesting that although herders could achieve a higher net income with the new management practices, they still do not want to reduce animal numbers due to other considerations, possibly including complex social and cultural barriers. Therefore, although the new grazing livestock system appears to be an innovation with a bright future in pastoral areas in the world, it will take a long time to achieve wider adoption.

Table 2. The results of extension of the new grazing livestock management system in northern China.

Farms	Stocking rate (sheep unit/ha)	Cost of supplement (Yuan/household)	Gross income (Yuan/household)	Net income (Yuan/household)
Control	1.20±0.32[a]	12700±11610[a]	64880±18380b	56420±10470[b]
Experiment	0.84±0.09[a]	13180±10190[a]	97030±11820a	83850±6810[a]

Conclusion

The shift in emphasis to reducing stocking rates to a level where net income can be maximised proved highly valuable to households in northern China. The focus on improving profitability per head of sheep achieved the desired goals when it was accompanied by market changes that gave herders an incentive. Some government support is necessary to foster these changes as herders are understandably reluctant to reduce animal numbers.

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Vulnerability and Adaptation of Borana Pastoralists to Social-Ecological Change in Southern Ethiopia

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Key words: Pastoralism, agro-ecosystems, livelihoods, institutions, resilience

Introduction

Pastoralism provides a vital livelihood for many different peoples around the world. However, pastoralist systems currently face a number of common pressures as a result of social-ecological change, which has seen many pastoralists become increasingly marginalised and vulnerable. The southern lowlands of Ethiopia exemplify the types of changes that are occurring in many pastoralist systems and the increasing vulnerability of the predominantly Borana pastoralists that occupy this area. Traditionally, the Borana have managed their cattle based on the seasonal availability of water. However, in recent decades this management approach has been compromised primarily by limited access to traditional grazing areas and conversion of rangeland to cropland. Here we attempt to understand the drivers of these changes, specific aspects of the pastoralist system that have become more vulnerable over time and the resulting policy implications.

Materials and Methods

We focused our research on two pastoralist settlements, Miesa and Siminto, occupying the Liben Plain, a semi-arid grassland some 10 km south-east of the town of Negelle-Borana. Data collection involved accessing existing local secondary data and primary data collection. The latter consisted of interviews with key informants and focus group discussions complemented by a series of semi-structured interviews with pastoralists at each settlement. In analysing the data we used the vulnerability framework of Fraser (2007) as adapted by Dougill et al. (2010) for use in pastoralist systems. This conceptualises vulnerability as part of three dimensional framework comprising agroecosystems, livelihoods and institutions.

Results and Discussion

Agroecosystems

Annual rainfall measured at Negelle declined steadily from about 900 mm in the mid-1960s to about 700 mm in 2000, and has since remained relatively stable at this amount. The population of the two settlements on the Liben Plain has almost doubled since 1994, from 5,700 to 11,165. Associated with population increase, has been a rapid expansion of the amount of arable land, which now occupies some 50% of the grassland area of the Plain. The remaining grassland has deteriorated in quality with a decline in key grazing species and an increase in invasive shrubs, particularly *Acacia drepanolobium*. Efforts are being made to offset this through the increased use of collective enclosures known as *kallos* which provide forage reserves for livestock. However, given that more than 47,000 cattle are estimated to be held at the two settlements, the impact of these *kallos* has so far been limited. Likewise, increased production from agriculture is unable to buffer the decline in productivity of the pastoral system in an equitable manner and is itself vulnerable to unreliable local rainfall and declining soil fertility.

Institutions

Local institutions on the Liben Plain take two forms: the *gaada* system of traditional management and local state government structures (*kebeles*). The latter have appeared since 1974 and their principal role is in the allocation and administration of arable land. The former is associated primarily with collective decisions about the grazing of livestock (controlled through individuals called *aba didas*), the use of fire as a management tool and resting of areas through *kallos*. However, the *gaada* system is no longer able to function as effectively in these management roles. Grazing management directives issued by *aba didas* concerning the movement of livestock off the plain during the wet season are frequently ignored by pastoralists who now make their own decisions about livestock grazing. Likewise, the burning of the plain during the dry season has not been possible since the 1980s due to a lack of standing biomass. This has significantly impacted the quality of the grazing sward and facilitated shrub encroachment. Thus, the legitimacy of traditional institutions is being undermined both by the decline in productivity of the grazing system that they are responsible for and the co-existence of government *kebeles*, which allocate good quality grazing land to crop production.

Livelihoods

Three broad livelihood types were identified amongst pastoralists. *Accumulators*, are the wealthiest pastoralists with the strongest social networks. Their ability to accumulate arable land and maintain large herds of cattle (and, increasingly, camels) has enabled this small group to improve their livelihoods. *Consolidators* have not been able to increase their arable holdings but have instead focused on maximising crop and livestock yields. They demonstrate variable livelihood trajectories. Finally, *marginalised* pastoralists are those with little or no land and few livestock and are the least able to adapt to changing social-ecological conditions.

Conclusions and Implications

There has been a rapid movement to an increasingly intensified agro-pastoral system. As part of this, we argue that both the agroecosystem and the traditional institutions that govern and manage it have become more vulnerable over time. In contrast a number of different livelihood trajectories are evident. Accumulator and to some extent consolidator households have been able to buffer increasing levels of uncertainty through crop production. The more marginalised pastoralist households, however, are the most vulnerable and many have become reliant on food aid or have been pushed out of pastoralism altogether. On this basis we recommend: -

- Greater integration of state institutions such as *kebeles* and traditional authority in a co-management approach to local governance of natural resources.
- Expansion of *kallos* as part of an integrated management plan for the Plain.
- Formation of collective-action groups based on the approach of Coppock et al (2011) to build capacity in the development of alternative livelihoods, particularly for the most marginalised.

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Ecological Impacts of Rangeland Management Changes in the Middle Atlas Mountains of Morocco as Response to Implemented Policies

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Key words: Pastoral systems, rangeland degradation, Timahdit, sheepherder

Introduction

Pastoral systems have been undergone profound changes. Among the trends and perturbations faced by pastoralists across the world, we can enumerate; population increase, agricultural encroachment, breakdown of the traditional, local institutions and systems for managing natural resources, sedentarization and concen-tration of livestock and the growing economic vulnerability of pastoralists (Niamir 1999; Reid et al. 2014).

The Ait Arfa du Guigou (AAG) tribe in the Timahdit county was semi-nomadic and its main activity is livestock husbandry, especially sheep herding associated to subsistence farming. They used to graze their land with a vertical migration pattern, i.e., winter on the Azarhar (low-lying areas) and summer on the "Jbel" (highlands).

This paper aims to study the changes and the impacts on the socio-ecological system (SES). We hypothesize that sheepherders were obliged to settle in their highland rangelands in response to reduced grazing areas following the implementation of several policies. Practical adaptations were developed at each of the different states of the SES of the AAG.

Methods and Materials

The study was carried out in the rural Community of Timahdit, which is located in Morocco's Middle Atlas. A succession of policies from the Royal Dahir (1917) to Plan Maroc Vert (2007) have had a myriad of impacts ranging from decreased tribal grazing lands, overgrazing of common lands, reduction in herdsmen mobility, reduced transhumance as a result of grazing area restrictions (creation of 10,000 ha King Ranch in 1972), and marginalization of grazing lands.

Changes in land cover were assessed by using remote sensing from Landsat-5 Thematic Mapper (TM) from the mid-1980s and mid-2000s and were analyzed by supervised classification for identification of land cover types. A comparison of multi-date surveys of vegetation since the late 1970s, 2001 was done within the pelouse plant community to document the changes in vegetation structure.

Results and Discussion

Our results indicated a change in land occupation (Table 1). Forest area declined by almost 47% within 23 years showing an annual decrease of 46.69 ha/year and 76.94ha/year for dense and sparse forests, respectively. The decline in forest area is even drastic if we compare the actual figure with those of 1969 (Lecompte 1969); an annual decrease of 172.37 ha and 55.27 ha for dense and sparse forest, respectively. Matorrals of Artemisa spp and Xerophytic species (*Buplorum spinosum* etc.) increased slightly. The matorral of *Genista pseudopilosa* decreased by 29.30 ha, i.e., a yearly decrease of 68.87 ha. The decrease in the size of this latter matorral can be explained by the overgrazing since *Genista pseudopilosa* may contribute to sheep diet up to 27% late in the season (El Aich et al., 1980). The area of the grasslands remained almost unchanged in quantity. However, the vegetation composition of these grassland areas is changing drastically as it is showed in Table 2. Finally, the amount of bare ground is increasing over time leading to a great amount of fragmentation, i.e., the annual progress of bare ground averaged 141 ha/year.

Table 1. Change in land cover of the Ait Arfa du Guigou between 1984 and 2007.

Land cover (in ha)	1984	2007	Change (in ha)	Change (in %)
Croplands	10253.5	10071.2	-182.3	-1.78
Dense forests	4666.4	3592.5	-1073.9	-23.01
Sparse forests	7511.6	5741.9	-1769.7	-23.56
Xerophytic shrubs	15980.2	17218.2	1238.0	7.75
Genista spp	5392.6	3812.8	-1579.8	-29.30
Artemisia spp	5658.4	6076.1	417.7	7.38
Grasslands	15851.1	16633.4	782.3	4.94
Bare ground	8643.3	11886.4	3243.1	37.52
Wetland	1982.3	911.4	-1070.9	-54.02

Changes in vegetation structure of the grassland community are reported in Table 2. There is a decrease (loss in the self-organization capacity) of the more abundant species such as a replacement among species (more annuals, less perennials and reduction of shrubs) as response to the sustained high grazing pressure because of the shortage of generalist species (low pastoral species value) to colonize the gaps made by fragmentation due to grazing disturbance, and a decrease in diversity and evenness with increasing grazing disturbance.

Table 2. Changes in the vegetation structure in the grasslands of the AAG*

Percent Cover	1978	2001
Perennial grasses cover	33.441	40.933
Perennial forbs cover	16.071	3.821
Shrubs cover	18.331	5.962
Annuals cover	31.656	49.284
Species richness	22	27
Diversity (Shannon Index)	2.516	1.832
Evenness	0.814	0.556

*Additional data to be collected in spring 2016

Conclusions and Implications

The succession of policies during the last decades enhanced the agriculture and impacted negatively the transhumant and nomads. In the Middle Atlas, the sendentarization of the herdsmen on highland pastures as an adaptation to the inexistence of the low-lying grazing areas resulted in the increase of grazing pressure which led to great amount of degradation, materialized by change in landscape occupation, decline in the quality of rangelands by decrease in perennial species being replaced by annuals and unpalatable species. These changes are influencing the whole farming systems, inducing a switch to more intensive agriculture since the cost of production for grazing animals is increasing.

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Cross-Level Governance of Common Property Rangelands: Three Cases from East Africa

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Key words: Environmental governance, institutions, landscape approaches, pastoralists, rangelands

Introduction

Over the past two and half decades a body of scholarship on the governance of commons has expanded and evolved. However, although rangelands in developing countries are in large part commons, there are concerns, about the applicability of commons scholarship in these settings. One such concern is that commons scholarship has tended to emphasize local (village-level) resources, whereas the appropriate level at which to manage rangeland resources may instead be the *landscape*. The other relates to the relevance of identified "design principles" for effective governance of commons (Ostrom, 1990; Dietz et al., 2003) to rangelands. In particular, the first of these principles, *the need for well-defined resource and group boundaries*, runs up against "the paradox of pastoral land tenure", which is the challenge of defining "spatial and social boundaries around resources and user groups in situations where spatial and social flexibility are intrinsic and essential characteristics of resource use patterns" (Fernandez-Gimenez, 2002: 50). In this paper, we consider the implications of three case studies from East Africa where attempts have been made to foster effective landscape governance in dryland pastoralist settings. We pay particular attention to challenges of governing common rangeland resources across scales and levels.

Methods and Study Sites

Case study research was carried out in connection with three rangeland landscapes in pastoralist settings where attempts have been made to foster effective governance of rangeland resources. The case studies were Il'Ngwesi group ranch and conservancy and Garba Tula *dheeda* in Kenya and Gomole rangeland unit in Ethiopia. In each of these three cases, non-governmental organizations and other external actors worked with local communities to create and/or strengthen local institutions and to facilitate resource planning at a landscape scale.

The methods were qualitative, involving review of planning and other documents, key informant interviews, and focus group discussions (see Table 1). The data were analyzed according to a common framework which identified for each case key characteristics relating to the distribution of governance powers, the way in which the spatial extent of the landscape for governance and planning purposes was defined, the approach to planning at different spatial levels, and so on.

Table 1. Methods – No. of interviews and focus group discussions conducted.

	Method	
Rangeland	***Key informant***	***Focus group discussions***
Garba Tula	24	18
Gomole	18	8
Il'Ngwesi	12	3

Findings

In each of these three cases, there was a pre-existing, socially relevant landscape which afforded a geographic scope for the interventions. These pre-existing landscape definitions provided a history and logic for working at scale that seemed to correspond to the needs of pastoralist livelihoods. Moreover, in all three cases the external agents worked with local communities using a participatory approach. Each case has shown promising signs of community support for the landscape institutions and processes, and two of the three were in operation long enough to witness some success in managing pasture resources.

Yet in all three cases, governance structures for the landscape have been facing great difficulties in being able to exercise management authority. For example, the Gomole rangeland council has struggled to receive recognition or support from the Ethiopian government, as the government meanwhile has instituted its own grazing committees at a much smaller scale. At Garba Tula, the community's seasonal grazing plans have not been recognized or respected by either neighboring communities or the county government. In Il'Ngwesi, twice during the course of our field research in 2015 herders from another ethnic group brought huge herds of cattle into sections of land reserved by the group ranch/conservancy for wildlife and dry season grazing. These challenges relate to the relationships beyond the rangeland landscape, both vertically to higher levels of decision-making and horizontally in relation to other communities. The actual governance powers that the landscape institution(s) are able to exercise are insufficient to allow them to manage their resources, to exclude outsiders, or even to require outsiders to observe the same rules which local resource users follow, such as following seasonal grazing patterns. In the Gomole case, the government has never recognized the right of the Rangeland Council to make management decisions for the rangeland. Similarly at Isiolo County, attempts to formally legitimize the Gabra Tula system of management at the County stalled. At Il'Ngwesi, while the tenure rights of group ranches are formally established, higher levels of government have been either unwilling or unable to consistently protect those rights when faced with an influx of livestock herds from other counties.

Discussion

Commons scholarship, despite much of it having focused on local level resources, has noted that local level commons should not be seen as discrete, self-contained "islands"; they are embedded within larger landscapes and exist within a multi-level world (Berkes 2009). Landscapes too, it must be remembered, are embedded within larger watersheds, bioregions, and jurisdictions. The broader governance context is critical, because without its support, any mechanisms for management and governance at the landscape level may not be seen as legitimate by other communities and stakeholders. Moreover, the non-equilibrium dynamics of dryland ecosystems and the imperative for mobility provide an impetus "from the bottom up" against the strengthening or consolidation of governance powers, and against any neat resolution to the paradox of pastoral tenure.

For any initiatives aimed at strengthening governance powers of community-based mechanisms at a landscape level, a caution is in order. Doing so in a way that results in less permeable borders will run up against the bottom-up impetus for flexibility and fluidity. In dryland pastoralist settings, governance arrangements needed to foster effective management will not be a replication of local level commons only larger. Effective landscape level governance cannot be accomplished only through action at the landscape level; it is a task that must be pursued at multiple levels and in relation to the connections across scales and levels. Rather than entrenching fixed and comprehensive management authority within a series of discrete, non-overlapping territories each with its well-defined membership—as suggested by the first of the eight design principles proposed by Ostrom and others—fluidity, negotiation and overlapping rights are likely to be key features of effective landscape governance arrangements for pastoralists.

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The Effect the Highland Clearances Had on the Scottish Uplands

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Key words: Highland clearances, cattle, biodiversity, sheep, clan

Introduction

To this day the Scottish highland clearances remain a very emotive subject, to many people worldwide. Today many descendants of the families of the clearances can be found living in Canada and the United States. The Clearances were not just a social upheaval of the people of the highlands, but also a degrading loss of the biodiversity of the Scottish Highlands.

Timeline of the Scottish Highlands

13th - 17th century
Cattle herding, main industry in the Scottish Highlands.

18th Century
"Year of the sheep": Northern English sheep replacing cattle of the Highlands. Highland people forced to leave their homes.

19th Century
In 1840, more Highland People forced off the land to make way for more sheep and also the introduction of the first sporting estates and deer farming.

Present Day
The main land use in the highlands is sporting estates with some sheep farming taking place.

Material and Methods

In the early 18th Century, the Scottish highlands supported a thriving community of pastoral farmers. The main income source was from the export of cattle to the southern English cities such as London. At the peak output, the Scottish highlands were exporting 150,000 cattle annually (Dennis, 1998). At the same time, managing to maintain the biodiversity on the land and produce a healthy ecosystem. This sustainable farming system was such a success, because the people of the highlands had a skill set to manage the livestock properly that evolved from their ancestors 5000 years before them. These colonists arrived to the British Isles with their domesticated livestock. Over time these cattle would be developed into the kyloe breed of the Scottish highlands and islands. The kyloe were the original seed stock of the Scottish Highlander cattle.

The bond between man and animal was so profound, the communities which were cleared in the land grab of the late 18th Century, took their livestock with them to a new life in North America or Oceania. Today, the largest population of Highland cattle can be found in Canada and the United States.

This pastoral system of the 18th century, involved herding the cattle to fresh vegetation on a daily basis. This provided fresh pasture to the animal, and also allowed the grazed spots to have adequate time to recover before being re-grazed. This understanding of allowing an adequate recover period before re-grazing, was first documented by James Anderson of Aberdeenshire in 1770. The grazing nature of the highland cow allowed biodiversity to thrive, as it did not single out entire species.
The cattle were able to maintain the low growing perennial shrub, purple heather (Calluna vulgaris). Browsing of heather by cattle reduces its competitiveness and encourages grasses and herbs to compete with the heather.

Pre-Highland clearances islands such as Islay were able to maintain a population of 15,000 people. Today it has a population of 3000 people.

1792 - "The year of the Sheep" was the start of what would become a turbulent time in the Scottish Highlands. Land owners removed the tenants with their cattle from the land, to make room for higher paying sheep. Shepherds from northern England were brought in to manage these large flocks.

Results and Discussion

Sheep production initially prospered, taking advantage of the biodiversity, created by good pastoral management of the cattle by the Highlanders. However, shepherds did not carry on the good management practice of herding the sheep to fresh vegetation like the previous graziers. Instead the shepherds' preference was to "Heft" the ewes where the sheep would set stocked on the land throughout the year. This meant ewes, would selectively graze out beneficial grass species, allowing purple heather to dominate the sward.

The biodiversity suffered so much under the poor management of ewes, the production of the land reduced in time (Cooper, 1953). Bracken (Pteridium aquilinum) and gorse (Genista anglica) spread widely through the Highlands and has caused large areas to be unproductive and remains this way today.

Photograph 1. "The Sheep on Skye" by C. Reid 1891. Shows how Bracken (Pterdium) spread with the mismanagement of sheep in the Scottish Highlands.

As a consequence, by the early 19th century, estates who owned the land cleared more cattle to introduce sporting estates and also deer farming. To this day, sporting estates have maintained the status quo and the land has not been able to return to the diverse range of plants that were once there pre-highland clearances. To this day sporting estates burn the heather annually, in an attempt to stop it from dominating the pasture.

Conclusion and Implications

The farming system in the Scottish Highlands in the early 18th Century should be commended for being able to produce sustainable beef. The clans, the highland cattle and the biodiversity of vegetation all benefited on the land. Restoring these farming methods may help address the challenges currently facing livestock production in the UK today.

The Highland Clearances caused suffering not just for the people but also for the land. Biodiversity declined in the highlands due to miss management of shepherding and this has not yet been restored. There is hope to restore this biodiversity through the traditional herding of cattle. This would also bring back people to the Scottish highlands and restore it to a functioning ecosystem.

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Ecological-Cultural Feedbacks in Mongolian Social-Ecological Systems

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Key words: Coupled human-natural system, resilience, absentee herd owners, threshold

Introduction

A growing body of theory recognizes the complex interactions between human society and the earth systems we depend upon (Liu et al. 2007). Understanding feedbacks and identifying potential thresholds in these linked systems is a priority for sustainability science, to avoid undesirable transitions or regime shifts (Scheffer and Carpenter 2003) and to foster transformations to new system configurations when necessary. Resilience theory suggests that moderately coupled social-ecological systems are resilient, because the feedbacks between sub-systems enable learning and adaptation (Walker and Salt 2006). In a moderately coupled system, humans are more likely to detect and respond to changes in ecosystems in time to avert undesirable regime shifts or thresholds. Traditional ecological knowledge (TEK) and formal monitoring can play key roles in coupling, especially when embedded within natural resource management institutions that facilitate timely response to information about environmental changes. Uncoupled systems or those that are too tightly linked create vulnerabilities due to lack of sensitivity (uncoupled) or oversensitivity (tightly coupled) to change. We synthesize recent biophysical and social research on Mongolian pastoral systems and analyze regional-scale climate, vegetation and human population data to identify potential ecological-cultural feedbacks within this system that may shape future system dynamics.

Methods

We reviewed and synthesized existing research to evaluate recent trends in key system attributes. We then analyzed climate, livestock and human population data at the regional level to assess changes in these variables independently. We qualitatively explored potential future trajectories of change as a result of interactions and feedbacks among system drivers, parameters and state variables. These qualitative explorations were informed by participatory scenario planning with Mongolian herders and local and regional officials.

Results and Discussion

We found four clear trends and three less certain ones in contemporary Mongolian social-ecological systems: 1) temperatures are warming and water sources are declining; 2) livestock populations and grazing pressure are increasing, and the spatial distribution of stocking densities and grazing pressure are increasingly heterogeneous; 3) rural and herder populations are declining and urban populations expanding (Fig 1a); and 4) agriculture and livestock husbandry are declining in economic importance based on gross domestic product (GDP) (Fig 1b). Potential but less certain and more spatially heterogeneous trends emerging from these dynamics are: 1) decline in rangeland resilience as signaled by loss of species and species composition shifts in the mountain and forest steppe, and some semi-arid steppe regions, especially those in central Mongolia; 2) potential loss of pastoral culture, identity and traditional ecological knowledge; and 3) probable increase in absentee-owned livestock.

Historically, livestock mediated feedbacks between culture and ecosystem. Domestic animals supported pastoral livelihoods and culture on the semi-arid steppe, and human management of livestock, in combination with weather, affected the health and productivity of rangeland, which in turn influenced human well-being through livestock health and productivity. Under this coupled system, when rangelands are productive, herds grow until they reach ecological saturation and reduce plant biomass production and forage quality, limiting further herd growth, or the population is reduced by a severe winter or other density independent factor. A sudden loss of livestock, due to a harsh winter, for example, leads to a decline in the human population through mortality or temporary migration. A decline in the human population is expected to lead to an associated decline in herd numbers, as fewer animals are needed to support the smaller human population.

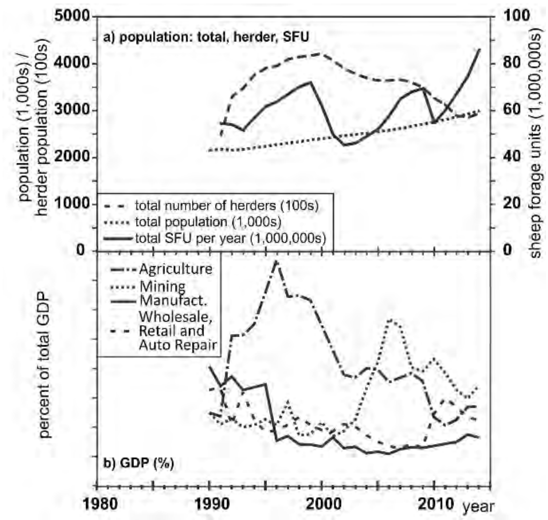

Figure 1. Change in total, herder and livestock populations (a) and agriculture as a percent of GDP (b).

In contrast to these expected dynamics, at a national scale in the past 15 years we observed a negative correlation between herd size and herder populations: as the number of herders declines, the number of sheep forage units (SFU) increases. (1 sheep = 1 SFU, a goat = .9 SFU, camel = 5 SFU, cow/yak = 6 SFU, horse = 7 SFU) We hypothesize this is due in part to absentee-owned herds owned by urban residents, some of whom are former herders and others non-herders who own livestock as an investment or status symbol. This trend could signify a de-coupling of the cultural system and the ecosystem. If the link between livelihoods and herds is less direct and weaker for urban residents, their values and attitudes towards ecosystems and animals transformed, and the associated cultural norms, TEK and management knowledge lost, then this trend could signal the end of pastoralism as it existed for millennia in Mongolia. However, this trend could also be interpreted as an attempt by newly urban Mongols to maintain their pastoral wealth and identity by keeping their herds, and by wealthy urban Mongols to revive and perform their Mongolian pastoral identity by acquiring the markers of a high-status herder, such as a large horse herd. It is unclear what this may mean for the maintenance of herders' ecological and management knowledge, which is passed on through family relationships and community social networks, and is thought to be a key resource for sustainable management and future adaptation.

Conclusion and Implications

Recent trends in Mongolia's livestock and human populations signal a potential de-coupling of cultural and ecological systems and weakening of cultural-ecological feedbacks. This exploratory analysis suggests that the role of culture in social-ecological feedbacks deserves greater attention, including methods of assessing and quantifying culture change that can inform analysis of shifting system dynamics. At a more practical level, it is urgent to investigate the drivers and consequences of the apparent increase in absentee herd ownership in Mongolia, and its implications for social relations, ecological conditions and cultural maintenance or loss. If sustaining pastoral social-ecological systems in Mongolia is a desirable social goal, then policy-makers must support herder education, social development, and continued investment in improved rangeland monitoring and management institutions in order to develop the system's capacity to detect, learn from and respond to environmental change.

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A Framework for Studying the Drivers of Grazing Systems Intensification in the Tropics

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Keywords: framework, pastures, grazing systems, drivers, agricultural intensification.

Introduction

The sustainable intensification of grazing systems (GS) in the tropics is an under-researched sustainable agricultural intensification strategy that has been suggested as a key solution to carry on providing livestock products to a growing human population while potentially mitigating greenhouse gas emissions and sparing land for crops and natural ecosystems. The premises of sustainable intensification consist in increasing food production through increasing yields, not land cultivated, while emphasizing food security and environmental sustainability (Garnett et al., 2013). GS are changing at very fast rates, especially in the developing world which rates of livestock production growth now exceed those in developed countries (>2%/yr and <1%/yr, respectively) (Herrero et al., 2009). There have been various theories on the drivers of agricultural intensification, but the GS in the tropics are very diverse and complex; many variables and their interactions may hamper the theorised progression of agricultural intensification (Williams et al., 1999) and need urgent consideration. Identifying the drivers of GS intensification is essential to better understand the dynamics of land-use changes in the tropics and to recommend policy interventions for sustainable livestock systems. The objectives of this paper are to 1) provide a synthesis on the main drivers that impact the production of livestock products per land area and thus the level of intensification; and 2) present a conceptual framework that integrates drivers from environmental, social, economic and political dimensions.

Methods

We reviewed the literature and developed a theoretical framework that will be tested thanks to analyses of a number of existing-households surveys, global geospatial datasets and case-studies.

Synthesis of the Main Drivers

We identified agro-ecological drivers of GS intensification such as changes in climate, pests and diseases. We also identified demographic drivers such as population pressure and dynamics of urban areas. Economic drivers include changes in input/output prices and variability, increasing opportunities for non-livestock related jobs and changes in access to markets, infrastructures and credits. Political drivers include shifts in land-use choices, land and water tenures, political control over mobile populations and subsidies. The farmer's socio-economic background, including the farmer's objectives, past experiences, values and traditions, risk perception, education, age and stage of life, as well as the household size might also influence the level of GS intensification. Moreover, the farmer's knowledge, which often depends on the presence of programs and organizations for technology transfer, training costs and communication effectiveness might also influence the farmer's decision to intensify.

Theoretical Framework

Agro-ecological, socio-economic and political factors interact in complex ways, defining the level of GS intensification (Fig. 1). The context determines how, where, when and which drivers play the most important roles in the systems.

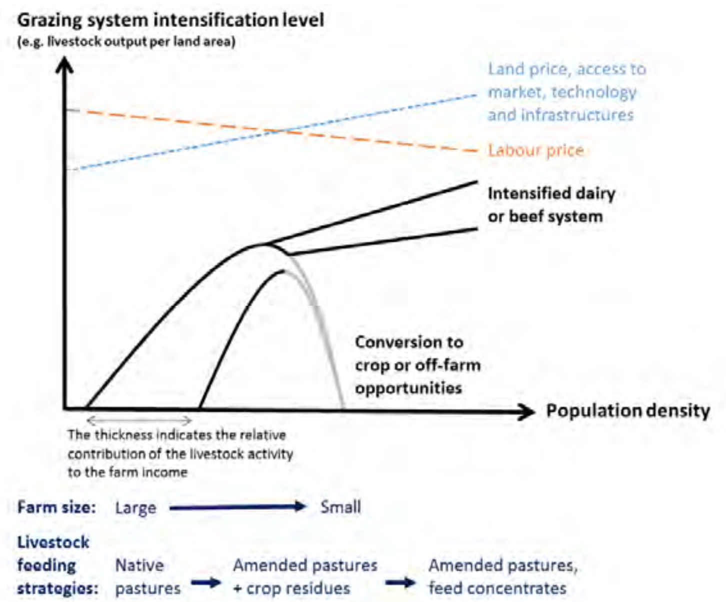

Figure 11: Hypothesis on the relationship between the level of GS intensification and population density within a climatic zone. The black curve, indicating the level of GS intensification, is inspired by McIntire et al. (1992)'s theory on the relationship between crop-livestock interactions and population density.

Conclusions and Implications

Drivers emerging at a global scale as well as drivers specific to local conditions influence the level of GS intensification at all scales by influencing the differences in comparative advantages of the different possible development pathways. The understanding of the drivers of intensification is crucial to apprehend the dynamics of land-use and to provide policy recommendations for sustainable livestock systems. These drivers may not lead to sustainable systems and pathways for sustainable developments must be assessed, taking into account the agro-ecological, socio-economic and political specificities.

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Perception and Awareness of Pastoralists towards Livestock Marketing and Products in Butana Area, Sudan

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Key words: Rangeland, extension, information, participation, culture

Introduction

The Sudan has an area of about 1,886,000 km^2 and a population of 42.9 million (WPR, 2015). It has about 104 million head of livestock. This study was conducted in the Butana area. Most livestock producers are transhumant or sedentary farmers maintaining herds and also, practicing arable farming and/or wage labor. Livestock and livestock products generally meet domestic demand and provide a surplus for export. The dominant species are cattle, sheep, goats and camels. The focal problems are lack of decision on market participation, distance to markets and lack of market information. This study aims to assess perception and awareness of pastoralists towards livestock marketing and products in Butana area, Sudan.

Materials and Methods

A field survey was conducted between July and September 2011. Accidental sampling was used due to unavailability of records of producers and because of all the diverse and considerably unsettled pastoralists in that area. In this method any pastoralist met was interviewed until the sample was completed. A random sample of 407 pastoralists' households was chosen to collect primary data. Both descriptive statistics and econometric model were used for data analysis.

An Ordinary Least Squares (OLS) regression technique was used to determine the relationship between livestock marketing and products and the hypothesized explanatory variables. A general equation for a multiple linear regression (OLS) given k variables was specified as:

$$Y_i = \beta_1 + \beta_2 X_{1i} + \beta_3 X_{2i} + \dots + \beta_k X_{ki} + \mu_i$$

Where Y is the dependent variable, $X_1 \dots X_{ki}$is a set of explanatory variables, i denotes ith household, μ is the error or disturbance term associated with the model, and $\beta_1 \dots \beta_k$ are coefficients representing parameters estimators of the variables in the model. Binary regression is the most suitable method for analysing discrete binary data in which the dependent variable evokes a yes or no response (Farah *et al*., 2003).

Results and Discussion

Table 1 for OLS regression shows the coefficient (values), standard error and significance values. The OLS is used where the dependent variable is continuous. The sign of the coefficient shows the direction of influence of the variable on the regression equation. The model was employed to analyze the important variables explaining the perception and awareness of pastoralists towards livestock marketing and products. Out of the eight explanatory variables hypothesized to affect marketing of livestock and their products and which in turn affect the outcome, four variables were found to be statistically significant. These include lack of decision on market participation, lack of market information, weak extension and distance to market.

An unexpected negative sign was found for education but it was non-significant. This is an indication that continuous movement of pastoralists from one place to another makes it difficult to literate them which may affect marketing of livestock and their products. The coefficient for livestock keeping had a negative but non-significant influence on marketing of livestock and their products. This could be that in most pastoral communities livestock are regarded as wealth and play an important role in social functions.

Effect of distance to livestock market was negative and significant ($P<0.010$). Mobility of pastoralists and livestock in search of forage and water is a major characteristic of rangelands. Lack of decision on market participation had a negative and significant effect ($P<0.0001$) on marketing of livestock and their products probably due to culture of pastoralists. Moreover, lack of market information had a negative and significant ($P<0.003$) effect on marketing of livestock and their products which agreed with Montshwe (2006) who reported a severe lack of timely and reliable information, particularly in the communal areas. Extension affected marketing of livestock and their products positively and significantly ($P<0.002$). Remittance/Miscellaneous in Sudanese pound (SDG) and experience positively but not significantly affected marketing of livestock and their products.

Table 1. Ordinary Least Square regression explaining the perception and awareness of pastoralists towards livestock marketing and products

Dependent variable	**Livestock marketing and products**			
Independent variable	**Coefficient**	**Std. Error**	**Z**	**P-Value**
Purpose of livestock keeping (Social =1, otherwise = 0)	-1464.234	864.2031	-1.69	0.091
Decision market participation (Lack=1, otherwise = 0)	-3427.024	877.7095	-3.90	0.0001
Market information (Lack=1, otherwise = 0)	-5113.586	1722.349	2.97	0.003
Extension (Getting extension=1, otherwise = 0)	5673.219	1815.325	3.13	0.002
Education (illiterate= 1, otherwise = 0)	-13.59671	54.00405	-0.25	0.801
Experience (years)	133.6455	155.7344	0.86	0.391
Distance (km)	-24.24071	9.421577	-2.57	0.010
Remittance/ Miscellaneous (SDG)	2.339931	1.520917	1.54	0.125
Constant	6220.23	1724.038	3.61	0.000

Prob > F= 0.0000; Number of obs = 407; R-squared = 0.1142; Adj R-squared = 0.0964; Root MSE = 7658.8

Conclusion

The lack of decision on market participation, distance to markets and lack of market information had a significant negative effect on marketing of livestock and their products. Livestock marketing, milk processing and increasing the efficiency of marketing channels of milk should be improved through improving access to markets and income generation.

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Ecological Intensification in "Livestock - Local Development" Interaction

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Key words: Ecological intensification, livestock, local development, rangeland management

Introduction

Livestock is on the global agenda to address nutritional issues or food security but also environmental challenges. Global governance is exploring solutions, make recommendations for sustainable livestock. Ecological intensification (Bommarco *et al.*, 2013) emerges as a key concept to redefine the animal breeding research. But how this concept can be declined at the local scale? The MOUVE project (livestock, local development and the ecological intensification movement) aimed to better understand the ecological intensification in the interaction between livestock and local development especially regarding landscape, supply chains and stakeholders' expectations. The project concerned rangeland areas where the classic intensification has had a limited impact, for bioclimatic, social and political reasons, as well as due to the nature of the zones and institutional dynamics.

Conceptual Framework

Ecological intensification acts in both the scientific and political domain to respond to agricultural challenges focused on food production and environment impact. Ecological intensification intersects with other concepts such as sustainable intensification (Garnett *et al.*, 2013), and agroecology (Francis *et al*., 2003).

"Livestock - local development" interaction was analyzed in three topics: relationship between livestock and natural resources; livestock diversity and dynamics; identities and collective actions. According to Morales & Dieguez (2009), four drivers of change were analyzed: policies at local scale, value chain strategies, collective actions affecting livestock, and family-farm dynamics. Finally, we assumed that local scale involves diverse points of view on what livestock is waited for.

Materials and Methods

Based on interdisciplinary and comparative analysis, our approach combined a set of methods to better understand the changes at the local scale, especially diverse expectations of stakeholders regarding livestock, livestock governance, collective actions, ecosystem services and future scenarios. Eight rangeland areas were selected in Europe (Alps, Pyrenees, Massif Central), Mediterranean (Morocco and South of France), West Africa (North Senegal Sahel) and South America (Pampa and Eastern Amazon). Interviewed stakeholders were breeders, traders, staff of agro-industries, staff of development, financial agencies, environmental NGO leaders, local authorities.

Results

Stakeholders' responses show four main functions of livestock at the local scale: food security for breeders, commodities for food chains and industries, local development factor, and environmental impact. However, they have different hopes and fears regarding livestock, sometimes leading to conflicts on what the future of livestock should be at the local scale. Debates mainly focus on the five following topics: intensification pathways for the livestock emblematic model, coexistence of different livestock and food models, livestock and landscape interactions, future of farming, tradition and local knowledge. The image of livestock is currently acute due to the current criticism about environmental impacts of animal breeding, especially extensive farming based on pasture. Breeders usually do not understand this criticism which contributes to depress their identity, forcing new models and strongly reducing the attractiveness of livestock for young people.

Livestock policy analysis shows the strengthening of market in the building of food safety norms in the 80s and 90s, and more recently environmental norms (which cannot avoid greenwashing cases). In Europe public norms play a key role. In South countries, big chains (notably involved into international markets) are proactive regarding environmental improvements. Regarding supply and market chains, we noticed the frequent coexistences of long chain turned on to national / international markets, focused on price competitivity and local chains, valorizing traditions, knowledge, grazing, and driven by local people. But the equilibriums between the two models are dynamics and rather complex.

Family farms dominate in rangeland areas and continue to define the future at local scale. However, the family-livestock links are becoming less strong than in the past. The changes are in the origin of holders of new investments, in the land-use, in more contracted labor, weight of livestock in farm income and multi-activity.

Three kinds of collective actions were identified: building by local leaders to adapt livestock to environmental norms (case of *Green County* in the Amazon); incentive by supply chains to better valorize livestock products; complex systems joining several governance focused on environmental challenges. Collectives actions usually have positive a footprint (Morris & Kirwan, 2011), but not necessary in the ecological way.

The analysis of farms long term trajectories shows three patterns: stable, changing from time to time (every 10 – 15 years) and labile (very sensitive notably to local market signs). The "changing" trajectory can be defined as for example conversion to organic production, but usually the change is just going with radical changes affecting farm objectives, labor force, combining of activities.

Ecosystem services (MEA, 2005) strengthen the functions of ecosystems out of forage production. A toolbox for comparative analyze of rangeland ecosystem services was built based on agro-ecological metrics and used to assess the consequences of breeders' decisions regarding grazing.

Discussion and Conclusions

Approach to define diverse expectations on livestock is relevant and was applied in other research sites. Set of methods to assess long-term dynamics was also essential to understand the combinations of drivers of change, either global or local. Ecological intensification, as a technical message holding food security and environmental trade-offs, should be though with other issues such as land-use changes, landownership, market, attractiveness of the profession, livestock policy, farming future trends etc. Global messages are somewhere rather consensual. But the pathways to the future of livestock farming can be subjects of deep conflicts or un-understandings between local stakeholders, playing as lock-in factors. Participative scenario methodologies with stakeholders can help stakeholders to research common understandings on pathways and impacts. Some complementary research could be developed to better define expectations of consumers and urban populations and to include more intensive rangeland case studies.

Acknowledgments

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Communal Farmer Perceptions on Linkages between Livestock, Rangeland Condition, Water and Well-Being in the Rural Eastern Cape, South Africa

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Key words: Livestock, rangelands, people, participatory GIS, communal farmers

Introduction

Livestock are a major contributor to the livelihoods of subsistence farmers in developing countries and have social, cultural and spiritual significance in the lives of many people (Vetter, 2013) emphasizing their role in human well-being. Most communal land used for grazing in South Africa (SA) is usually managed under communal tenure or open access where grazing lands are often poorly managed because of lack of individual responsibility, leading to degraded rangelands that are prone to soil erosion and invasion by alien and non-palatable plants (Fraser, 2004). These in turn affect other ecosystem services such as water quality provision (Mander et al., 2006). Rangeland degradation and water resource decline not only affect livestock production but the well-being of people. Thus, issues around livestock have social, economic and ecological implications, indicating a need to use a social-ecological systems approach to address them. In the past, government efforts to conserve rangeland and prevent rangeland degradation have not given much attention to communal farmer concerns, which has made these efforts less effective (Vetter, 2013). Hence, an understanding of the strong links between rangeland condition, water, and people as components of livestock management is necessary. We report on the pilot phase of a longer term study whose overall aim is to evaluate the role of urban-rural linkages associated with livestock, and to quantify their impacts on rural livelihoods and people's well-being, rangeland condition and water resource. The pilot study was conducted in order to satisfy the ethics requirement from Dundalk Institute of Technology, and presents results of the perceptions of communal farmers obtained from a combination of participatory GIS, structured interviews and focus group discussions.

Material and Methods

Pilot Study Site Description

A pilot study was conducted in Mzintshane, a village located about 15 km from King Williams Town in the Eastern Cape Province of South Africa. The area has a mean annual rainfall of ± 400 mm; temperature is 19°C and 28°C in winter and summer, respectively.

Method

A mixed-method approach was used to gain an understanding of people's perceptions of the current condition of rangelands and water resources and how these resources affect them. Participatory mapping exercises were undertaken to obtain indigenous spatial knowledge about the current and temporal changes in rangeland condition, locations of water points and changes in water quality and quantity. These were followed by face-to-face structured-interviews with 21 participants. Questions were framed around rangeland condition and management, livestock ownership; livelihoods, water and government services. Individual responses to initial questions were validated through focus group discussion with thirteen participants. Data collected from both the face-to-face interviews and focus group discussion was analysed using a thematic analysis method.

Results and Discussion

People's perceptions on rangeland condition and livestock significance

Participatory mapping established that the boundary fence for the village rangeland as well as that of the grazing camps no longer existed. Participatory mapping also showed that erosion gullies have been expanding over the past 20 to 25 years, resulting in muddy streams. Grazing quality has decreased over time as evidenced by invasion of *Vachellia karroo,* a native woody shrub which has been spreading to most parts of arable land. Taking it a step further, a thematic map from interview data was produced (Fig.1). Theme 1 showed that people place both spiritual and social significance on their livestock and rangelands, while theme 2 revealed what was viewed as obstacles to livestock and rangeland quality improvements (Fig.1).

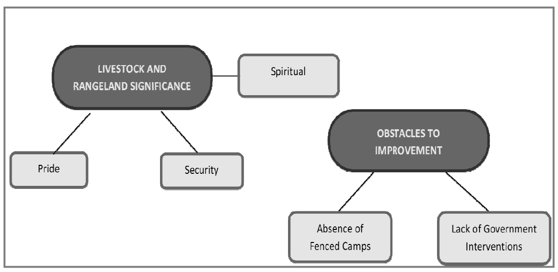

Figure 1. Interview Thematic Map

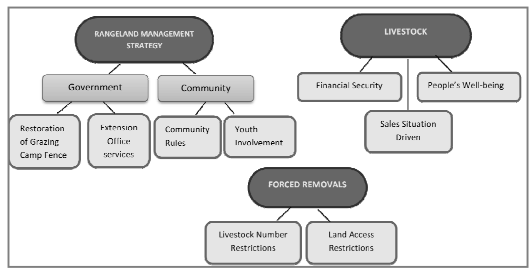

Figure 2. Focus Group Discussion Thematic Map.

Focus group discussion provided more insights as shown in the focus group thematic map (Figure 2). Although participants complained about the lack of services from the agricultural extension office, they recognised that they had a responsibility to take initiative and liaise with the Department of Agriculture. Older participants expressed concerns about their failing strength, the need for help and lack of interest in livestock matters by the village youth. The need to return to the grazing camp system which is fencing off of different parts of the rangelands into camps and then use some for either summer or winter grazing while others are rested for a season was mentioned repeatedly throughout the discussion. Participants believe that the grazing camp system would improve grazing quality and consequently animal performance, and would reduce stock theft (Figure 2). In trying to understand what happened to the boundary and camp fence, the issue of Apartheid era forced removals was brought up and the unhappiness it brought which led to vandalising of the fence. Participants were satisfied with the quality and quantity of their water, and there was no mention of muddy stream as in the participatory mapping exercise.

The results obtained from participatory mapping, interviews/questionnaires and focus group discussion are synthesized in the flow chart below (figure 3), to show how people perceive the interactions of livestock, water and land, role of human activities and effects on human well-being.

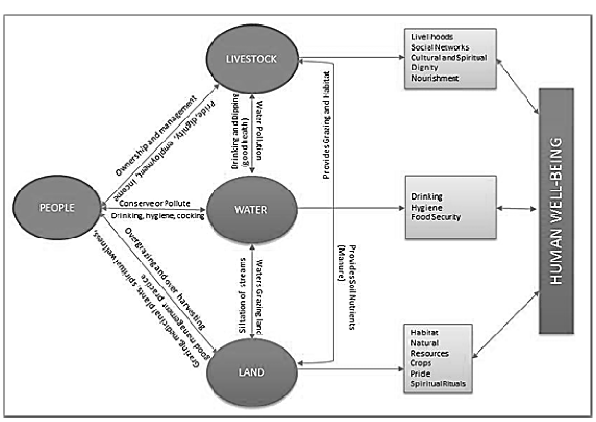

Figure 3. Diagrammatic representation of the linkages between livestock, water and land.

Conclusion and Implications

Results of the pilot study show that people are aware of the changes in grazing quality and how grazing quality has affected the quality of their livestock. The need for the restoration of grazing camps and community action shows that people know that there has to be a management system in place in order to improve the current condition. Of particular significance, is the importance placed on the spiritual and social aspect of both livestock and rangelands by the local communities.

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Eleven Years Change in Plant Presence on Mongolian: Desert and Desert Steppe Rangelands

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Key words: Time series analysis, Gobi, Mongolian rangeland, rangeland monitoring, Steppe

Introduction

Mongolia is situated in Central Asia with area comprising 1.566 thousand square kilometers. The country is located between 87º41′ and 119º56′ of east longitude, and 41º35′ and 52º09′ of north latitude. From north to south, the major ecological zones are: 1) Forest steppe in the northern border area of Mongolia, 2) Grass steppe stretching east to west in a nearly contiguous belt across Mongolia, 3) Desert (Dry) steppe forming a precipitation and productivity ecotone between grass steppe and desert, and 4) Desert or Gobi which comprises approximately 40% of Mongolia's land area (Sheehy and Damiran, 2012). The objective of this paper is to document changes to vegetation growth forms that occurred between measurements in 1997 and 2008 of Desert and Desert Steppe rangelands of Mongolia.

Materials and Methods

In 1997, 53 rangeland monitoring sites were established to investigate long-term change and condition of Desert rangeland (n=27) in GobiAltai Province and Desert Steppe rangeland in Zavhan province (n = 26). Monitoring sites in both areas were located along linear transects in winter, transitional spring and autumn, and summer rangeland pastures. Vegetation monitoring sites were measured again in 2008. At each monitoring site, vegetation cover and soil surface attributes of the site were evaluated in three clustered plots (Damiran et al., 2008; Sheehy and Damiran, 2012). Plant species presence and preference of livestock for three vegetation growth forms on the two study areas are presented in this paper (Sheehy and Damiran, 2012; Damiran, 2005).

Results and Discussion

Desert

In 1997, 253 plants comprised standing crop found at Desert monitoring sites. In 2008, 128 plants comprised standing crop, which indicated a 50 % decrease in plant presence on the study area. Winter rangeland had the most change in total plant presence (67%), and the most change in presence of graminoids, forbs and shrubs (Table 1). Summer rangeland had higher change in total plant and graminoid presence compared to transitional rangeland. Transitional rangeland had the least change in total plant, graminoid and forb presence compared to winter and summer rangeland, but the highest change in shrub presence. Among plants comprising standing crop, livestock preferred plant species declined by 41 %, desirable plant species by 39 %, and undesirable plant species by 34 % (Table 2). The substantial decline in all categories of forage plants, especially livestock preferred plants, indicated high grazing pressure by livestock.

Desert Steppe

In 1997, 339 plants comprised standing crop at Desert Steppe monitoring sites. In 2008, 282 plants comprised standing crop vegetation, which indicated a 16 % decrease in plant presence on the study area. Summer rangeland had the most change in total plant (25%) and forb presence while no change occurred in graminoid presence (Table 1).Winter and transitional rangeland had similar change in presence of total plants, graminoids and forbs. Transitional rangeland had least change in all categories of plant presence, except for shrub presence which was similar to summer rangeland. Between measurements, graminoid and forb growth forms on summer rangeland had the most decline in plant presence. Among plants comprising standing crop, preferred plants decreased 6%, desirable plants decreased 18 %, and undesirable plants decreased 16 % (Table 2). Although all preference categories of plants declined, the lower decrease in plants comprising standing crop indicated that livestock grazing pressure, while high, had less impact on vegetation of the Desert Steppe study area compared to the Desert study area.

Conclusion and Implications

At the time of measurement in 2008, total plant presence in the two study areas changed 42.2 and 21.4% for Desert and Desert Steppe zones, respectively. Although some change in plant presence can be attributed to yearly variations in annual plant presence, the majority of plants comprising vegetation growth forms are longlived perennial plants, especially graminoid and shrub plants. We think the primary causes of lower plant presence in both study areas are: 1) the increase in total number of livestock, 2) dominance of livestock herd structure by goats, and 3) increased severity and duration of drought. Our conclusion is supported by the general decline in vegetation productivity and total precipitation that occurred in the interval between measurement (Sheehy and Damiran, 2012). If current trends continue, continued degradation of Desert and Desert Steppe rangelands can be expected.

Table 1. Change (%) in plant presence between 1997 and 2008.

Seasonal Rangeland	Total Presence	Plant Growth-Form Change (%)		
		Grass	Forb	Shrub
Desert				
Winter (n=8)	-67	-60	-87	-31
Transitional (n=13)	-32	-29	-54	-10
Summer (n=6)	-43	-52	-44	-9
Desert Steppe				
Winter (n=9)	-20	-17	-23	0
Transitional (n=6)	-18	-17	-19	-17
Summer (n=9)	-25	0	-40	-12

Table 2. Change in standing crop composition of plants between 1997 and 2008.

Vegetation Zone	Interval	Forage Plant Preference		
		Preferred	Desirable	Undesirable
Desert	1997	63	93	97
	2008	37	57	34
	% Change	-41	-39	-34
Dry Steppe	1997	16	141	182
	2009	15	115	152
	% Change	-6	-18	-16

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Eleven Years Change in Plant Species Presence in Mongolian Rangelands: Forest Steppe and Steppe Zone

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Key Words: Mongolian rangeland, time series analysis, steppe, monitoring, succession

Introduction

Mongolia is situated in Central Asia with area comprising 1.566 thousand square kilometers, and rangeland 126.9 million hectare. The country is located between 87º41′ and 119º56′ of east longitude, and 41º35′ and 52º09′ of north latitude. From north to south, the major ecological zones include: 1) Forest steppe, which in the northern border area of Mongolia is classified as mixed forest and needle leaf forest, with southward extensions of Sparse Forest in the Khangai Mountains, 2) a Grass or pasture steppe (Steppe) zone that has largest area in the eastern plains but stretches in a nearly contiguous belt across Mongolia, 3) Desert steppe that includes significant areas of shrub steppe and forms a precipitation and productivity ecotone between grass steppe and desert, and 4) Desert or Gobi which comprises approximately 40% of Mongolia's land area (Sheehy and Damiran, 2012). The objective of this study is to document changes that have occurred in Mongolian Forest Steppe and Steppe zones relative to rangeland plant species presence.

Materials and Methods

In 1997, 53 rangeland monitoring sites were established to investigate long-term changes and condition of major type of rangelands (including winter, transitional spring and autumn, and summer range) of Forest Steppe (n=33; Bulnai suom in Zavkhan aimag; E98º33′, N48º55′; Elevations 1820-2250 m) and Steppe (n=14; Altanbulag suom in Tuv aimag; E106º21′, N47º30′; Elevations 1433-1600 m). Vegetation monitoring sites were remeasured in 2008. Canopy cover was measured in a rectangular frame (0.5×1 m, 0.5 m^2) on each plot by ocular estimation (Daubenmire, 1959). All vegetation within the rectangular frame was clipped at ground level. Clipped samples were separated by species, oven dried at 60°C, and weighed. Total species presence of each vegetation type was determined by summing all species accounted in each affiliated plot.

Results and Discussion

Forest Steppe

The Forest Steppe study area contained 7 distinct vegetation types (Table 1). Vegetation types in the higher elevation winter range included Larch Forest on north and west aspects, Shrub-Meadow associated with stream drainages, and Mountain Steppe on stream terraces and south and east aspects. During the 11 year interval between measurements, total plant presence at monitoring sites declined 28.3%, grass 16.1%, forbs 29.9%, and shrubs 12.8% (Table 1). In winter range, Mountain Steppe had the highest decline in total plant presence (36.5%) with graminoids having highest decline (47.2%) in plant presence. The Larch Forest vegetation type had highest decline in shrub presence (80%) while the Shrub Meadow vegetation type had highest decline in forb presence (35.6%). On transitional range, presence of total plant, graminoids, forb declined 38%, 16%, and 49%, respectively. There was no decline in shrub presence. On summer range, total plant presence declined 22.1%, graminoid presence declined 7.7%, forb presence declined 27.2%, and no change occurred in shrub presence. Among vegetation types, decline in total plant presence was high in both Shrub Steppe (36%) and Mountain Steppe (39%) vegetation types, and moderate in the Shrub Meadow (20%) vegetation type. Graminoid plant presence declined in all vegetation types except Shrub Meadow (increased 40%) while forb plant presence declined in all vegetation types except Grass Steppe (increased by 25%). There was no change in shrub presence among the four vegetation types. The overall ecological condition of Forest Steppe Zone pastureland shifted from fair to poor in the 11 year interval between surveys. Livestock number had increased from ~30,000 in 1997 to ~65,000 in 2008 for study area (Bulnai suom in Zavkhan aimag).

Steppe

On winter range, total plant presence declined 11%, graminoid presence declined 21%, forb presence declined 11%, and shrub presence increased 25%. Among vegetation types, total plant presence declined almost 35% in the Mountain Steppe vegetation type but increased 33% in the Typical Steppe vegetation type. In both vegetation types, highest change occurred in forb presence. Forb presence declined in Mountain Steppe (50%) and increased in Typical Steppe (50%). In summer range, total plant presence declined 45%, graminoid presence declined 39%, forb presence declined 48%. Among vegetation types, total plant presence had highest decline in the *Achnatherum splendens* inclusion in the Typical Steppe vegetation type. The Mountain Steppe vegetation type had no decline in graminoid presence but forb presence declined 50%. Both graminoid (57.1%) and forb (46.2%) presence had high decline in the Typical Steppe vegetation type.

Conclusion and Implications

During the 11-yr, total plant presence decline averaged by 32.8% and 24.6% for Forest Steppe and Steppe zones rangelands, respectively. While overgrazing is the main driver of change in Forest Steppe and Grass Steppe zone, increasing aridity combined with overgrazing will accelerate ecological degradation in more xeric vegetation types.

Table 1. 1997 and 2008 plant species presence in Forest Steppe and Steppe rangeland monitoring sites of Mongolia.

	Total Species		Growth Form					
			Grass		Forb		Shrub	
Year	1997	2008	1997	2008	1997	2008	1997	2008
Forest Steppe (Zavkhan aimag Bulnai soum)								
Winter Range	337	230	90	70	227	157	20	14
Larch Forest (n=3)	40	30	11	13	23	16	5	1
Shrub-Meadow (n=6)	138	99	43	38	90	58	6	6
Mountain Steppe (n=8)	159	101	36	19	114	83	9	7
Transitional Range	156	97	37	31	111	57	8	8
Mountain Steppe (n=7)	143	89	31	29	104	51	8	8
Sedge Meadow (n=1)	13	8	6	2	7	6	0	0
Summer Range	129	91	39	33	82	50	8	8
Shrub Steppe (n=3)	58	37	16	14	38	19	4	4
Stream Meadow (n=1)	20	16	5	7	14	8	1	1
Mountain Steppe (n=2)	36	22	12	7	22	13	2	2
Grass Steppe (n=2)	15	16	6	5	8	10	1	1
Steppe (Tuv aimag, Altanbulag soum)								
Winter Range	44	39	14	11	26	23	4	5
Mountain Steppe (n=2)	26	17	8	6	16	8	2	3
Typical Steppe (n=5)	18	22	6	5	10	15	2	2
Summer Range	65	36	18	11	43	22	3	3
Mountain Steppe (n=2)	25	16	5	5	18	9	2	2
Typical Steppe (n=4)	20	10	7	3	13	7	1	1

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Eleven Years Change in Ground Cover Attributes of Mongolian Rangelands

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Key Words: Canopy cover, Mongolian rangeland, monitoring, succession, time series analysis

Introduction

Mongolia is situated in Central Asia with area comprising 1.566 thousand square kilometers. The country is located between 87º41′ and 119º56′ of east longitude, and 41º35′ and 52º09′ of north latitude. From north to south, the major ecological zones include: 1) Forest steppe, which in the northern border area of Mongolia is classified as mixed forest and needle leaf forest, with southward extensions of Sparse Forest in the Khangai Mountains, 2) Grass or Pasture steppe zone that has largest area in the eastern plains but stretches in a nearly contiguous belt across Mongolia, 3) Desert steppe that includes significant areas of shrub steppe and forms a precipitation and productivity ecotone between grass steppe and desert, and 4) Desert or Gobi which comprises approximately 40% of Mongolia's land area. The objective of this paper is to describe changes that have occurred on Mongolian rangelands in 4 dominant ecological zones in terms of ground cover attributes.

Materials and Methods

In 1997, rangeland monitoring sites were established to investigate long-term changes and condition of major type of rangelands of Desert (n=27; Erdene suom in Gobi-Altai aimag; E97º18′, N44º51′; Elevations 1380-2555 m), Desert Steppe (n=26; Tsetsen-Uul suom in Zavkhan aimag; E95º45′, N48º23′; Elevations 1735-1932 m), Forest Steppe (n=33; Bulnai suom in Zavkhan aimag; E98º33′, N48º55′; Elevations 1820-2250 m) and Steppe (n=14; Altanbulag suom in Tuv aimag; E106º21′, N47º30′; Elevations 1433-1600 m). In 2008, monitoring sites were remeasured. Ground cover was measured in a rectangular frame (0.5 × 1 m) on site plots by ocular estimation (Daubenmire, 1959). Briefly, at each monitoring site, three sampling plots oriented to cardinal directions from the center of the monitoring point were used to measure cover of four site attributes. Herbaceous plant cover (%) was determined by estimating basal cover of vegetation in the plot (vegetation cover). Non-vegetative cover in the plot was determined by estimating surface cover of bare ground, litter (including herbaceous and woody; >5 mm), rock fragment (rock) >5 mm, bryophyte, lichen or other biological soil crust (cryptogam), and bedrock. However, bedrock was negligible in study sites, therefore was removed from analysis. Statistical analysis was conducted using mixed procedure of SAS (SAS Institute Inc.).

Results and Discussions

Ground coverage of sites by ecological zones are presented in Table 1.

Desert
From 1997 to 2008, surface rock and gravel, and cryptogam cover increased, while vegetation litter and vegetation basal cover decreased. The increase in cover of surface rock/gravel and the decrease in vegetation litter and cover was most apparent in Desert zone vegetation types. The negative trend in site cover was least apparent on the lower elevation transitional range. The transitional range had less grazing pressure because livestock water sources were not available during the measurement interval. In this seasonal range, vegetation litter and basal cover had improved (data not shown), especially on the lower elevation portion of transitional range dominated by Desert Steppe vegetation types.

Desert Steppe
Cover of bare ground and surface rock/gravel increased (P<0.05) on transitional ranges while vegetation litter, and cryptogams cover decreased (P<0.05). Among seasonal ranges (data not shown), high bare ground and low basal cover of vegetation on spring-fall transitional range indicated degradation was occurring. Summer range site attributes, especially bare ground caused by sand deflation, indicates that degradation is occurring as livestock grazing intensity increases on forage in the remaining rangeland. Winter range appeared to have least change in site attributes indicating degradation is not a major factor.

Steppe
Cover of bare ground increased (P<0.05) while litter and cryptogam decreased (P<0.05). Although surface rock/gravel numerically decreased (P=0.30) decreased on sites, the high cover of bare ground indicated that valley monitoring sites were being covered by wind-blown sediments. Among seasonal ranges (data not shown), changes in cover of site attributes indicated a negative trend in ecological condition of both summer and winter range. The negative trend was most apparent in the Typical Steppe vegetation type which dominates summer range, and in the Mountain Steppe vegetation type on winter range.

Forest Steppe
Cover of bare ground and surface rock/gravel increased while cryptogams and vegetation litter cover decreased (P< 0.05) on the Forest Steppe study area. Among seasonal ranges, a negative trend in ecological condition of spring-fall transition range was indicated by increased cover of bare ground and surface rock/gravel, and less cover of cryptogams, vegetation litter and basal cover. Upland vegetation types had increased bare ground cover and reduced cover of vegetation litter.

Table 1. Change in ground cover attributes of Mongolian rangeland between 1997 and 2008.

% Cover of Site Attributes	Year 1997	Year 2008	SEM	*P*-value	Year 1997	Year 2008	SEM	*P*-value
	Desert (n=27)				*Desert Steppe (n=26)*			
Bare ground	30.4	32.3	3.81	0.72	31.2	41.3	5.69	0.02
Litter	11.2	4.3	2.22	0.02	17.1	8.9	2.63	0.03
Rock	36.7	47.4	4.39	0.07	11.3	14.0	3.69	0.60
Cryptogam	0.5	1.4	0.36	0.06	10.8	2.9	1.53	<0.01
Vegetation	21.3	14.6	2.43	0.04	29.7	32.9	4.18	0.59
	Steppe (n=14)				*Forest Steppe (n=33)*			
Bare ground	29.9	54.5	3.08	<0.01	21.4	27.7	3.16	0.04
Litter	15.3	8.3	2.01	0.02	16.8	9.7	1.94	0.01
Rock	16.3	9.8	4.18	0.30	14.2	9.3	2.55	0.18
Cryptogam	7.5	0.8	0.96	<0.01	17.3	15.0	3.39	0.64
Vegetation	31.0	26.6	4.18	0.47	32.5	38.3	2.84	0.15

Conclusions and Implications

A negative trend of rangeland ecological condition in the ecological zone study areas was indicated by increased cover of bare ground, and less cover of cryptogams and vegetation litter. Overgrazing alone or aridity can affect pastureland condition; but a combination of factors has potential to exacerbate the rate at which rangeland condition changes, and the severity of the disturbance. Developing the capacity of the herders and government staff to effectively manage and monitor grazing animal use of rangeland will play a crucial role.

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Voicing Pastoralism though *Integrative* Advocacy: Experiences and Lessons Learned from Ethiopia

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Key words: Pastoralists, pastoralism, Ethiopia, advocacy, lobbying, partnership, networking

Introduction

In Ethiopia pastoralist population accounts more than 10million (total population nearly 90million) and inhabit more than half of the total landmass (FDRE HPR-PASC 2009). Almost all of pastoral inhabitants are considered rangelands. Pastoralists are endowed with huge livestock resources (42% of the total national TLU) and an indigenous knowledge system that provides them with a rich resource for optimising production in often-challenging dryland environments. The contribution of pastoralism to national GDP is estimated 9% (Rodriguez, 2008 pp21.). However despite the contribution and opportunities of pastoral livelihood systems, pastoralists have suffered from marginalization (economic, social and political) and exclusion from policy and decision-making processes.

This Paper

Our aim is to share experiences and lessons learned from advocating pastoralism and improving the voice of pastoralists in policy-making processes in Ethiopia through a specific activity and process, namely, the Ethiopian Pastoralist Day (EPD). The paper has been developed through a self- and peer-reflective process by individuals and partners who have been involved in the development of EPD over the years. Questions considered include: What is the extent to which the EPD has helped mobilise pastoralists and created a common platform for pastoralists to enable them to share experiences, both among themselves and with other stakeholders? What is the extent to which EPD has raised the profile and promoted the concern of pastoralists including through creating an enabling policy environment for pastoral development at local, regional and national levels? What have been the key successes and challenges of EPD? What are the lessons learned, including those relevant to other pastoral communities outside Ethiopia and those organisations that wish to support them?

The Birth and Development of Ethiopian Pastoralist Day

Cognizant of the age-old marginalization and exclusion, pastoral community elders and leaders from the Somali and the Oromo pastoral groups in Ethiopia and civil society organization (Pastoralist Concern Association Ethiopia, a local NGO) organized a conference in 1996 to discuss situation of pastoralists and they voiced for the first time uniqueness pastoral system and need for inclusive development. That was the birth of the EPD in 1999 and its subsequent development. EPD has now been celebrated for fifteen times since the first celebration on 25th Jan 1999. EPD is an *integrative* advocacy instrument. It is a unique process and an event that brings together almost all pastoral actors in Ethiopia for a common concern. The Day is marked in the presence of pastoralists, policy makers and dignitaries from Government of the Federal Democratic Republic of Ethiopia (FDRE). EPD has been marked to influence policy makers, media and development actors to change policy, practices and behaviour. PCAE and pastoral representatives organized the first three EPDs (1999-2001) focusing on recognition of pastoralism as a way of life and viable production system. The pastoral groups in Ethiopia are diverse in terms of identity, geographical location and the scope of problems. As a result, PFE has taken the role of spearheading EPD at national level. Since 2008, EPD has been organized jointly by the Government, the House of Peoples' Representatives Pastoralist Affairs

Standing Committee (PASC), and PFE. In our thinking, the innovative collaboration among these institutions makes EPD an *integrative* advocacy instrument.

Key Successes and Challenges of EPD

EPD mobilised pastoralists and helped create a common platform to enable them to share experiences

EPD has been celebrated in rotation at the national and regional (sub-national) levels so the pastoralists share living costumes and environment and level of development from each avenue. Thus, pastoralists coming from different localities have opportunity to discuss their respective and common issues and to present to the Government. The derogatory word (*Zelan,* local language, literally mean wanderers and lawless) has been slowly fading away and they are named *Arbetoader* (pastoralist). It was in 2008 (eight EPD) the Government of FDRE recognized EPD as a National Day. This is a milestone in the advocacy and lobby works of the PFE and partners.

EPD raised the profile and promoted concern of pastoralists and improving enabling policy environment

At each EPD, pastoralists have drawn up their own priority resolutions that have included amongst others the recognition of the uniqueness of pastoral livelihoods and requests for the establishment of pastoral oriented institutions. In terms of institutional development, the establishment of the PASC in the Federal Parliament was influenced by EPD. Most recently in 2015 a Ministry of Federal and Pastoral Development Affairs was established which is successor of MoFA; and, various regional pastoral government organs have been formed. And, subsequent national plans (e.g. poverty reduction or growth-transformation papers) have included pastoralism; and, aggregated pro-poor services (health, education, water) have been increased in triples. The challenges observed so far are low level of institutionalization of EPD as it lacks clear monitoring and evaluation system and a slow move of the EPD into the regional and/or continental levels so that pastoralists living at adjacent countries would benefit more from opportunities created by EPD.

Lessons Learned for Other Countries

Though a multi-pillar approach EPD has opened up different opportunities for influencing policy and decision-making approaches, through working with different sets of actors from national to local government, from elders to marginalised community members, and from international to local NGOs, EPD has brought together what were disparate sets of actors and developed agreement and a common voice supporting pastoralism.

Conclusions and Implications

The EPD has proved to a challenging but innovative approach to raising the voice of pastoralists and improving the profile and investment in pastoralism as a way of life, productive livelihood and land use system. EPD has brought about change in social development and inclusion of pastoral agenda in policy process. The Government of the FDRE has acknowledged EPD as a “national day” and high-level officials including the Prime Minister attend the celebration. However, some compromises and trade-offs have had to be made along the way in order to address some of the challenges faced. And though the situation for pastoralists has certainly improved there is still much to do in terms of fully recognising and supporting the full potential of pastoralists and their livelihood systems. We believe also the continental and the regional organs in Africa would consider lessons and contributions of EPD to promote regional economic integration and sustaining peace and stability in the region.

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Present State of Desert Pastures of Uzbekistan

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Key words: Types of pasture, venomous plants, productivity, seasonal use, degradation indicators.

Introduction

The total area of desert pastures in the Union of Independent States (UIS) is about 180 million hectares and is used all year round thanks to the presence of natural fodder. Natural pastures in Turkmenistan is 95%, Uzbekistan – 84% and Kazakhstan – 89% of the total agricultural land (Penjiyev, 2013).

In the countries of Central Asia, the Kyzylkum desert provides valuable forage for livestock. At the same time the Central Kyzylkum, located on the territory of the Republic of Uzbekistan, is of great importance to maintain the well-being of a million people in the desert zones and economic development of the county. Unfortunately, to date, the degree of degradation by overgrazing of the vegetation cover of the Central Kyzylkum is 35.7% (Yusupov et al., 2010).

Central Kyzylkum is an independent geobotany district, where, unfortunately, there is no data on its pastoral response. In addition, the recent increase in the number of livestock, cutting forage shrubs, various anthropogenic impacts during the construction of linear structures and geological exploration have their negative impact on the pasture ecosystems of the research area.

This paper presents the current state of pastures of the Central Kyzylkum, the characteristic of pasture types and shows indicators degradation.

Materials and Methods

Central Kyzylkum includes several remote mountains that cover the northern, southwestern and south-eastern district of Kyzylkum (Granitov, 1964) and is located within two administrative regions (Bukhara, Navoi) of Uzbekistan.

The research was conducted in the largest and most anthropogenic-dynamic territory of the Central Kyzylkum – on the massif of "Kukcha". It includes remote mountain Kokchatau, massif area – 341 521 hectares, of which 89% (304 806 ha) are pasture.

Defining pasture differences was conducted identifying the dominant plant species. Vegetation cover and forage yields were determined among pasture types by transect (10 × 2 m) and mowing areas (1 × 1 m) (Guidelines for geobotanical investigation of natural grassland in Uzbekistan, 1980).

Pasture types and difference corrected by the explication of vegetation Uzbekistan (Legend and symbols to the vegetation map of Uzbekistan, 1965).

Results and Discussion

In the vegetation cover assessment 229 species of vascular plants belonging to 144 genera and 40 families was recorded. Of these, 218 species (95%) are forage plants. The pasture flora of the area is dominated by species of the family *Chenopodiaceae*, *Asteraceae*, *Fabaceae*, *Brassicaceae*, *Boraginaceae*, *Poacea*, *Ranunculaceae*, *Lamiaceae*, *Liliaceae* and *Caryophyllaceae*. The analysis of the distribution of plant species showed that annual species were dominant followed by perennials. According to Kh.F. Shomurodov and F.O. Hasanov (2014), in the flora Kizilkum prevalence of annual taxons is an alarming indicator of the increasing anthropogenic pressure on the pasture vegetation.

Pastures of the Central Kyzylkum were distributed on sand (14%), salt marshes (6%), gravelly-loamy gray-brown soil (75%) and riparian nature-territorial complexes (5%). Mostly pastures are on gravelly-loamy gray-brown soils, which dominated by species of sagebrushes (*Artemisia turanica, A. diffusa*).

There are 8 pasture types and 12 varieties in the study area. The main type of pasture is wormwood (Mixtoartemisieta), which occupy 60% of the pasture area. Then follow Peganeta harmala (13%), Mixtocalligoneta (7%), Halocnemeta strobilacei (6%), Tamariceta varia (5%), Haloxyleta aphylli (5%), Convolvuleta hamadae (2%) and Mixtoshrub (2%) pasture types. Of those Halocnemeta strobilacei and Tamariceta varia pasture types are newly formed, since the formation of the new lake "Agitma" and the expansion of the reservoir "Shorkul" contributed to the formation of vegetation and pastures of the study area. Peganeta harmala pasture type is considered as anthropogenic transformed. This type has formed as the result of overgrazing resulting in the changing composition and structure of sagebrush pastures of the Central Kyzylkum.

Average seasonal aboveground yield (kg/ha) of the Mixtoartemisieta pasture type is – 235, Convolvuleta hamadae – 310, Mixtocalligoneta – 440, Tamariceta varia – 390, Mixtoshrubs – 330, Halocnemeta strobilacei – 52, Haloxyleta aphylli – 400, Peganeta harmala – 130 kg/ha.

According to seasonal grazing, pastures of the Central Kyzylkum can be divided 5 groups: year-round (48%), spring (2%), spring-summer (1%), autumn-winter (32%) and unsuitable pastures for grazing (17%). Among them are prevail year-round grazing pastures (Mixtocalligoneta and Mixtoartemisieta pasture types). Unsuitable pastures differ by the uneven distribution of seasonal eaten features of forage plants, as well as an abundance of uneaten and venomous plants.

The numbers of annual plants and abundance venomous plants in the flora are indicators of pasture degradation in the study area. Analyses of the flora show, that in the study area, annual plants may occupy 55% of composition of plant communities on degraded sites, besides the pasture types which formed under the influence of anthropogenic factors.

Pastures in the study area are dominated by the following annuals: *Strigosella grandiflora, Astragalus campylotrichus, Eremopyrum buonapartis, Alyssum desertorum, Koelpinia linearis, Ziziphota tenuior, Salsola sclerantha, Ceratocarpus utriculosus, Girgensohnia oppositiflora, Climacoptera lanata* et al. Plant group, which in their composition abundantly found venomous plant species (*Peganum harmala*, *Goebelia pachycarpa, Haplophyllum bungei*, *Ceratocephalus testiculatus, Phlomoides eriocalyx)* are occupy 14% of the pasture area and are degraded pastures.

Conclusions and Implications

There are registered of 8 pasture types and 12 varieties in the Central Kyzylkum. The main type of pasture is sagebrushes (*Artemisia turanica, A. diffusa*) which occupy 60% of the pasture area. The share of forage plants is high (95%) in the flora of the study area. The 67% of the areas correspond to the share of pastures which are using year-round, and it is typical for the desert pastures of Central Asia.

In Central Kyzylkum newly formed and transformed pasture types and differences is occupy 25% of pastures. The Halocnemeta strobilacei and Tamariceta varia pasture types in the salt marshes are considered as new formed pastures or new map-units, which are not registered in the reference map of the study area in 1995 year. Violation of the soil hydrological regime after the appearance of the reservoir "Shurkul" and collector lake "Agitma" contributed to the formation of new pasture types.

As a result of overgrazing and man-made effects are observed the transformation of the sagebrush pastures, are especially formation of *Peganum harmala* – Peganeta harmala pasture type. Pasture type formed near the village, the well and paddock, where the soil structure is deteriorating due to the continuous compression of the hooves of farm animals. The appearance of the venomous plant *Peganum harmala* is an indicator of the watering presence and absolute digression of pasture.

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Anthropogenic Exploitation of Grazing Lands in the Eastern Ghats of India

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Key words: Ecosystem, grasses, burning, degradation.

Introduction

Grasslands are a major part of the global ecosystem, covering 40% of the earth's terrestrial area (Blair *et al*. 2014). In India, nearly 34% of the land area comes under grazing lands. Today, there is a growing evidence of grazing land degradation throughout the world. Approximately half of these grazing lands have become degraded due to various human activities. The present study reviews the prior work of the authors and those of other ecologists to give a clear picture about the present status of grazing lands in the Eastern Ghats if India. Frequent burning and over grazing are the two major contributors in desertification of these grazing lands (Manoharan & Paliwal., 1996., Paliwal & Manoharan., 1996).

Materials and Methods

After a through survey, twelve sites were selected based on different geographical location and altitudes. In all the sites, data for floristic composition and biomass were obtained at monthly. Biomass estimation was based on the methods of Milner and Huges (1968). Soil samples from all the sites were also collected on each sampling date from three depths (0-10, 10-20, 20-30 cm) and analyzed for moisture gravimetrically, texture using sieve method and nutrients using Auto analyzer and Atomic absorption spectrophotometer.

Vegetation & Data analysis

The system transfer function was calculated using the compartment values following Singh and Yadava (1974). Sample variables and "t" test were applied to evaluate the burning and grazing effects. Mostly all grass species present in this region are c_4 types. Selection of the species in response to the environment and imposed stresses is one of the outstanding features of succession.

Burning effect

It is common practice for herders to burn the grasslands in this region in February when plants are dry. This increases palatable, fleshy, nutrient rich young sprouts for their cattle population. In the burned sites,the percentage of soil moisture and clay are decreased and there is nutrient loss due to soil erosion and vegetation loss (Manoharan & Paliwal 1996). Nutrients, biomass, soil moisture and clay are the major controlling factors of productivity in this grazing land ecosystem. If any of these factors are affected negatively, it will cause damage to this ecosystem under typical grazing pressure. Present observation clearly indicate that fire in this region is helpful to the herders but not to the ecosystem.

Grazing effect

Grazing lands in this region are not enough to meet the needs of the cattle population. So over grazing is common in this region which leads to vegetation loss, moisture loss, soil erosion and nutrient loss in this region which leads to land degradation (Paliwal & Manoharan, 1996). Schematic representation of grazing land ecosystem model shows the ecological status of the grazing lands in the Eastern Ghats of India (Fig.1). Too frequent burning together with over grazing degraded the grazing lands in the Eastern Ghats of India. Moderate grazing and controlled burning is recommended to maintain this fragile ecosystem in this region.

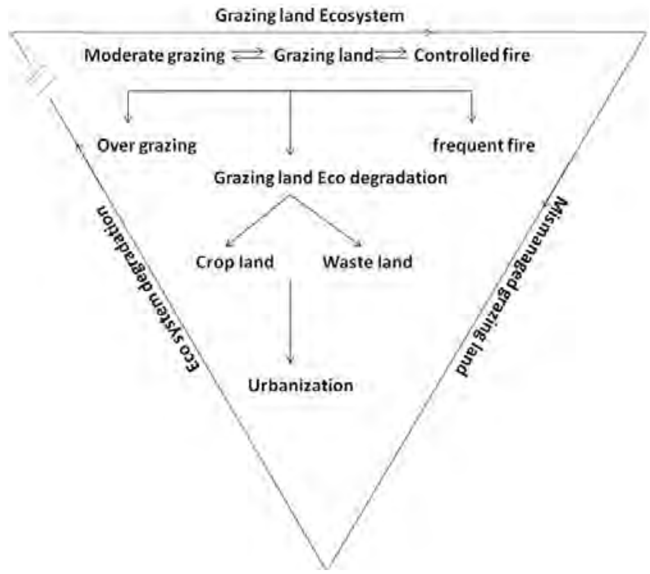

Figure 1. Schematic representation of grazing land ecosystem model in the Eastern Ghats, India.

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Influences of Institutional Designs on Social Outcomes of Community-Based Rangeland Management in Mongolia

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Key words: Institutional design, social outcomes, Mongolia.

Introduction

Rural poverty and resource degradation have been the two major problems facing post-socialist Mongolia. The mixed results of Community-based rangeland management (CBRM), which was promoted to address these problems, prompted us to investigate factors influencing CBRM success. In 2007, 14 external donor programs facilitated over 2000 herder groups. This study sampled groups supported by four agencies: United Nations Development Programme (UNDP), New Zealand Nature Institute (NZNI), Swiss Development Agency (SDC) and Wildlife Conservation Society (WCS). The different membership approach, program focus and, possibly, other variations in facilitation may have shaped institutional designs of CBRM. This motivated us to test the effect of group types or donor facilitation approaches on CBRM group institutional design. We addressed the two research questions: (1) does group type or donor facilitation approach influence the institutional design of CBRM? and (2) which institutional design elements most influence social outcomes for Mongolian pastoral groups?

Methods

We sampled 77 CBRM groups and 392 member households supported in Mongolia. Our sample included 36 herder groups, 33 pasture user groups (PUGs), and eight nukhurluls (groups supported by NZNI).

Our data included household interviews and organization profile questionnaires. Household interviews measured household demographics, livelihoods, rangeland management practices, norms, behaviors, and social networks. The organization profile represented an initial synthesis of qualitative interview and focus group data about group characteristics, organizational management, social capital, and leadership.

The group type was an independent categorical variable including herder groups, PUGs, and nukhurluls. We had three sets of institutional design variables (Agrawal, 2002): group attributes, institutional arrangements, and external environment (Table 1). Institutional design variables were dependent for ANOVA test (Table 1) but functioned as independent in multiple regressions (Tables 2 and 3) influencing social outcomes.

Intermediate and ultimate social outcomes commonly measured for the performance of community-based resource institutions (Agrawal, 2002; Fernandez-Gimenez et al., 2014; Leisher et al., 2012) were dependent variables. Six intermediate outcome variables included information diversity, leadership, knowledge exchange, the presence of rules, income diversity and cooperation. Six ultimate social outcomes included household assets, cognitive social capital (trust and norms of reciprocity), structural social capital (the presence of social ties), rangeland practices (traditional and innovative types) and proactive behavior (members' engagement in rangeland issues).

Results and Discussion

Comparison of institutional designs by group types

Four group attributes varied significantly among the group types (Table 1): group size, group experience, and group diversity. Institutional arrangements did not differ by group types except document records. The group types significantly differed in external environment variables including access to training, ongoing donor support, and market integration. Herder groups had significantly greater access to training and market integration than PUGs. PUGs were larger and had more donor support than herder groups.

Effect of institutional designs on intermediate social outcomes
Group attributes had significant positive effects on all intermediate outcomes while three variables had a negative influence (Table 2). Among them, group size, heterogeneity of well-being and homogeneity of interests significantly influenced three intermediate outcomes each. However, institutional arrangement variables had a limited effect: influenced rules, cooperation and information diversity. The presence of sanctions had a consistent positive effect on these outcomes. The external environment significantly influenced four intermediate outcomes including rules, information diversity, cooperation and leadership. Access to training had a strong positive effect on these outcomes.

Effect of institutional designs on ultimate social outcomes
Group attributes significantly affected all ultimate social outcomes except structural social capital (Table 3). Among them, three were most influential: dependence on livestock, homogeneity of interests, and leader legitimacy. Institutional arrangements had a significant effect on two ultimate social outcomes: structural social capital and innovative rangeland practices. Leader meeting was the most influential variable increasing the levels of five outcomes. External environment significantly influenced four ultimate social outcomes including both types of social capital, innovative practices, and proactiveness. Local government support had a strong positive effect on these outcomes.

We found that group attributes and their external environments were associated with donor approach. However, donor approach did not influence institutional arrangements. A prevailing dichotomy was shown between herder groups and PUGs in institutional designs. Herder group had more of the attributes theorized to promote successful outcomes in commons institutions, such as smaller group size, longer cooperation experience, heterogeneity of well-being, and homogenous interests of the members. Herder groups also had greater access to training and markets. In contrast, PUGs had only two positive features to group outcomes: maintaining good documentation and available external assistance.

Intermediate outcomes: Our study supported that small group size, homogeneous interests, and heterogeneity of well-being can predict higher levels of intermediate social outcomes. Institutional arrangements such as the presence of sanctions, group-devised rules, frequent leader meetings, and recording documents increased cooperation, agreed rules, and information diversity. Access to training and local government support provided a favorable external environment for these three intermediate outcomes as well as leadership.

Ultimate social outcomes: Group characteristics such as dependence on livestock, homogeneity of interests and leader's legitimacy were critical for increased social capital, livelihood and rangeland practices and proactive behavior of members. From institutional arrangement variables, leader meeting frequency was the most influential for ultimate social outcomes. Among external environment variables, local government support and ongoing donor support increased trust and norms of reciprocity, rangeland management practices, proactiveness, and herd size.

We also found that group attributes and external environment were more influential determinants of social outcomes than institutional arrangements. Along with these theoretically supported outcomes, we found results that contradict theoretical expectations. These included the negative effect of group size, experience and heterogeneity of well-being on knowledge exchange. Also meeting attendance and cooperation with outside agents negatively influenced the presence of rules. We suspect that most of these negative influences may be associated with group size.

Table 1. Results of Comparisons of Institutional Design Variables by Group Types: Herder Groups (n=36), Pasture User Groups (PUGs, n=36) and Nukhurluls (n=8).

	Institutional design variables	Sample mean	Sample range	Herder groups[a] *M*	Herder groups[a] *SD*	PUGs[b] *M*	PUGs[b] *SD*	Nukhurluls[c] *M*	Nukhurluls[c] *SD*	*F*	η^2[e]
Group attributes	Group size	89	8-482	44	32	156	100	55	47	21.32***	.38
	Group experience	5	0-14	5	3	3	2	9	4	16.07***	.30
	Leaders' legitimacy[d]	3.3	2-4	3.41	.61	3.17	.69	3.36	.63	1.26	.03
	Heterogeneity of well-being	.47	0-.73	.40	.26	.58	.10	.39	.23	6.44***	.16
	Homogeneity of interests	1.62	.5-2.0	1.75	.29	1.49	.40	1.56	.28	5.20***	.12
	Poverty level	.11	0-.94	.11	.11	.13	.16	.09	.07	.23	.01
	Dependence on livestock	.65	.18-.91	.61	.18	.70	.11	.64	.10	2.61	.07
Institutional arrangements	Ease of rules	2.57	1-3	2.68	.48	2.50	.64	2.29	.76	1.64	.05
	Awareness of rules	3.31	1-5	3.50	1.14	3.03	1.12	3.57	1.13	1.54	.04
	Group-devised rules	1.61	1-3	1.72	.81	1.44	.76	2.00	.89	1.77	.05
	Quality of rules	2.96	0-4	3.06	1.11	2.84	1.44	3.00	.63	.26	.01
	Presence of sanction	.50	0-1	.54	.51	.50	.51	.29	.49	.76	.02
	Leaders' meeting	3.18	1-8	2.80	2.03	3.76	1.92	2.71	2.14	2.05	.06
	Members' meeting	3.41	1-7	3.03	1.81	3.93	1.70	3.14	2.04	2.19	.06
	Meeting attendance	2.38	1-3	2.50	.66	2.21	.63	2.43	.79	1.51	.04
	Transparency	4.33	1-5	4.24	.74	4.42	1.12	4.43	.54	.37	.01
	Document records	8	0-15	6	4	9	4	9	3	7.60***	.18
External environment	Access to training	1.99	0-3	2.39	.87	1.55	1.15	2.00	1.31	5.61***	.13
	Local government support	1.31	.2-2.6	1.36	.59	1.27	.53	1.28	.44	.24	.01
	External cooperation	1.38	0-3.	1.39	.73	1.38	.71	1.38	.92	0	0
	Ongoing donor support	.72	0-2	.44	.76	1.07	.79	.50	.84	5.34***	.14
	Market integration	107	20-230	82	28	137	56	93	69	11.79***	.24

[a] Groups supported by the United Nations Development Programme, [b] Pasture User Groups supported by the Swiss Development Agency, [c] Groups supported by the New Zealand Nature Institute and Wildlife Conservation Society, [d] Variable was coded as follows: 1 = Not accepted at all, 2 = Little acceptance, 3 = Majority acceptance, 4 = Openly accepted. [e] Eta squared is the proportion of variation in *Y* that is associated with membership of the different groups defined by *X*. An effect size can be small (η^2=.01), medium (η^2=.06) and large (η^2=.14) (Cohen, 1988).

*, ** and *** significant at 0.10, 0.05 and 0.01, respectively.

Table 2. Results of Multiple Regressions of Institutional Design Variables on Intermediate Social Outcomes.

Dependent variables Independent variables	Rules	Cooperation	Information diversity	Knowledge exchange	Income diversity	Leadership
Group attributes						
Group size	.38***	.21*	-.01	-.04	-.33**	.04
Group experience	.14	.18	-.13	-.45***	.24*	-.22*
Leaders' legitimacy	-.07	.23**	.11	.23**	.14	.14
Heterogeneity of well-	.04	.25*	-.18	-.42***	.22	-.13
being	.23*	.29**	.35***	-.01	-.12	.36***
Homogeneity of interests	.25*	-.07	.17	-.02	.07	.01
Poverty level	0	.15	.09	.09	-.15	.13
Dependence on livestock	.22/2.26**	.30/3.40***	.21/2.20**	.29/3.39***	.24/2.59**	.23/2.48**
R^2, and F						
Institutional						
arrangements	-.07	.13	.23	.01	-.29**	.05
Ease of rules	.08	.03	-.21	.05	-.07	-.11
Awareness of rules	-.14	-.10	.18	.19	.39**	.26*
Group-devised rules	.13	-.13	-.14	-.02	-.03	-.07
Quality of rules	.30**	.45***	.32*	-.20	.07	.03
Presence of sanction	.20	.32*	.38*	.21	.07	.34
Leaders' meeting	-.15	-.16	-.40**	-.08	-.19	-.13
Members' meeting	-.33**	.02	.08	.06	.15	-.04
Meeting attendance	-.16	-.30*	.16	.06	-.04	.10
Transparency	.39***	.35**	.03	-.02	.06	-.03
Document records	.54/5.03***	.43/3.25***	.31/1.89*	.11/.52	.25/1.43	.17/.86
R^2, and F						
External environment						
Access to training	.46***	.42***	.25*	-.09	-.05	.05
Local government	.18	.12	.18	.31**	.01	.37***
support	-.29**	-.15	.05	.12	-.09	0
External cooperation	.37***	.16	.14	-.04	.06	-.08
Ongoing donor support	.07	-.12	-.23	.08	-.32*	.05
Donor approach	-.01	.11	.05	.08	.16	.19
Market integration	.36/5.59***	.23/2.98**	.21/2.63**	.16/1.85	.07/.77	.20/2.45**
R^2, and F						

*, ** and *** significant at 0.10, 0.05 and 0.01 respectively

Table 3. Results of Multiple Regressions of Institutional Design Variables on Ultimate Social Outcomes.

Dependent variables / Independent variables	Assets	Cash income	Herd size	Social capital: cognitive	Social capital: structural	Rangeland practices: traditional	Rangeland practices: innovative	Proactive behavior
Group attributes								
Group size	-.33**	.01	-.16	.12	.15	-.14	-.23*	-.10
Group experience	.15	.22	-.26**	-.05	.02	-.10	.18	-.08
Leaders' legitimacy	.15	.11	.22*	.19*	.04	.36***	.20	.32**
Heterogeneity of well-being	.04	-.06	0	-.21*	-.10	-.18	-.02	-.01
Homogeneity of interests	-.06	-.09	-.24*	.37***	.31**	-.07	.08	.24*
Poverty level	.06	-.18	-.19	-.24**	-.17	.07	.01	.05
Dependence on livestock	.33**	.25*	.33***	-.36***	.07	.26*	.28**	.21
R^2, and F	.19/1.91*	.22/2.32**	.31/3.73***	.40/5.44***	.17/1.63	.22/2.27**	.21/2.17**	.23/2.48**
Institutional arrangements								
Ease of rules	.29*	.10	-.05	-.0	.06	.07	.40***	-.01
Awareness of rules	-.09	-.11	-.18	.09	.06	-.03	-.22	.06
Group-devised rules	.01	-.05	-.13	.09	.35**	.12	.23	.04
Quality of rules	-.37*	.01	-.05	.08	-.15	-.31	-.44**	-.09
Presence of sanction	.23	-.08	-.11	-.17	.08	.19	.44**	.16
Leaders' meeting	.47**	-.14	-.08	.01	.42**	.41*	.40**	.39*
Members' meeting	-.28	.21	.21	-.02	-.15	-.24	-.37**	-.43**
Meeting attendance	-.01	-.20	-.08	.30*	-.21	.01	.10	.15
Transparency	-.08	.27	.06	.26	-.02	.01	-.33**	-.07
Document records	-.20	-.15	-.04	.04	-.01	-.03	-.13	.12
R^2, and F	.16/.83	.18/.94	.17/.88	.22/1.22	.30/1.79*	.14/.69	.36/2.38**	.20/1.10
External environment								
Access to training	-.15	-.04	-.12	-.18	.26*	-.14	.05	.12
Local government support	.02	-0.3	-.17	.41***	.21	.28**	.14	.36***
External cooperation	-.05	.21	.09	.01	-.04	.13	-.20*	-.03
Ongoing donor support	.15	-.04	.29**	-.13	-.23*	.14	.25*	-.05
Donor approach	-.34**	-.20	-.10	-.14	.20	-.24	-.49***	-.20
Market integration	-.18	0.22	0.04	.12	-.21	-.02	-.10	.24*
R^2, and F	.14/1.65	.09/1.01	.13/1.44	.27/3.60*	.18/2.05*	.15/1.77	.29/4.06***	.25/3.22***

*, ** and *** significant at 0.10, 0.05 and 0.01 respectively.

Conclusions and Implications

The design principle sets for group characteristics and external environment were shown to be applicable for predicting social outcomes of Mongolian pastoral institutions. Methodologically, two design variables, including market integration and heterogeneity of endowments, needed to be contextually specific to Mongolia. Practically, the results provided a potential solution to the current disputes over the appropriate size of CBRM groups in Mongolia. The study demonstrated that for the majority of social outcomes, traditional small groups were more effective, while for cooperation and setting rules, large groups sizes were appropriate. Hence, CBRM facilitation should start from small groups eventually leading to a nested structure of CBRM.

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Mediating and Moderating Factors for Positive Social Outcomes of Community-Based Rangeland Management in Mongolia

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Key words: Community-based management, pastoralism, Mongolia, social outcomes

Introduction

Several studies of Community-based rangeland management (CBRM) in Mongolia have revealed improved livelihoods, better resource condition and increased adaptive capacity (Leisher, 2012). In contrast, others showed CBRM to be ineffective and potentially exclusionary (Upton, 2008). However, research on the relationships between factors that may explain mixed outcomes of CBRM has been limited. To address this gap, we examined how and why CBRM increases social outcomes and if the group's ecological zone influences this relationship. We advanced three hypotheses:

(1) The effect of formal organization on social outcomes is mediated by intermediate variables including access to diverse information sources, leadership, knowledge exchange, and the presence of rules.
(2) The ecological zone moderates the mediated effect of formal organization on social outcomes.
In this study, pastoral groups sharing resources in the same area and organized into groups under external donor support are defined as formal CBRM groups. They had agreed-upon rules to manage rangeland resources, in contrast to informal non-CBRM groups practicing customary norms for resource use.

Methods

We sampled 142 pastoral groups and 706 member households in four ecological zones including desert steppe, steppe, eastern steppe and mountain and forest steppe. Adjacent counties (*N*=36) were paired with (*N*=77) and without (*N*=65) CBRM groups in 10 provinces. We collected data using household interviews and organization profile questionnaires. Household interviews measured household demographics, livelihoods, rangeland management practices, norms, behaviors, and social networks. The organization profiles represented an initial synthesis of the field data about each group's characteristics, organizational management, social capital, and leadership.

Variables

The independent variables were organization status and ecological zone. The organization status was coded as either "no formal organization" (non-CBRM) or "formal organization" (CBRM)." Ecological zone included four categories mentioned earlier. Ultimate social outcomes were dependent variables, which measured household assets, cognitive and structural social capital, rangeland practices, and proactive behavior. Intermediate outcome variables were dependent on organization status and ecological zone but functioned as independent for ultimate social outcomes. Intermediate outcomes included information diversity, perceptions about local leadership, reported knowledge exchange within and outside of the group, and the presence of rules for rangeland management.

Analysis

We used a regression-based conditional process analysis (Hayes, 2013) to test a moderated mediation effect of organization status on ultimate social outcomes. This is a causal model where a mediator links a cause and an effect, and explains "why" and "how" this causal process occurs (Wu and Zumbo, 2008). A moderator modifies this causal effect and clarifies "when" or "for whom" independent variable most strongly causes dependent variable (Wu and Zumbo, 2008). We used a serial-multiple mediator model of the path analysis using bias-corrected bootstrap confidence intervals. For the moderation test, we used a model that treated four mediators as parallel controlling combined indirect effects on social outcomes. To define causal relationships between the four intermediate variables, we conducted multiple regressions controlling organization status and ecological zone.

Results and Discussions

We found a significant interdependence of four mediators except the relationship between leadership and the presence of rules. Information diversity significantly affected leadership, rules and knowledge exchange. Leadership had a significant effect on information diversity and knowledge exchange. Knowledge exchange had a significant positive effect on information diversity and leadership and a negative effect on rules. Rules significantly influenced information diversity but had a significant negative effect on knowledge exchange. We found a significant total indirect effect of organization status on four ultimate social outcomes: traditional and innovative rangeland practices, proactive behavior and structural social capital.

We also examined which mediators were more influential for transferring the effect of formal organization onto social outcomes. These indirect effects were channeled through information diversity path alone onto traditional practices, innovative practices, proactive behavior and assets. Information diversity and leadership together transferred the organization effect onto traditional practices, proactiveness and structural social capital and cognitive social capital. Figure 1 shows these two influential paths.

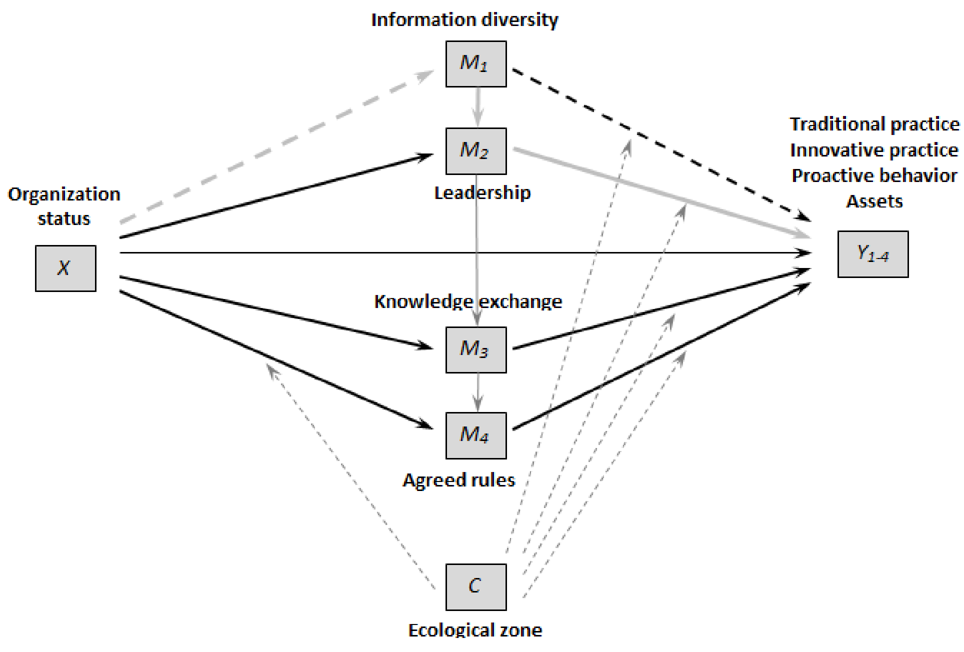

Figure 1. The mediated effect of organization status is depicted on four ultimate social outcomes through serial-mediators: bold lines represent a variable's effect on other variables and arrows show the direction of the effect. Ecological zone moderates the combined effect of mediators ($M_{1\text{-}4}$) and organization status (X) on ultimate social outcomes ($Y_{1\text{-}4}$) shown by dashed grey lines. Information diversity alone (thick dashed lines) was the most influential path, and the second influential was the path through information diversity and leadership (thick grey lines).

Ecological zone significantly moderated two ultimate social outcomes with the significant mediation effect at *p*<.05 (Figure 2). Desert steppe ecological zone had a significant positive moderation of the indirect organization effect on proactive behavior through agreed rules. However, the steppe zone had a significant negative moderation of the same path. Eastern steppe also had a significant negative moderation on structural social capital through leadership.

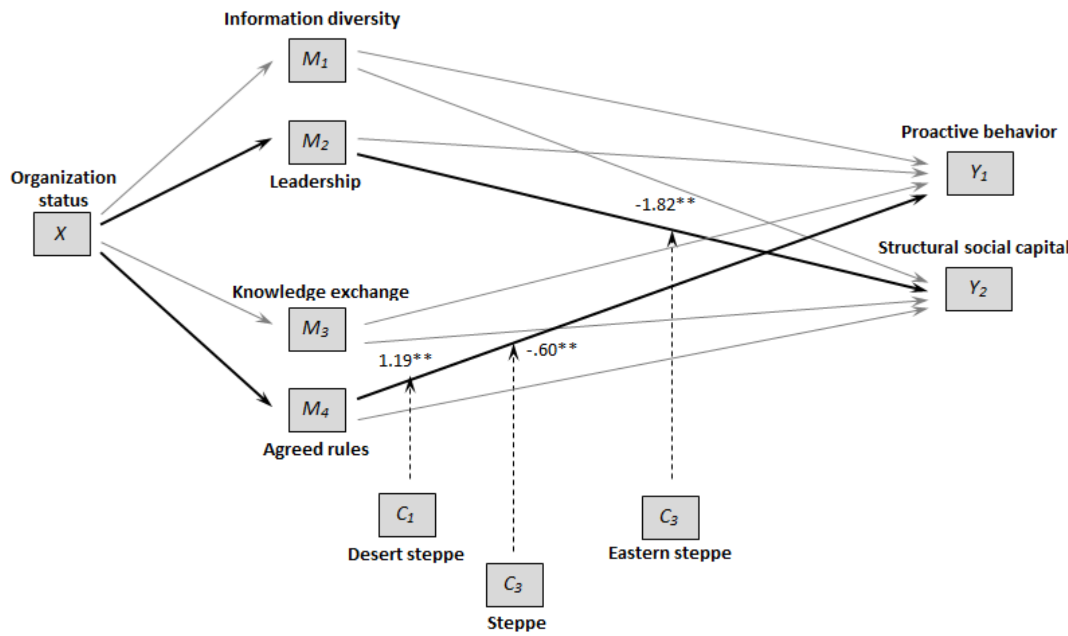

Figure 2. Significant conditional indirect effect of the organization status on two ultimate social outcomes through four mediators is shown by bold lines. Desert steppe had a significantly positive moderation (dashed line) of the indirect effect of the organization status on proactive behavior of members through rules. Eastern steppe and steppe zones had a negative conditional indirect effect (dashed line) on proactive behavior and structural social capital through leadership and rules respectively. Unstandardized coefficients are shown at *p*<.05 (**).

The results partially supported our hypothesis about the mediation effect of intermediate variables. The effect was found on four of six ultimate social outcomes. The most influential mediators were information diversity and information diversity together with leadership. We found significant relationships among the four mediators. The results revealed a sequential order of these factors, where better access to information triggered an increase in subsequent variables including leadership, knowledge exchange and the presence of rules. Lastly, the significant moderation of ecological zone partially supported the second hypothesis affecting only two social outcomes. The desert ecological zone has a positive moderation effect on the effect path to proactive behavior through agreed rules. The same path was negatively moderated by the steppe zone. We also found that the path to structural social capital through leadership was less effective for eastern steppe CBRM.

The results were consistent with our prior findings that formal organization had a stronger effect on proactive behaviors and rangeland management practices than on other social outcomes. The fact that the mediation of information diversity alone was powerful in increasing traditional and innovative practices is worth noting. It may imply that adequate education and training is the key for herders to revive proven traditional practices and introduce new adaptive methods for rangeland management.

Conclusions and Implications

The study has theoretical, practical and methodological implications. The results partially confirm that the formal organization of resource users increases their social outcomes. These outcomes are theorized to be essential to long-enduring successful commons institutions (Ostrom, 1990). In the Mongolian context, such outcomes included herders' traditional rangeland management practices, management innovations, and herders' pro-activeness in addressing rangeland- related issues. The study contributes to commons theory by examining underlying mechanisms through which formal organizations affect social outcomes. It showed that formal organization of herders could achieve social outcomes given their access to information, increased leadership, knowledge exchange and resource management rules.

Our findings showed differences among ecological zones, potentially associated with their resource characteristics. However, in contrast to predictions, we observed more proactive behavior and social networking among desert steppe CBRM members. Further, more proactive behavior and social networking among herders in the harsher desert steppe environment were in line with our prior findings of higher levels of reciprocal norms and mutual assistance in the desert steppe groups. Overall, our findings suggest that the mixed conclusions about CBRM reported by past studies may be explained in part by failure to consider mediating and moderating factors and the sequential order of intermediate variables during the CBRM implementation.

Two major policy implications emerge from this study. First, policy for CBRM development should prioritize information and training to herders. Second, policy should aim to provide organized groups with mediating factors including information access, knowledge exchange, leadership and rules for resource use to support proactive behaviors and management practices thought to benefit resource conditions. Methodologically, the conditional process analysis provided a powerful tool to test underlying mechanisms for achieving CBRM social outcomes. Finally, our study highlights the need for further research to elucidate why rules have a negative effect on social outcomes, how rules were negotiated, and the specific content of resource use rules.

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Pastures Need People to Manage Them

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Key words: Impacts, small farmers, management, conservation

Introduction

Starting with the premise that small farmers in Alto Camaquã — as long as there is a human/nature symbiosiswould favor conservation of the ecosystems in which they participate, and that such a characteristic could support a strategy of rural development with national vision, a group of researchers at Embrapa South Livestock developed, along with family cattle owners, a methodology of intervention aimed at the valuing natural resources, product differentiation, and social organization. Based on participatory research methodologies and network organization, a collective of Participatory Experimental Units was established. These units, PEUs, or UEPAs as they are known in Portuguese, are productive units in which, starting with a process of reflection/action, knowledge about the processes of ecosystem function, and strategies of resource management, especially natural grasslands, are constructed. In these PEUs, in partnership with farmers and their associations, various practices of rational and sustainable management of the farms' available resources were introduced. This implied a redesign of the production systems. The effects of the tasks in the PEUs were experienced by all the farmers, all of whom belonged to local community associations. In this article, we will present a report about the study of the economic, social and environmental benefits brought about by the implementation of the described intervention methodology.

Materials and Methods

For the evaluation of the impact, we conducted interviews with the family members of small farmers, with a time span of three years starting from the initial intervention by the research group. The evaluation methodology normally implemented by Embrapa throughout Brazil was followed. This methodology takes into consideration different indicators, while considering the point of view of the interviewees as paramount. At the same time, this methodology entails direct observation on the small farmers' properties, focusing on the fundamental elements of their production systems, not only on pastures or the animals.

Results and Discussion

Among the results that need to be highlighted is the collective construction of the idea of lasting cattle farming as that which supports itself on natural resources and promotes "conservation in use" of resources. In this context, the importance of the handler comes into play, who determines the utilization of available resources through management strategies, starting with carrying out the production process in a conscientious fashion, and becoming strategic in natural resource management (Borba, 2009). The tools used include the monitoring of climatic variables (daily minimum and maximum temperatures, precipitation), growth (control of biomass accumulation), and availability of natural pastures (Embrapa Pecuária Sul, 2011).

An analysis of the results shows that there were economic benefits in the region, calculated at R$3,267,997.50 between 2009 and 2014 (around US$830 thousand)--a positive result for the farmers, given that it allowed an important increase in business revenue. Moreover, there was a change in mentality among the small ranchers in the manner in which they think about natural resources, which prompted them to implement modifications in field management related to cattle grazing, create changes in the business infrastructure, and to be concerned systematically with the subdivision of areas, stocking rate control, and streamlining of animal health management. At the same time, a more systematic inclusion of these small ranchers in the improvement of administrative and commercialization aspects of their products was established. It was verified that they have maintained not only daily registers about variables at their farms, such as temperature and precipitation, but also, in some cases, they have advanced to accounting registers, like those that show production costs and sale of the products on the market. This fact can be seen as having important social impact, in that it improves the management capability of those small producers as a group.

The modifications in cattle grazing field management (subdivision of area, animal capacity corresponding to forage supply, deferred rotation) provide important environmental benefits, such as moderated recuperation of degraded soil and the improvement of the vegetation structure and associated biodiversity in the Pampa biome, the biome where Alto Camaquã is found. The interviewees consulted during the fieldwork highlighted that an essential benefit was brought about by the use of field and animal management on their properties. This can be corroborated in the regional land through maintenance of natural grasslands areas. Most of this land, without intervention of researchers and small cattle farmers, would be planted with soy at this point. Soy farming has expanded significantly in the past five years in areas traditionally occupied by ranching, in large part by land leasing. This is a result of the increase in price of this commodity in the international market.

Conclusion

The intervention by a group of researchers from Embrapa South Livestock in areas of small cattle farming, who are not yet touched by the modernization process in Brazilian agriculture, consisted of a participatory pedagogy that provided recognition and appreciation of family ranching as an activity that preserves the ecosystem in which the farm is found. The study results indicate that modifications to the grazing management of natural pastures in the family ranches of Alto Camaquã, RS, transformed the small ranchers into skilled pasture managers, according to Borba & Trindade (2009). In social and economic terms, it was observed that farmers improved their ability to market their products (beef and sheep meat) by aggregating their marketing efforts –consequently also giving them new access to the larger regional market which allowed them to increase income. And, finally, in environmental terms, the maintenance of natural pasture areas and the improvement in its biodiversity are noteworthy.

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A Critical Assessment of Regulatory/Policy Framework for Nomadic Livestock in West Africa

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Key words: Nomadic, policy, West Africa, regulatory

Introduction

Over the years, the contribution of livestock production has been very evident as it reveals various forms of socio-cultural, economic and health significance such as employment creation, serving as a source of food, income, foreign exchange, etc. AU/IBAR & UN OCHA-PCI, (2007) postulates that the contribution of the livestock sector to agricultural GDP within West Africa, ranges from 5 percent to 44 percent depending on the country. The livestock sector also provides employment for about 50 percent of the economically active population. As suggested by Chauveau (2006) Africa remains the continent with the largest land area dedicated to pastoral land use, of about 40% of land mass, and the largest percentage of the population dedicated to pastoralism. Paradoxically however, developing trajectories regarding nomadic livestock within the West African sub-region have revealed major border and migration difficulties with myriad of cross border security manifestation and conflicts. Within West Africa, nomadic livestock are often used by pastoralists to access poor and unevenly distributed resources in dryland areas, while ensuring their livestock graze off the most nutritious pastures available. This is partly so because there appears to be no workable policy for regulating nomadic livestock (Hesse & Thébaud, 2006). Within the West African sub-region, efforts have been made to promulgate a universal law (*terroirs d'attache* common) that seeks to advocate for legally protected home areas for pastoralists within which land uses other than pastoralism are prohibited. Notwithstanding the existence of this overarching legislative framework by ECOWAS, there appears to be a demonstration of sectoral and contradictory legislations by most member states. Following from the unrealistic nature of this governing framework, some West African countries such as Niger, Burkina Faso, Mali, and Mauritania among others have all enacted restrictive anti-pastoralist laws to prohibit livestock mobility-hence the excessive fragmentation, lapse-bound and porous nature of the policies governing nomadic livestock in the region. Therefore, investment in a potent policy framework and an assessment of existing regulations for pastoral development and movement of livestock in and across the sub-region remains very acute. This study therefore examines the regulatory and policy frameworks governing livestock mobility, and brings the other studies up to date with developments in Pastoral Codes or Charters and decentralization within the sub-region.

Materials and Methods

In order to better examine the existing policy frameworks for nomadic livestock within the sub-region, the study employed a desk-top review of empirical and conceptual studies conducted within the West African sub-region. The study also supported these findings with other interviews conducted among key informants and built on pre-existing studies of the regulatory and policy environment governing livestock mobility study on 'Custodians of the Commons'. These groundbreaking studies were conducted at a time when a new wave of nomadic legislation in West Africa was in formation, and hence a reappraisal of the legislative gains or otherwise within the one decade is timely. By focusing on legislation and institutional environment governing livestock mobility, a more recent studies such as Hesse (2000) and Hesse and Thébaud (2006) have drawn on this new wave of legislation, with exclusive focus on West Africa.

Results and Discussions

Ineffectiveness in policy and regulatory interventions

The study argues that the nomadic livestock difficulties recorded in the West African sub-region is as a result of the ineffective policy intervention in the region.

Sustainable livelihood strategies by pastoralists

The study averred that to engender sustainable livestock production, prominent livelihood strategies are usually adopted by pastoralists by moving their herds in reaction to anticipated seasonal and annual changes in pasture availability. This is propelled by the unwavering need for sustainable source of forage for nomadic livestock which are practically unavailable therefore causing nomadic or transhumant herd movement on communal lands as a response to the erratic rainfall patterns.

The paradox of nomadic livestock policy

In order to achieve the expected results, there is the need for overarching and integrative policy regime governing nomadic livestock activities. Quite paradoxically, the policy and regulatory framework governing nomadic livestock within the West African sub-region are yet to serve as a proxy to sustainable development. The findings of the study also suggests that though there are currently mixed positions on legal recognitions of pastoralism and livestock mobility, it is argued that there is a need to further strengthen country specific policies and regulations to restrain any nomadic activities that will render sustainable development plans.

Legal dualism

It is also posited that West African pastoralists are faced with the paradox of legal dualism. This phenomenon tends to create a multiplicity of legislations thereby making it extremely difficult for pastoralists to comply and comprehend the livestock mobility policies and regulations.

Socio-cultural and religious dynamics of the nomadic livestock policy

It is evident from the study that most governments within the West African sub-region are still struggling to implement or enforce the ECOWAS regulation due to differences in social and religious dynamics existing in each country, inadequate administrative and financial capital. The study argues for a comprehensive and overarching policy framework that integrates all sectors within ECOWAS member state.

Conclusion and Implications

In order to resuscitate, rejuvenate and emancipate the ailing nomadic livestock systems within West Africa, there is the need for a more pragmatic and proactive policies interventions from each country since the ECOWAS treaty has since its inception failed to produce the intended results. Also the study highlights the need for policy interventions on strategic mobility of pastoralist in order to avoid any nomadic livestock related environmental challenge which may serve as an impediment against sustainable development within the region. A strong monitoring and evaluation mechanism for nomadic livestock is very imperative in order to achieve sustainable development within the sub-region. Future studies could concentrate on implementation challenges of West African nomadic policy.

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Enabling Environment for Pastoralists by Bridging Practice and Policies

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Key words: Pastoralism, mobility, livestock trade, trade barriers, advocacy

Introduction

Global figures indicate that pastoralism supports worldwide an estimated 200 million households and one billion head of animals including camelids, cattle, and small ruminants contributing to about 10% of the global meat production (FAO, 2001). Pastoralism is practiced on roughly 25% of the world's land area. In spite its importance no uniform definition of pastoralism and rangelands exists, which leads to the situation that estimates of proportional pasture area may vary between 18% and 80% of the Earth's land, depending the measurement- and calculation methodology used in more than 300 published definitions (Lund 2007). Growing concern of increased marginalization, in particular if production standards are unknown in an ever more globalized and regulated environment, have let a number of institutions to put pastoralism on the agenda. In this context the International Fund for Agricultural Development on request of the Farmers Forum conducted a consultation process to evaluate the global political integration and the enabling environment of pastoralists.

Materials and Methods

As part of the consultation process the international network of Vétérinaires Sans Frontières and their partners in 5 subcontinents carried out a survey in 26 countries and in greater depth in 8 selected pastoralist hotspots. On aspects of enabling environment and policies related to pastoralism, a minimum of 3 well informed interlocutors have been consulted per country, whereas a total of 315 pastoralists have been interviewed in the hotspots in respect to pastoralist practices. Multiple comparisons of means were carried out using Scheffe function of the statistical package of SPSS.

Results and Discussion

For pastoralists, mobility is a critical livelihood feature that enables adaptation to harsh conditions. Results from the survey revealed that interviewed pastoralists in Afar (East Africa) (annual migration distance 85 km ±14.1), Arkhangai (Asia, 67 km ±13.4), Chaco (55 km ±12.7) and Altiplano (67 km ±8.1) (South American) were characterized by limited mobility, while pastoralists in Tiris Zemmour (North Africa, 100 km ±13.3), East Gourma (168 km ±14.1) and Wagadou (105 km ±14.1) (West Africa) reported migration from significant higher distances and were only exceeded by pastoralists from the East African Chalbi territory reporting in average 345 km (±14.1) annual herd migration. Even though in the present study we have not analyzed the historic dynamics, it is though widely assumed that movement patterns of pastoralist have dramatically declined.

When asked about the most important adaptation mechanisms in times of drought, only 50% of pastoralists mentioned migration and 29% herd splitting. A possible reason for that could be that pastoralists face some limitations to mobility. Instead, selling livestock even with reduced prize was, for most pastoralist (62%), the main coping mechanism during periods of stress. It is remarkable that pastoralists chose distressful coping mechanisms, which require longer periods to recover, over adaptive mechanisms that do no harm. If mobility limitations play a role in influencing the choice of coping mechanisms, consequently market access becomes important.

In the assessed hotspots the findings highlighted that rural markets play a dominant role for pastoralist trade, except for fermented dairy products. A share of 60% of the interviewed pastoralist stated that they sell live animals in rural markets in contrast to 27% who trade live animals in urban markets. While rural markets are important for milk (45%), meat (41%), hides (28%), wool (22%), feeds (13%) and manure (9%), urban markets tend to be important for sales of butter (15%), cheese (22%) and meat (31%). The dominance of rural markets as outlet of the pastoralist produce is indeed remarkable, since the rural community consists mainly of pastoralist dependent households. Several trade barriers have been stated by the pastoralists, which may explain partially this phenomenon. Besides the frequently mentioned trade barriers such as transport and feed cost, barriers related to information access and governance ranked among the most decisive. High cost of middlemen, rent-seeking behavior, market inefficiency and information asymmetry are clear indications that governance and information policy in pastoralist territories have to be rethought.

A total of 45% of the pastoralists preferred as appropriate engagement with the public sector local presence through group meetings, but also the use of local radio (31%) and cell phone messages (31%). More than 57% of the pastoralists indicated regular but few consultations by veterinarians, while in contrast 25% have frequent contact with both community animal health workers and animal health technicians. This is a rather low number considering the longstanding support to the formation of community animal health workers. In 26 countries 48% of all policies that affect pastoralism originated from the Ministry of Agriculture, followed by the Ministries of Livestock (16%), Rural Development (7%) and Health (5%), hence pastoralist advocacy could effectively target those ministries. Nevertheless, data revealed that pastoralist participation in policies related to crucial topics such as trade, animal health, and hygiene did not evidence significant pastoralist participation.

Conclusions and Implications

More than half of the interviewed pastoralists believe that policy harmonization efforts amongst the Ministries and agencies are rather very low. Improving information flux amongst Ministries and towards the pastoralist communities is seen as a priority. Nevertheless, pastoralist development is about enabling access to information and knowledge, but also about rights and participatory decision making.

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Features of Using Pastureland and Soil Fertility in Mongolia

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Keywords: Soil fertility, pastureland, sheep unit, vegetation.

Introduction

Mongolia has wide-open spaces with sparse vegetation cover and weak soil fertility that reflects its topography and climate, and that has caused the people to dominantly engage in free-range livestock herding for hundreds of years as their main source of sustenance. Free-range livestock herding has helped to maintain the territory's natural beauty and unique characteristics.

Generally, the Mongolian territory is elevated from the sea level and the land surface differs greatly in topography. Considering these specific features, it was determined that the land surface could be divided into two groups, mountain and steppe, in which both groups could be differentiated, not only in geo-morphological conditions, but also soil pedogenesis processes.

A soil study of Mongolian pastureland was implemented in all administration units during 1968-1990, to determine soil fertility levels, and produce thematic maps with scales of 1:100000-1:200000. The study is used as the primary source for evaluating pastureland ecological feature, and developing pastureland use plans in relation to the soil surface origin, in order to minimize the impact of climate change faced today and human-caused changes in scale and quality of pastureland.

Materials and Methods

This paper presents a summary drawn from comparisons of two separate data sets: i) information on the quantity of livestock and Mongolian pastureland area of the time period of 1918-2013 and ii) data delivered by the researchers who have investigated the question. Moreover, findings of the study on pasture yield and pasture degradation that we have done in the past, are presented here in brief.

Results and Discussion

73.9% of Mongolia territory is agricultural land, and 96.3% of that is used for pastureland. Thus, the pastureland issue plays an important factor that affects the future of the Mongolian ecology and economy. As seen in Figure 1, the number of livestock was 9.6 million in 1918, but increased to 45.0 million by 2013. On the other hand, total pastureland area was 130.0 million hectare in 1918, but fell to 111.0 million hectare by 2013. A total of 19.0 million hectares of pastureland has disappeared. One sheep unit took 8 hectares of pastureland in 1918, gradually but continuously it declined for the next 100 years reaching only 2.0 hectares in 2013. Comparing data of 1918 and 2013, the reduction is 75 percent.

Not only has the area of pastureland decreased, also the quality of pasture has changed drastically in terms of pasture yield per hectare and plant composition. The last 40 years of study results show yield per ha is down 50.0 percent.

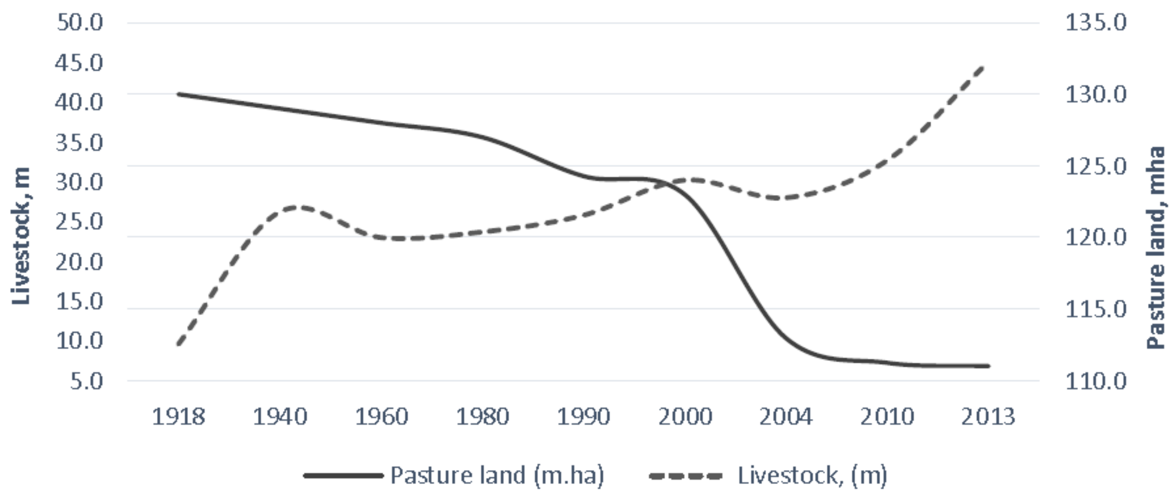

Figure 1. Mongolian Livestock Inventory and Pasture land, 1918 to 2013.

The decline in pasture area and quality is expected to continue worsen and cause further difficulties in finding fodder for livestock. As a result it is crucial to change the present non-intensive methods of using pasture by introducing good pasture management practices that bring together the best of traditional and advanced techniques and technology. Therefore, to improve pasture land quality and the efficiency of its usage, it is necessary to closely collaborate with pasture users and pasture possessors by enabling their voices to be heard indecision and policy making s as well as practical rehabilitation methods for pastureland recovery.

Conclusions and Implications

The majority of the country's land is agricultural, and ecological quality is changing due to misuse and lack of protection. Therefore, in order to improve agricultural land use and its protection, the following recommendations are to be considered. Although Mongolian has abundant pastureland resources, the majority is being degraded. It is important to improve the legal environment enabling the pasture users and possessors to establish lease contracts to improve agricultural land use and protection. A shift to protection and rehabilitation methods and technologies is needed to improve the soil fertility and vegetation cover in the areas that are affected.

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Collaborative Management of Natural Resource: The Indigenous Community's Contributions towards Sustainability of Common-Use Pasture in Mongolia

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Key words: *soum and bag*[1], herder groups, vegetation coverage, yield

Introduction

Natural pasture is considered as not only an ecological factor that influences to animal husbandry but also the main source of healthy food in Mongolia. Growth of animal numbers depends on the carrying capacity of pastures, which is estimated 86 million sheep units in Mongolia (Tserendash et al, 2000). But 77.8% of national territory is experiencing desertification and other forms of land degradation (Desertification atlas of Mongolia, 2014). An external factor causing land degradation is a climate change. Unfavorable climatic changes are negatively affecting the ecosystem, livestock and rural herders' livelihoods. In this situation, collaborative management across all levels to protect a pastureland and adapt to a climate change should be introduced to help reduce the vulnerability and susceptibility of pasture to change. In Mongolia, the pastureland belongs to the state, whereas livestock is generally private property. According to national legislations, the summer, autumn and *otor*[2] pastureland are to be allocated among *bag* and *khotail*[3], and utilized in common (Law of Land, 2002). Collaborative management of pasture is to be introduced based on indigenous herders' traditional knowledge and experiences, which can be enriched with scientific knowledge and globally acknowledged best practices. Due to the incomplete application of traditional methods on pasture over the last 30 years, unexpected changes on pasture conditions have continued to expand. This paper is prepared based on industrial experiments and socio-ecological research investigations that took place in Buutsagaan, Zag and Khureemaral *soums* of Bayankhongor *aimag* (province) of Mongolia between 2012 and 2016 within the project[4] funded by Japanese Fund for Poverty Reduction of Asian Development Bank. The research investigations revealed noticeable changes on pasture conditions that were produced as a result of introduction to a collaborative pasture management, and of application of combined traditional and expert's knowledge.

Methods and Materials

Traditional pasture use was based on large seasonal migration of livestock together with herding family, which secured the growth, development and maturity of vegetation, the accumulation of sufficient nutrient substances for subsequent growth, and the building of pasture resilience and adaptation to climate change. There were 111 pasture monitoring plots within 10 treatments, where experimented pasture release, resting, non-resting, rotation and fenced areas under collaborative management practices. Vegetation in each pasture was sampled for structure, species composition, development stages, height, coverage and yields. Records of investigation contained top soil coverage with green plants, litter, rocks, and bare. Yield was estimated with 5 repetitions of 1 square meter area each, samples taken were classified into 6 groups such as grass, sedge, leguminous, forbs, annual plants and weeds. Wet and dry mass were weighed. We also conducted a social (questionnaire) survey of 66 herders from three *soums* in the experimental areas, in order to identify their perspective on collaborative pasture management, and

[1] *Soum* (district) *and bag* (sub-district) are administrative units in Mongolia.
[2] *Otor* is a kind of traditional movement to access to good pasture resources in harsh climate.
[3] *Khot ail* is 2 or more neighbor herding families.
[4] The title is "Establishment of climate resilient rural livelihoods project".

how they use outputs of experiments. Basic materials of the research were (i) 6,200 yield samples and 250 vegetation records collected from 111 monitoring plots, which are located on pastureland of about 70 herder groups that are in 13 *bags* of the three *soums*, and (ii) information obtained with social survey that contains 59 questions of 6 sections collected from 66 herders who represented their relevant *soums*.

Results and Discussion

According to the principles of ecological resource applications, the herders' idea and thought should be a core of the pasture use planning. Herders are now learning to unify, protect their pastureland, and to let pasture grow. 84% of herder families of the three *soums* organized into 76 herder groups based on their own social-ecological heritages to harmonize with surrounding changing environments. Each herder group designed a pasture use and protection plan in participation with different stakeholders. Training is important for proper planning. Pasture use planning had three stages in our experiments. The first is planning in a herder group level. The second one was planning in a *bag* level comprising herder group plans. Third stage was a planning in a *soum* level comprising the b*ag* level pasture management plans. Enrollment of the indigenous people into the entire planning process ensures quality planning, and implementation. For instance, pasture resting and rotation initiatives, which are incorporated into in Buutsagaan, Khureemaral and Zag *soum* pasture management plans, were accomplished covering 63.1%, 77.8% and 80% of overall pastureland in 2013, 2014 and 2015; that is 972.8 thousand hectares were rested and rotated in 2015.

There were observed positive changes in vegetation structure, species compositions and yield as result of resting and rotational use of summer pasture. Pasture yield of trial plots increased 13.9-22.5% compared with control plots. 56.3-60.6% of the yield was composed with *Koeleria macrantha, Agropyron cristatum, Poa attenuata, Stipa Krylovii* and coincided with structural recovery of vegetation (Tserendash, 2014). The most resistant pasture results after application of a four season migration. Repeated use of summer pasture and too many rodents result in poor composition of vegetation; 70% of the yield is composed with poorly palatable annual weeds such as *Artemisia Adamsii and Chenopodium album*. As a result of the winter and spring pastures left unused for traditional certain periods and the resting and rotational use of summer pasture, there was an increase in the number of plant species, vegetation cover increased 3 to 7%, and bare ground was reduced 5 to 8%. The development of pasture use plan and the application of resting and rotational methods do build not only a resilience of vegetation to climate changes but also ensure pasture sustainability. When pasture rotation is applied a root sugar content of *Elymus chinensis* was 11.1% more compared to non-rotated one (Tserendash, 2006). Social survey taken from 65 herders representing the *soums* also verified the results of ecological surveys. Out of 51 interviewed members of the group[5], 90% replied their herder group apply the pasture resting and rotation practice, 88% said they started pasture planning since 2012, when the research experiments started, 94% replied that they participate in pasture use planning, 67% said that the planning is done in a group manner, 45% replied that it is important to involve only stakeholders from herder group to *soum* administration for planning, while, another 43% required input of the professional expert in addition, 75% assumed that planning should be initiated from the *khotail* and group level, 28% said the members should be more responsible for planning, 45% said the members is more responsible for actual implementation, and 53% said that most heavy punishment for rule-breaker is decrease of reputation among the group and *bag*. In terms of imagination of outputs of experiments, out of all responses 21% says the increased carrying capacity, 18%-the increased species composition, 16% - the increased animal weight and 94% replied that they will continue using a pasture management in a group manner.

[5] Out of all 66 interviewed, one was non-member of the group and 14 submitted incomplete replies.

Conclusions and Implications

In local areas, a “boss” centered pasture management planning is gradually shifting to a “herder” centered one. Stakeholders such as herders, group leaders, *bag* and *soum* governors and specialist are participating in “collaborative community based pasture management practices” by creating a whole system for planning, organization, implementation, controlling, monitoring and evaluation of outputs and impacts, which maintains pasture sustainability. Usage of the summer pasture without rotation and resting practices advances land degradation so that it should be planned to introduce such practices at least 20% of the summer pasture per a year in Mongolia. In such case, a second round of the rotation will start in 6 years and pasture sustainability is to be ensured. Traditional groups such as “people from the same place or river” and other kind of new groups such as partnerships and cooperatives should be responsible for pasture planning and its implement in collaboration with other stakeholders.

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3.2 Privately Owned and Leased rangeland Systems

Cowboys or Grass Farmers?

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Key Words: Forage budget, land condition, Stocktake

Introduction

Graziers and property managers in the rangelands of northern Australia manage cattle on extensive properties for beef production where the main focus is often on cattle not the pasture resource. Increasing stock numbers, particularly breeder numbers, and improving herd genetics are seen as avenues for increased turnoff and profits. Management is often focussed more on stock husbandry for profitable enterprises rather than resource management. But should managers be "grass farmers" first?

Climate variability and limited rainfall are key factors driving the productivity of pastures in the semi-arid rangelands of northern Australia and thus, managing stock numbers to match feed supply is a significant challenge but also a highly desirable management strategy. Overstocking, particularly in times of drought, has led to declining pasture and land condition (McKeon et al. 2004).

This paper tracks the history of a property where the manager has become a "grass farmer", managing stock numbers to match feed supply and resting pastures from grazing periodically to improve pasture and land condition.

Materials and Methods

NAPCO is a privately owned pastoral company based in Australia. It owns 14 cattle stations, totalling 5.8M ha, in Queensland and Northern Territory running approximately 200,000 head of cattle, and managing the complete supply chain. One of those properties, Goldsborough (12,446 ha), located near Roma in southern Queensland, was bought in 1999 to receive young cattle of approximately 200 kg weight and grow them to about 340 to 380 kg weight, suitable for entry to the company feedlot. The Goldsborough manager improved infrastructure with more strategic fencing, laneways to reduce labour and mustering costs and provision of better water distribution. Annual rainfall is approximately 600 mm (34% coefficient of variation) with 2/3 falling over the hotter months (October-March) and 1/3 in the cooler months. Annual pasture growth generally ranges from 2,000 to 5,000 kg/ha but can be almost absent during extreme droughts.

Cattle were transported from northern properties to Goldsborough during the north Australian dry season (April-October) so that Goldsborough was progressively stocked over this period. Stock were grazed on pastures of mainly buffel grass (*Cenchrus ciliaris*) for 6-10 months to achieve target weights for feedlot entry. This led to a system of increasing stock numbers over the drier part of the year and gradually destocking over the remainder of the year resulting in lighter stocking rates in summer and early autumn, the main pasture growing season when pastures are most sensitive to overgrazing. Cattle were rotationally grazed through paddocks to allow additional resting of pastures. There was little control of the number of cattle to be received at the property in any one year other than the manager checking paddocks and making decisions based on past experience as to a suitable carrying capacity for the period. The manager felt a more objective measure was required.

Taking control

In 2011 the Stocktake monitoring system (Aisthorpe et al. 2004) was adopted. Stocktake measures and records land condition, pasture dry matter yields and calculates forage budgets where stock numbers are adjusted to utilize a percentage of the forage supply. This allows users to estimate land condition by assessing pasture and soil condition, preferably at the end of the growing season, to give a land condition rating of A, B, C or D, where A is excellent, B is fair, C is poor and D is extremely poor. Nine monitoring sites were established to represent the property.

Pasture dry matter yields and a safe utilisation rate of 30% for the budgeting period were used in whole property forage budget spreadsheets to calculate the number of stock that could be safely carried. Additionally, a rotational grazing forage budget was employed to determine how long to graze each paddock before moving to the next paddock, thus allowing each paddock to be grazed once or twice during the dry season without significant additional pasture growth.

Results and Discussion

When the properties were first bought many paddocks were in poor condition. Land condition appeared to improve with time as infrastructure was developed and through resting pastures from grazing during the summer growing season. Stock numbers on the property in May and November each year varied markedly with seasons from 1,200 to 8,600 as shown in Figure 1. Forage budgets based on consuming 30 % of the feed on hand in May each year showed desirable stock numbers for the dry season were 7,914 in 2012, 6,099 in 2013, 7,650 in 2014 and 8,350 in 2015.

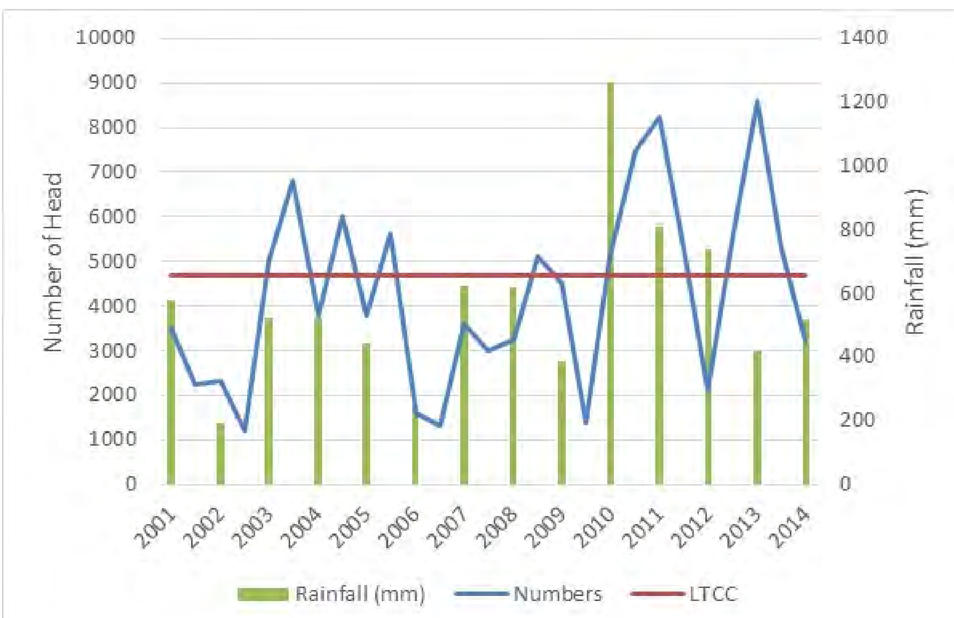

Figure 1. Cattle numbers in May and November, long term carrying capacity (LTCC, using cattle average liveweights of 300kg) and annual rainfall on Goldsborough from 2001 to 2014.

Conclusions and Implications

Improved infrastructure, rotational grazing, resting pastures from grazing and stocking to carrying capacity has improved land condition from C in many paddocks to A or B in 2015. Employing a monitoring system that uses photos, pasture, soil and tree density data documents changes that occur over time and gives objective information on resource condition. This data can be used to identify management strategies required to improve land condition and carrying capacities, or objective assessment of current strategies. Forage budgets help to determine the safe short-term carrying capacity of a property or paddock, are an objective measure for matching feed supply with stock numbers, and assist communication with management. Using the Stocktake approach of measuring land condition and doing forage budgets has allowed the manager to take control of his property management situation. Also, this information could be useful for legitimising the company's "green credentials" and perhaps obtain premium prices for their product in the future.

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Managing for Biodiversity: A Rancher's Perspective

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Key Words: Biodiversity, sage grouse, elk, ranching, grazing behavior

Introduction

Before the adoption of the Species at Risk Act (SARA) in 2002, the ranch (East and West Ranching Company) had already either initiated, or participated in, a number of projects intended to manage habitat for endangered and non-endangered wildlife species in southeastern Alberta. The participants of each of these projects recognized manipulating the grazing behavior of livestock had the potential of being an effective means of manipulating the habitat of the target species. Consequently, each of these projects employed a flexible grazing strategy, intended to achieve the ecological goals associated with each project and permit the ranch to adapt its management strategies to changing environmental conditions. In addition, by working in cooperation with range ecologists, ranch management developed a better understanding of the ecological processes shaping the landscapes on the ranch, allowing ranch management to create better resource management strategies for the entire ranch.

Projects

The ranch participated in a number of projects that included, endangered species habitat restoration, and large ungulate habitat management. What follows is a brief discussion of the projects involving managing Greater Sage-Grouse (*Centrocercus urophasianus*) and elk (*Cervus elapus*) habitat.

Greater-Sage Grouse (Centrocercus urophasianus) habitat management (The Lodge Creek Project)
In 2000, East and West Ranching Company purchased a grazing lease south of the Cypress Hills, located on Lodge Creek located in the transition zone between the Dry Mixed Grass Prairie and the Moist Mixed Grass Prairie.

With the co-operation of Public Lands and Alberta Fish and Wildlife, the ranch created a management plan with the goal of managing Greater Sage-Grouse habitat associated with this lease. This management plan involved the cooperation of Public Lands (monitoring the range health), Alberta Fish and Wildlife (monitoring the Greater Sage-Grouse population), Alberta Conservation Association (monitoring the small bird populations), and Cows and Fish (monitoring the riparian area associated with Lodge Creek). To ensure the ranch's management strategy was effective, these groups collected baseline data at the beginning of the project, throughout the course of the project, and a biologist would consult with ranch management on a regular basis to review the progress of the project.

Elk (Cervus elapus) winter habitat management (The Brost Field Project)
In 2002, Ducks Unlimited Canada (DU) and Nature Conservancy of Canada (NCC) invited the ranch to participate in a management program to manage waterfowl habitat and elk winter range on the northeast slope of the Cypress Hills in Alberta, located in the transition zone between the Moist Mixed Grass Prairie and the Montane Fescue grassland associated with the Cypress Hills.

The ranch was required to construct a management plan with the goal of improving the health of the rangeland and riparian areas associated with this property. To accomplish this, the ranch used base line data collected by NCC to calculate the carrying capacity of the field. However, it was necessary to consult with an Alberta Fish and Wildlife biologist to create a model that would help estimate the forage consumption of the herd of elk using this field. With this information, it was possible to determine the field's grazing capacity and then create livestock grazing strategy that was satisfactory to NCC and DU. As part of this grazing plan, NCC would conduct yearly riparian and range health assessments and meet with ranch management to review the progress of the project.

Discussion

Although sage grouse and elk occupy different ecological niches, each of these species requires relatively large, heterogeneous and intact landscapes that are in healthy condition (Adams et.al., 2004; Alderidge, 2005; Hegel, 2004; Lee, 1979). With a basic understanding of livestock grazing behavior (Bailey et.al., 1996) it is possible to design and implement grazing strategies that create the degree of landscape heterogeneity required by wildlife (Adler et.al., 2001), like elk and sage grouse. To achieve the goal set for each project, the ranch implemented a flexible grazing strategy to control where livestock grazed, the number of animals grazing at a particular site, and the length of time the animals grazed in these areas. The ranch chose season long continuous grazing using Ecologically Sustainable Stocking Rates recommended by Alberta Public Lands. With the use of salt/mineral placement, low stress herding, and the improvement of water distribution, it was possible to modify livestock grazing behavior to achieve the desired ecological goal. Where it was impractical to develop new watering sites, the ranch used solar powered pumps to pump water to locations away from sensitive areas.

Conclusion and Implications

By manipulating the structure and function of ecosystems, it is possible to alter biodiversity. Developing grazing strategies focusing on manipulating the grazing behavior of cattle is an effective way to manipulate the structure and function of ecosystems associated with landscapes in western Canada. However, during the formation of these grazing strategies government and non-government agencies must be included in the planning process. Never the less, in addition to meeting ecological goals, these management strategies must also meet the producer's economic goals and be flexible enough to allow the producer to make crucial management decisions.

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Social and Economic Characteristics of Public Lands Ranchers in the United States: Results of a 2015 Survey

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Key words: Socio-economic characteristics, grazing permits, public lands ranchers, heterogeneity, policy

Introduction

Changing land management constituencies, priorities, and grazing policies impact the importance of public lands to local communities. When policy adjustments are considered, decisions should be made with due care and diligence, based on sound science. With regard to federal grazing permits, the permittees themselves are a useful, but complex source of information. Engaging western public land ranchers requires interacting with a very heterogeneous group.

For this reason, a survey developed with a statistically valid national sample, designed to extract socio-economic information, serves as a useful tool to derive data directly from ranchers' responses. Such information can be useful for addressing issues related to public land grazing policies and management options in various decision documents. Grazing permits play an integral role in ranching operations of public lands ranchers. Coupled with the importance of rangeland resources and the goods and services they provide to current and future generations (Maczko et al. 2011), establishing a source of sound data for policy and management decisions will prove beneficial.

Materials and Methods

With this in mind, the national survey of social and economic characteristics of public lands ranchers in the United States was designed to gather information directly from ranchers, pertaining to the socio-economic attributes of their ranches, how they contribute to their local communities, and how changes in policy might affect their operations. Conducting the survey was dependent upon cooperation of the USDA Forest Service and USDI Bureau of Land Management, since they administer permittee lists.

Receiving these lists was the first step in the survey process. Concurrently, researchers worked to develop the survey instrument. This involved testing questions in focus groups to make sure the wording was interpreted similarly by ranchers across the country. The survey was administered following Salant and Dillman (1994). Using a formula from Dillman et al. (2009) with a 95% confidence interval and +/-4% margin of error, it was determined that 582 surveys were needed. Surveys were sent to 1911 permittees to ensure adequate response rate, and a four step mailing process developed by Dillman et al. (2009) was used.

Cluster Analysis

Cluster analysis was used to sort the raw into groups. Clusters had to be distinctive enough to differ, while still having enough ranchers per group to justify separate groupings. Six clusters offered the most accurate representation of the data. Cluster analysis attributes selected were based upon variables used in the Gentner and Tanaka (2002) study. This duplication allowed researchers to determine whether the same attributes would generate the same cluster groups.

Results and Discussion

Six rancher groups were identified through cluster analysis. Significant factors determining the groupings were membership and leadership in community organizations, ranch labor, ranch income, retirement income, business organization structure, and the head number of livestock. The six rancher groups identified were (1) <100 head ranchers, (2) sheepherders, (3) family cattle ranchers, (4) corporate ranchers, (5) diversified agriculture ranchers, and (6) cattle and sheep ranchers. Ranchers with less than 100 head were the largest group of surveyed public land permittees at 70%, followed by diversified agriculture ranchers at 20% of permittee survey respondents. Family cattle ranchers were 5% of those operating on public lands grazing permits. Sheepherders (3%), corporate ranchers (1%), and cattle and sheep ranchers (1%) made up the remainder.

Ranchers in all categories were active in their communities and organizations, with more than half of the ranchers and their spouses participating. Ranchers also served in leadership positions within these organizations.

Survey respondents perceived federal regulation and policy as the greatest threat to their operations, and high livestock prices as the greatest benefit. Sources of income were diverse among ranchers, with <100 head ranchers receiving 43% of their income directly from the ranch. In contrast, cattle and sheep ranchers received 98% of their income from the ranch.

Significantly, profit was not found to be a primary value that keeps ranchers working on the ranch. Tradition, resource stewardship, and family ranked more highly. Though profit maximization is not a primary motivator, responses to questions dealing with potential policy changes for public lands ranching indicate that reductions in AUM's, changes in season of use, and increases in grazing fees above certain levels would impact ranching operations.

Conclusions and Implications

This study identified six distinct groups of public lands ranchers. Fifteen years earlier, Gentner and Tanaka (2002) found eight distinctive groups of ranchers. Operations with less than 100 head continue to make up the majority of public land ranches in the United States. According to the 2012 Census of Agriculture (USDA 2012) approximately 85.5% of beef operations in the United States have 100 head or less, consistent with this study.

Responses to changes in policy gave insight into the heterogeneity of public land ranchers. All of the policy questions showed differences in responses to change within and among groups. Therefore, standardized, uniform policies are likely to affect ranchers differently. This implies that policy makers may struggle to achieve consistent results to policy implementation nationwide.

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Publicly Owned Rangelands in Saskatchewan

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Key words: public lands, grazing, drought, ranchers.

Introduction

There are nearly seven million hectares of grazing land in Saskatchewan (Saskatchewan Ministry of Agriculture, 2012) a large proportion of which is publicly administered. The largest public administrator is the Ministry of Agriculture with 2.6 million hectares of grazing land. Other public institutions administer smaller inventories of public grazing lands including: Ministry of Environment, Water Security Agency, Environment Canada, Parks Canada, and Department of National Defence. The majority of lands are available to ranchers to graze livestock. This paper will discuss the history of these public lands and current management models.

Discussion

There were political, economic and environmental factors that affected the current inventory of publicly owned grazing lands in Saskatchewan. From 1870 to 1930 the Federal Department of the Interior (DOI) was responsible for all lands in what today is the Province of Saskatchewan. The primary role of the DOI at this time was to settle the Canadian prairies. Settlers were gifted a quarter section of land (65 hectares) and if they cultivated a certain portion of land each year, title would be transferred (Provincial Archives of Saskatchewan, 2011). Some large blocks of grazing land were leased to ranches during this period, but most were in the driest part of the Prairies deemed unsuitable for cultivation. By 1930 80% of Saskatchewan's native grasslands had been cultivated (McCartney et. al. 2010). The Federal government was responsible for the administration of all land in Saskatchewan until the *Natural Resources Transfer Act* of 1930 transferred both the surface and mineral rights of publicly owned land to the Province of Saskatchewan.

During the 1930's a vast drought hit the Prairie provinces, combined with trying economic conditions resulted in a disaster. There was land in the arid south and west of the Province which should never have been cultivated, thus farmers abandoned them and either left farming or were resettled to moister parts of the Province. This resulted in a large inventory of abandoned land. The province established the Land Utilization Board which was authorized to deem lands as unsuitable for agricultural purposes, and acquire them (Queens Printer, 1941). The lands were re-grassed and rehabilitated either through the Provincial Ministry of Agriculture or the Federal Prairie Farm Rehabilitation Administration. Fencing and water infrastructure were also put in place. The lands were then either put into Community Pastures, grazing cooperatives, fodder projects, or leased to individual ranchers. The policies discussed above resulted in the majority of the current inventory of publicly managed lands. The following outlines the management and administration of these public lands.

Crown Land Leases

Crown grazing land is allocated to ranchers using a scoring system including: proximity; current land base and age. Most grazing leases are for a term of 33 years with renewal being automatic if the lease is in good standing. Commonly leases are assigned through generations or transferred with the sale of the remainder of the ranch. Carrying capacity is entrenched in the lease. Leases are reviewed for management at lease renewal, or when specific issues warrant. The Ministry of Agriculture can mandate management plans to mitigate deteriorating range condition. Annual rental rates on Crown grazing land are directly related to average October/November sale price of cattle. Grazing leases range from 65 ha to 23,000 hectares.

Grazing Cooperatives
Grazing cooperatives were first established in the 1930s. Groups of ranchers joined together in cooperatives to lease, graze cattle and manage a particular block of land. The lease is with the cooperative, and not an individual. The cooperative is responsible for all aspects of managing the land and administering cooperative business. The Ministry of Agriculture must approve new members, and the cooperative is required to provide grazing reports. There are 126 grazing cooperatives ranging from 65-11,600 hectares (1970 hectares average).

Community Pastures
Community pastures are a unique institution to the Canadian prairies, as they are operated by both the Federal and Provincial governments and provide full care of the land and grazing livestock throughout the grazing season, on a cost recovery bases. Pasture Managers and riders are employed to care for the livestock.

The Saskatchewan Ministry of Agriculture administers 50 Community Pastures covering 802,617 acres of land ranging from 4,671 to 78,172 acres in size. Livestock producers are allocated grazing based on a scoring system: proximity; resource base; and age. Ranchers can deliver a maximum of 60 cow/calf pairs per year.

Agriculture and Agri-Food Canada used to administer 85 pastures covering 2.1 million acres across the Prairie Provinces (62 in Saskatchewan). The program operated similarly to that described above, except grazing is allocated based on criteria established by the local Pasture Advisory Committee. Each patron is limited to a maximum of 100 cow-calf pairs. The Federal government is divesting of these pastures. To date 33 pastures have been transferred to the province with the remaining 29 transitioning by March 31, 2018. The former patrons of these pastures have been forming for profit or non-profit corporations and leasing the pastures from the province. The Canada Community Pasture Transition Program provides funding to support training and costs associated legal entity formation. The groups must provide grazing, invasive species and infrastructure maintenance reports. The pastures are monitored regularly by Ministry of Agriculture staff.

Other Publicly Owned Grazing Lands
There are a number of other Federal and Provincial agencies which have tracts of grazing land. The Ministry of Environment leases grazing land on short term permits, as well as making some conservation lands available for grazing during drought. Several Provincial Parks with grassland areas permit grazing to local ranchers. The Department of National Defence has lands on Dundurn Military Base which are grazed through incorporation into the operations of Dundurn Community Pasture. The Last Mountain Lake National Wildlife Area uses grazing by local ranchers on a cyclical basis, as a tool to manage their grasslands. Grasslands National Park is a large block of grazing land in southwestern Saskatchewan where a government owned bison herd and native wildlife are the primary grazers, but some local ranchers graze portions of the park.

Conclusions and Implications

There are various models present in Saskatchewan for use of publicly owned grazing resources, each with its own tenure, rights, management and oversight. The commonality is the vast majority of publicly owned grazing land in Saskatchewan is made available to the ranchers in the Province.

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The Problem of Speaking for Ranchers: Reflexive Social Research in the Multifunctional Rangeland Context

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Key words: Social-ecological system; ethics; research methodologies; rangeland; social science

Introduction

Critically examining the role of humans in rangeland landscapes is made more complex by multiple, contradictory social demands for the use of rangelands. As Holmes (2002) and others have noted, rapid changes in policies, ideologies and production systems have created multifunctional rural landscapes where food production interests coexist with other landscape uses, including cultural landscapes, heritage and biodiversity. In this context, the old question of how to link rangeland science and management has re-emerged through discussion of social science methods, opportunities for interdisciplinary work, and a focus on rangeland manager decision-making processes.

As rangeland science engages with ranchers through research, the problem of 'speaking for ranchers' emerges (Alcoff, 1991). Academic representation of manger needs and views can be problematic, especially in a field where scholars may move between scientific and management roles in their professional and personal lives. This is a problem of power, voice, and representation that has gone largely unexamined in rangeland scholarship. In this paper I grapple with two key problems in critical methodology (speaking for others and insider/outsider research) and consider tools for reflexivity that attend to the contexts and subjectivity of social research.

Materials and Methods

I reviewed methodological papers from critical, decolonial and feminist methodologists (a full list available via email) and selected two key problems for social researchers in addressing voice and representation of research subjects. For each problem, I identified motivating questions and the corresponding tools for researchers suggested in the critical literature. Then, following the tradition of that literature, I discussed these tools within the context of my own social rangeland research.

Results and Discussion

Alcoff (1991) recognizes that the problem of speaking for others involves a tension in social research between making knowledge claims that inappropriately represent the experiences of others, and thus dominate and oppress them, and the problem of only speaking for oneself (Alcoff, 1991). Researchers must ask: For whom can I speak? How are subject voices represented, privileged or silenced in my work? Am I speaking for others or about others? Opie (1992) outlines tools for minimizing 'appropriation of the Other,' which is, in her view, an inevitable result of social research. These practices include careful analysis and presentation of data (including quotes) in research findings and recognition of the limits of knowledge. She asks researchers to build empowerment into the research process and to question who is an "authentic" research participant.

The problem of speaking for others prompts range social scientists to reconsider 'what we know' about rancher behavior based on the voices of a sub-set of politically active managers, social survey research conducted on (male) primary-decision makers, or information gathered through our own experiences in rangeland communities. As a qualitative researcher studying rancher decision-making, I have struggled to find new ways to 'hear' rancher voices, resist the impetus for over-generalization where possible, and co-present research findings with participants while striving for critical analysis and objectivity. The problem of speaking for ranchers is a continual issue for qualitative work positioned within the context of a field that is biophysical at its core.

The second problem is that of insider/outsider research. Rangeland scholars must ask: How do I recognize that I am the instrument of my research and best position myself to do ethical research? How do I understand the impact of my identity and relationships to my work? Rangeland scientists with connections to the communities we study must find new ways to problematize both outsider approaches to research that claim neutrality and objectivity, and insider approaches which assume depth and nuance is made available to those with an intimate knowledge of ranching communities (Khan, 2005). Rangeland social scientists may have multiple ways of being insiders and outsiders (Smith, 1999). Reflexivity, the process of addressing the context of research, including a researcher's subjectivity, is an important tool for social researchers in negotiating power relationships and insider/outsider perspectives (Smith, 1999). Smith argues for social researchers to practice localized forms of respect and consent, as it may take a great deal of time to build the trust needed to gain consent even when one is an insider.

I face insider/outsider problem in my qualitative research on rancher decision-making in Colorado and Wyoming. I have knowledge of ranching decision-making practices because I grew up in a ranching community and have family members who ranch. However, my position as a researcher and PhD student often places me outside of the ranching communities, as I have different knowledge, language, skills and relationships to rangeland resources than do the ranchers I work with. Some of my outsiderness is inherently material: unlike the ranchers I work with, my livelihood is not dependent on rainfall or the cattle market. My relationships to ranching individuals and communities, and their consent to participate in my work, is a dynamic process subject to fluxes in trust and respect.

Implications

Problematizing the claims of rangeland science to knowledge of manager needs and views requires a careful, reflexive reexamination of power, voice, and representation. A synthesis of two key themes from the critical methodological literature suggests that researchers take an interest in sharing power, strive to avoid speaking for others, work to build respect and consent, and acknowledge strengths and limitations of our own positions inside and outside of manager communities. While these problems, questions, and tools are not often discussed in rangeland science praxis, they will become increasingly important as rangeland scientists engage with diverse stakeholders in multifunctional rangeland systems.

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Introduction of Rangeland Leasing and Its Results in Mongolia

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Key words: Peri-urban, exclusive pastureland use right, rangeland leasing practice, randomized control trial

Introduction

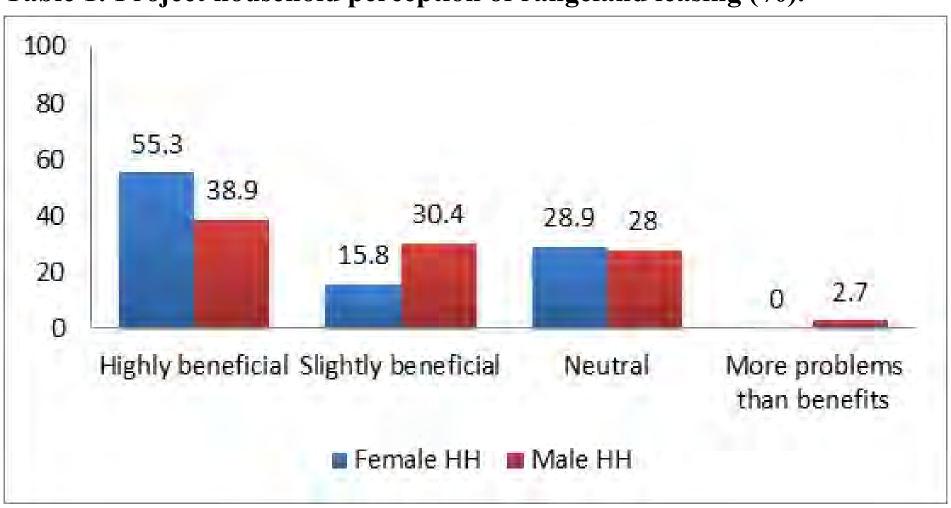
Overgrazing has become a major concern in the peri-urban areas due to rapid population growth over the last 20 years. The Peri-Urban Rangeland project funded by MCC with US$11.8 million was implemented during 2008-2013 to introduce rangeland leasing as a way to fight with overgrazing. The project identified and leased 400 tracts of pastureland to herder groups in the peri-urban areas of Darkhan, Erdenet, Ulaanbaatar, Kharkhorin, and Choibalsan. The project introduced a system of leasing peri-urban pasturelands to herder groups replacing the open access. It was aimed to encourage more sustainable rangeland management and adopt of 'intensive' dairy farm practices which are expected to increase herd productivity, decrease land degradation and ultimately raise herder income. As a result 398 herder groups consisted of 1500 households in the above peri-urban areas have signed 15-year exclusive land use agreements for pastoral use. Here, we would like to present the key highlights of a mid-term evaluation of the study.

Materials and Methods

We've investigated the mid-term study of the project impact evaluation completed in 2014. The IE uses randomized control trial assigning all eligible herder groups into control and treatment groups via lottery, disenabling any 'selection bias' and ensuring that the comparison groups are similar except one receives treatment and the other doesn't. The effect of lease is measured by the difference between the treatment average and control average. Key findings reveal that treatment households maintained a lower yearly pasture load per hectare and made attempts to control the overall size of their herds relative to control households. The treatment households also significantly increased the percentage milking cows of an improved breed relative to control households.

Overall, the rangeland leasing is perceived as beneficial as shown in Table 1, with 70 percent of the female and male household heads perceiving it as beneficial or highly beneficial.

Table 1: Project household perception of rangeland leasing (%).



The study shows some evidence of herder behavior changes as well as positive results relative to control households found in specific interest areas such as lower yearly pasture load, higher probability of pasture reserve, higher purchase of hay and fodder, higher percentage of improved breed milking cows, reduced mortality of sheep and goats, and increased investment in animal shelters. The change in pasture load and pasture reserving pattern are crucial short-term behavioral impacts expected to decrease land degradation. A higher percentage of improved breed cattle is expected to produce higher income in the future. At the mid-term of the study, 15% of the herder groups report that their livestock numbers exceed pasture carrying capacities (as estimated by the project), an improvement from 20% of the herder groups at the start of the project. The IE researchers claim that although there is no comparable information for the control herder groups, this change in pasture load can be taken as suggestive evidence of movement toward a sustainable number of animals.

The project reveals the following approaches lead to success:

- **Local government involvement**: Throughout the project all local administrative level officials were involved in the public consultations, meetings, and discussions with the herders. Consequently, the decision to secure pastureland leasing was made by the local government with support of all citizens of the soums/baghs. It introduced a transparent and fair system of addressing future local level pastureland issues.
- **Consensus**: Each herder group obtained written consent from their neighbors to obtain the 'exclusive' pastureland use rights. It was the most effective method to settle down pastureland conflicts among the herders and determine pastureland borders of each group.
- **Borders**: To keep the corridor to common use land accessible to all herders in the area and to avoid causing change in wildlife behavior and travel routes the project only allowed pastureland borders to be marked without fencing.
- **Inclusiveness**: Land right violation victims are often households that are single-headed or with fewer livestock. Requiring herder groups to include at least one disadvantaged household and establishing internal group agreements ensured equal participation in the decision-making, equal rights and access to pasturelands, and benefits to the group's business practices.

Conclusion and Implications

Pastureland leasing could be one of the most effective ways in engaging herders in sustainable pastureland management, preserving rangeland, and securing the tenure rights that include vulnerable groups. The data at the time of follow-up reveals some positive changes happened within 2 years of the project; however, the following questions still need to be addressed:

- What are the appropriate lease terms (currently it's 15 years with possibilities to renew)
- What is the best legal framework to settle the matters involving pastureland leases, to prevent land grabbing, and to implement pastureland leases considering area-specific characteristics
- What is the best method to improve grassroots herder organizations' involvement in pastureland leasing

There's an increasing interest in adopting the Peri-Urban Rangeland project leasing practices in other parts of Mongolia by international organizations. However, to optimize the impact it's important to first adequately address the above questions, examine the potential impacts of political instability and the weak monitoring system at the local level. Addressing these issues are important for development and implementation of management system that secures the pastureland lease rights.

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3.3 Urban and Sub-Urban Grassland Societies

Promoting the Value of Cattle Grazing and Ecosystem Services on Open Space through Curriculum and Interpretative Trail Signage

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Key words: Grazing, Open Space Lands Ecosystem Service Curriculum, trail signage

Introduction

In the western United States., lands deemed "open space or protected land", whether in private or public ownership, are frequently grazed by beef cattle. It is the most substantial use of land use in the western U.S. Cattle grazing supports the raising of beef cattle for meat and other by-products and provides other ecosystem services including: vegetation and watershed management; fire fuel control; and, increasingly, management of habitat of rare and endangered species. Decision makers and the public have little knowledge of animal agriculture production or the ecosystems services provided by livestock grazing on western open space lands. Their lack of knowledge puts the future of livestock grazing in the western U.S at risk and threatens the ability to manage large-scale landscapes for a variety of conservation values.

Materials and Methods

The project, "Ecosystem Services Curriculum and Interpretative Trail Signage", sought to increase awareness and knowledge of park visitors, managers and decision makers about working rangelands and the ecosystem services. Bay area open space lands provide an unprecedented opportunity to educate both the public and policy makers. The bay area has over 1 million acres of protected land; much of it managed as a working landscape. In fact over 25 different public entities in the San Francisco bay area manage their open space lands with livestock grazing. An ecosystem service curriculum was developed, "*Understanding Working Rangelands*" by the University of California Cooperative Extension in cooperation with the East Bay Regional Park District and Sonoma County Regional Parks. It targeted San Francisco Bay Area decision makers, park interpreters, and park users. Over 2.5 million people visit grazed open space annually in the Bay Area. Curriculum on beef cattle husbandry, cattle behavior, grazing management, ranching economics and infrastructure is found in a series of fact sheets and interpretative trail signage on working rangelands. Beef cattle management and production information is readily available; and, generally written for practioners with a focus on "how to" instead of "why." This curriculum and trail signage focuses on "why", i.e. "why are bulls grazing in the parks?"; "why do ranchers brand and castrate cattle?"; "why is barbed wire fencing necessary?", and other aspects of beef cattle production that have caught the uninformed public and decisions makers off guard in recent years.

Results and Discussion

Fact sheets, under the *Understanding Working Rangelands theme,* include "A Year in the Life of a Cow" which is instrumental in helping park interpreters explain why grass finished beef is not widely produced on public open space lands and the important role of animal feeding operations in supporting rangeland livestock production." Grazing Benefits" explains and provides research-based information about the role of livestock grazing in managing open space. "Sharing Open Space: What to Expect from Grazing Cattle" can inform the public about cattle behavior after negative interactions between dogs and cattle in parks were reported. “Bay Area Ranching Heritage: A Continuing Legacy”, describes the long heritage of ranching in California, focusing on the Bay Area, and the importance of public lands grazing. Most ranches now depend on some combination of owned and leased land, including both private and public for their livestock operations (Sulak and Huntsinger 2007).

“Cattle, Sheep, Goats, and Horses: What’s the Difference for Working Rangelands?” -- livestock affects land and vegetation in several interrelated ways, including removal of leaves, stems, and other plants; removal or redistribution of nutrients; and mechanical impacts on soil and plants through trampling (Vallentine 1990). “Cows Need Water, Too: Water Sources, Wetlands, and Riparian Areas”, explains that cattle grazing around vernal pools also supports habitat quality for vernal pool fauna such as fairy shrimp and tadpole shrimp (Marty 2005). “Grazing Systems Management” helps to educate the public on improved forage productivity, soil health and biodiversity and the use of grazing systems. Much has been publicized about one grazing system versus another; this helps to define when and how to select a certain system. For example high density, short-term duration grasslands are largely unfounded (Briske et al. 2014) and may neglect the special habitat management needs of the individual or groups of endangered species, as required by regulatory agencies.

Conclusions and Implications

Whether working ranches are on public or private land, many Bay Area ranchers represent the fourth, fifth, or sixth generations that have stewarded the land and their livestock. These working ranches also contribute over $132 million per year to the Bay Area economy and represent the third-highest value agricultural commodity in the region (Bay Area County Crop Reports 2012). These ecosystem services also provide improved overall human health, through increased park and trail access. A more informed public will lead to a stronger social cohesion between beef cattle grazers and the park users. This is an opportunity to strengthen the health and outdoor connections on working landscapes, i.e. rangelands, through ecosystem services curriculum and interpretive trail signage. Interpretive signage entitled “Why Cows”, “California Grazing”, and “Sharing the Lands” will be placed at trail heads to ensure that optimal usage is obtained. Providing comprehensive, research-based information that promotes animal agriculture literacy is a key first step to educating park users, public and decision makers on the importance of grazing as a tool in urban and suburban societies.

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Economic Valuation for Improving the High Andean Wetlands Ecosystem around Huaraz City, Peru

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Key words: wetland ecosystems, willingness to pay, LOGIT model

Introduction

In Peru wetlands are natural "mattresses" formed over thousands of years that retain large amounts of water and are located in the Andean region, near lakes, rivers and streams that provide water to cities. These ecosystems are important natural resources in terms of ecosystem services, such as storage and water regulation, harm reduction of landslides and floods, purification of polluted water by precipitation, and for providing beautiful landscapes for recreation and tourism (Barrantes & Flores, 2013). In the case of "Huaraz" city, the structure and function of wetlands is being affected by impact of mismanagement, overgrazing, deforestation, land use changes and climate change. In this context, development of so-called "Sustainable Economic Activities" (SEA) is important for the region, since they allow to state socioeconomic development alternatives against the overuse of wetlands. SEA is a tool to promote implementation of projects that allow execution of environmentally sustainable economic activities. A good option to finance SEA projects is raising awareness of Huaraz citizens about the wetlands importance; also valuing their willingness to pay (WTP) for improving quality of environmental services provided by this type of ecosystem. In this study it has been used the contingent valuation method in order to determine the WTP for the design and implementation of a conservation programme for wetlands ecosystem environment in Huaraz city, Peru.

Method

To estimate WTP, a preliminary survey (pilot) of "open" format was applied to 200 people; then another final random survey was applied to 271 citizens of Huaraz city. Results of the preliminary survey were used to define an optimal vector of payments made up 8 "bids" (fees), which in turn allowed applying the final survey with a random distribution of "bids" among the sample participants (Cooper, 1993). To obtain final results, including the optimal WTP, it was used a probabilistic model, called Logit model, which is based on the Bishop-Heberlein theoretical proposal (Bishop & Heberlein, 1979). The estimated dependent variable was the probability of the WTP, which is explained by a set of explanatory variables. Operational Logit model equation is as follows (Alarcón & Nolazco, 2014):

$$Ln\ \frac{P_i}{1-P_i} = L_i = \alpha + \beta X$$

Where P_i represent the probability that individuals pay the bid, X is a matrix of independent (environmental and socioeconomic) variables.

Results & Discussion

Logit model results express an expected inverse relationship between WTP and the suggested payment rates; it means that the higher the fee, the lower the WTP (Table 1).

Table 1. Proportion of responses to the rates (bids).

Would you pay ? (S/.)	Responses (%)			Proportion
	No (%)	Yes (%)	Total Number	
≤ 1	21%	78%	21	0.08
2	33%	67%	21	0.08
3	57%	43%	30	0.11
5	55%	45%	44	0.16
8	85%	15%	99	0.37
18	88%	13%	56	0.21
Total	*185*	*86*	*271*	*1.00*
%	*68.3*	*31.7*	*100.0*	

The most important determinants in explaining WTP are a set of "appreciation" variables (by population) about importance of wetlands for their region. Socio-economic variables, such as income, age, education, were not significant explaining the WTP variation.

The best statistical estimation of the WTP was provided by the median, which was calculated at US$ 1.05/family/month; reveals that the Ancash Region could raise approximately US$ 312,266 per year (Table 2). Being the sample a random representative portion of Huaraz population, and considering that this population (households) is approximately 24,783 families (INEI, 2012), it could be inferred that if a homogeneous "flat" rate of US$ 1.05 were applied to all families, it could be collected a total monthly amount of US$ 26,022, making an annual value of US$ 312,266. Under the assumption that Peruvian government, private companies, and citizens should finance the costs of implementing a SEA improvement program, in equivalent amounts, and considering that approximately 67% of respondents indicated that would pay the rate, then it would be possible to obtain up to US$ 936,797 to implement a significant SEA project in the wetlands conservation of Huaraz.

Table 2. Valuing measures of wetland services in Huaraz city, Peru (In US$ dollars; confidence intervals with α=0.10).

Indicator	LOGIT Lineal (US$) $\Delta v = \alpha - \beta A$	LOGIT Log (US$) $\Delta v = \alpha - \beta(LnA)$	WTP amount per month (000 US$)	WTP amount per year (000 US$)
Median (Me)	1.06	1.05	26.0	312.0
Mean	1.06	1.41		
Confidence Interval (Me)	[0.62 – 1.48]	[0.71 – 1.40]	[17.6 – 34.7]	[211.2 – 416.4]

Conclusions and Implications

Results have indicated that most of population consider the wetlands around Huaraz as important ecosystems that are under threat and must be preserved to continue providing essential environment services and amenities (70% of interviewed Huaraz citizens visit the wetlands an average of 2.1 times a year), and there is a large fraction of population willing to pay monetary resources for conservation. Economic valuation is important but could be considered the beginning of a process that will end successful if steps leading to success are also completed. Economic valuation eventually will be useful if it can be continued with: (i) clear identification of potential results of conservation project, (ii) implementation of actions that create awareness of population, (iii) monitoring and tracking applicability of the wetlands ecosystem conservation programme.

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3.4 Professional Extension and Technology-transfer

Western Beef Development Centre 1998 to 2018: Combining Research and Extension for the Benefit of the Saskatchewan Beef Industry

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Key words: Extension, applied research, beef cow-calf, grazing, economics

Introduction

The Western Beef Development Centre (WBDC) is a unique and evolving partnership among industry, government, and academics that has successfully provided applied research, extension, and demonstration in beef cow-calf production and grazing research for Saskatchewan for nearly 20 years. Currently it is a division of the Prairie Agricultural Machinery Institute (PAMI) and conducts its research at Termuende Research Ranch near Lanigan, Saskatchewan. In 2018, the WBDC will be combined with other units at the University of Saskatchewan to create the new Livestock and Forage Centre of Excellence located at Clavet, Saskatchewan.

1998 to 2005

Western Beef Development Centre Inc. started in 1997 because key stakeholders shared a vision for enhancing technology transfer to primary producers. The beef industry partnered with the provincial government of Saskatchewan's Ministry of Agriculture and the University of Saskatchewan to provide a focus for applied research, extension, economics, and demonstration to the province's beef cow-calf and forage producers.

The University of Saskatchewan (U of S) had a cow-calf research facility at the Termuende Farm located at Lanigan, Saskatchewan, which is approximately 120 km east of its main campus in Saskatoon. The Termuende family had donated the farm to the University in the 1970s for the sole purpose of beef cattle research. Rising costs and distance from campus forced the University to suspend research operations at the farm. Not wanting to sell the gifted property, the University faced the continuing costs associated with maintaining the farm. The idled facilities waited silently for a new vision and a new purpose while the political and commercial interests began to coalesce in a new direction.

The beef industry producer groups had become concerned about the future of research with the closure of the beef and forage program at the Agriculture and Agri-Food Canada (AAFC) Research Farm at Melfort, Saskatchewan. That program had conducted research relevant to the Parkland region of Saskatchewan in forage feeding and finishing research as well as pasture management. The producer groups controlled sizeable funding through the Cattle Marketing Deductions Fund and Horned Cattle Penalty Fund, a $2 per head levy collected from producers selling animals that had horns. The groups also owned a cow herd that AAFC Melfort researchers had used for research and demonstrations. Wanting to continue to make use of the herd and the collected penalty funds, the producer groups approached the provincial government with a vision.

Around the same time, the provincial Ministry of Agriculture was reducing its extension efforts, both in number of service locations and number of staff, due to budgetary constraints. It was looking to industry for expertise in beef production and extension that would be external to it, but available for all producers. The Ministry was willing to provide grant funding towards a new mechanism for extension.

All three partners agreed to form Western Beef Development Centre Inc. with each partner represented on the Board of Directors. The U of S provided the use of the Termuende Farm, the provincial ministry provided seconded extension staff and an operating grant, and the producer checkoff owned herd was transferred from Melfort to Termuende Farm. Under the leadership of Dr. George Lee, a retired agricultural economist, the WBDC undertook many projects. Project funding was obtained from CARDS (Canadian Agriculture and Rural Development Saskatchewan), Ducks Unlimited, Cattle Marketing Deduction Fund (CMDF) and AgriFood Innovation Fund (AFIF).

Forage crop demonstrations were seeded, cost of production (benchmarking) surveys were conducted to help producers improve profitability, and cow-calf management schools for producers were held in regional centres across the province. Water development, manure composting, manure as fertilizer, corn grazing and fencing technology for rotational grazing were demonstrated. Annual Field Days at the Termuende Farm became a centre piece of technology transfer. Between 2002 and 2005, 46 factsheets summarizing research results were published (WBDC 2016).

2006 to 2016

In 2006, WBDC transitioned to the Prairie Agricultural Machinery Institute (PAMI) after the Saskatchewan government expanded PAMI’s mandate to include beef research. An advisory committee representing industry, government, and academia meets with WBDC researchers twice a year and reports to the PAMI Board of Directors. Dr. Bart Lardner, originally seconded from the Ministry of Agriculture to WBDC Inc., became the Strategic Research Program (SRP) grant funded chair in Beef Production and Nutrition and Tim Highmoor became the SRP chair in Beef Economics. After Mr. Highmoor’s departure, Kathy Larson joined WBDC as the Beef Economics Chair in 2010. Dr. Paul Jefferson joined as Vice-President, Operations in 2007 and has contributed to forage crop research projects. The program has generated 55 research or demonstration projects during the last nine years from many funding sources (see Table 1). Several projects have support from both producer research funds and government funding, which demonstrates industry’s support for the project.

Research and demonstration ideas are presented to and gathered from the WBDC advisory committee. The committee’s input ensures that the proposed projects are relevant to industry. WBDC researchers then submit project proposals to the appropriate funding agencies. While presentations by WBDC researchers at producer meetings and at the Annual Field Days continue to be effective. Technology transfer vehicles such as webinars are also an effective way to share research with dispersed audiences. Factsheets (45 from 2006 to 2016) continue to be published on the website (WBDC 2016), but short videos of research results posted to Youtube™ have also become part of the research extension efforts. One video has received close to 35,000 views as of February 2016. WBDC also has embraced social media as a way to connect with producers, with Twitter and Facebook. Lastly, 20 graduate students from the U of S have been trained in various research projects and also present their results at industry and academic venues as part of WBDC’s goal to train highly qualified personnel.

Conclusion (2018)

Change continues; WBDC’s research program, resources, and staff are preparing to transition from PAMI’s leadership to the Livestock and Forage Centre of Excellence at the U of S by March 2018. The vision of this new initiative is to build on collaboration in applied research and extension with discovery science to better serve the Saskatchewan beef industry in the 21st Century.

Table 1. Number of Projects Funded by Funding Source.

Project Funding Sources	Number of projects
Agriculture Development Fund (ADF)	29
Agriculture Demonstration of Practices and Technologies (ADOPT)	10
Merck Intervet	4
Beef Cattle Research Council (BCRC) **	4
Saskatchewan Beef Industry Development Fund (SBIDF)**	3
Alberta Livestock Meat Agency (ALMA)	3
Horned Cattle Penalty Fund (HCPF) **	1
Canadian Agricultural Adaptation Program (CAAP)	1
Novartis	1
Prairie Farm Rehabilitation Administration (PFRA)	1
Total	55*

*number is lower than column total due to joint-funded projects. **Producer checkoff funds

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The Use of a Knowledge Broker to Counteract Remoteness in Delivering Appropriate Climate Change Knowledge in the Australian Rangelands

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Keywords: Rangeland, technology transfer, natural resource management

Introduction

This paper considers the impact of a knowledge broker in coordinating a cross-disciplinary project to overcome issues of remoteness to improve knowledge transfer, using the Rangelands Cluster Project (RCP) as a case study. The RCP aims to deliver climate change science and research for regional natural resource management (NRM) planning in Australian rangelands. Prior to the project, climate change information was not being transferred to and adopted by the NRM community. The Rangelands Cluster encompassed a huge area of Australia across its most remote environments and sparsest populations. A knowledge broker was used to achieve the following objectives: 1) identify climate change information needs, 2) provide quality information for incorporation into NRM planning, and 3) establish enduring networks of researchers and NRM planners.

Materials and Methods

The Rangelands Cluster Project (RCP) was one of 8 cluster projects funded through the Australian Government's Regional Natural Resource Management Planning for Climate Change Fund. At 4,519,756 km^2 the Rangelands Cluster is the largest consisting of 7 regional NRM organisations in Australia's arid and semi-arid zones. Most project scientists work outside the cluster boundaries.

The RCP was a collaboration of the Rangeland NRM Alliance, CSIRO, University of Canberra and Ninti One. The project aimed to improve the information available for regional NRM planning for climate change. Ninti One managed the project and created the independent knowledge broker position to facilitate the connection between project participants (Fig. 1).

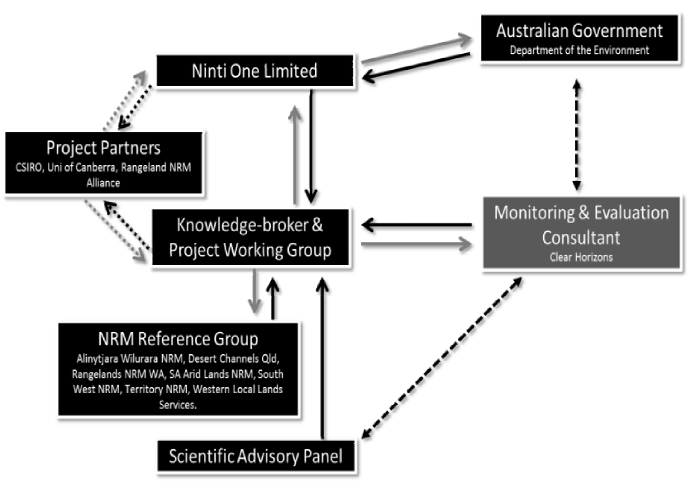

Figure 1. Rangelands Cluster Project (RCP) connection.

NRM is complex and involves social, economic and environmental considerations, which makes it difficult to ensure that the knowledge required to underpin effective NRM is available to those who need it (Pettit *et al.* 2011). In the RCP, an independent knowledge broker with extensive NRM experience and networks was employed to facilitate connections between climate change scientists and regional NRM planners. This was to address the reco-gnised gap between the disciplines and support work across vast distances. The knowledge broker managed day-to-day mechanics of the project: providing a central point of contact; arranged workshops at which scientists and NRM planners identified needs and available information; managed processes to share information; represented the RCP at national meetings and coordinated production materials.

Results and Discussion

The RCP implemented an engagement process that acknowledged and mitigated the potential reasons for climate change adaptation not being transferred to the NRM community: researchers and NRM staff (1) came from various disciplinary backgrounds using different technical languages and operating styles; (2) came from different work environments; and (3) had different aspirations, time frames and stakeholder responsibilities. In addition to the above, the very nature of the arid and semi-arid rangelands environment in Australia contributes to the difficulty in extending information regarding climate change. Stafford Smith (2008) describes the 'Desert Syndrome' — a range of causally linked factors that include climate variability, scarce resources, sparse population, remoteness, social variability, local knowledge (limited research knowledge and persistent local knowledge) and cultural differences. Stafford Smith states 'that the key consequence for desert people is that they should put more time into planning for and managing their apparently careless treatment by the environment and bureaucracy, and less time railing against it, because it will not go away'. In the RCP context, the existing structures of regional NRM organisations were used, with the knowledge broker as central coordinator, to provide local advice on how to operate appropriately to meet the project objectives. This allowed local knowledge of how to interact with a vast amount of scientific knowledge to produce excellent user friendly products. The project used a comprehensive monitoring and evaluation framework to track activity progress and successful use of products.

Effective knowledge brokering provides the means for partnering and collaborating in different ways to find solutions to difficult problems. It also deliberately establishes networks and builds trust and relationships to encourage interactions between different disciplines. Collaborating and building trust are important for ensuring information credibility and legitimacy, particularly when linking science and technology to sustainable development (Cash *et al*. 2003). Here climate projection modellers, rangeland scientists and NRM bodies had not met and yet expected each other to interact with their information or needs. This had not occurred despite the NRM bodies needing the information to plan and scientists wanting communities to consider climatic impacts in planning. It is only after direct investment and use of a knowledge broker that this was achieved.

Conclusions and Implications

This project demonstrates how investing in a knowledge broker can achieve effective delivery of results even with distant and diverse participants. Facilitation by the knowledge broker allowed clearer communication between parties who were very remote and worked in different disciplines, ensuring relevant scientific information was presented to end users in a format they could use. The project has achieved its aims for rangeland climate change information preparation and dissemination. The program and project included comprehensive monitoring and evaluation that included stakeholder surveys and interviews, which supported anecdotal positive messages received from NRM planners and scientists. The innovative use of a knowledge broker to manage continued interaction between the parties forged relationships, built trust and empowered all partners to better deliver the project objectives.

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Evolving Deployment of Extension Resources for Rangelands in Wyoming: Moving from County Generalist to Regional Specialist

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Introduction

Extension programs in the 21st century have had to adapt organizational models to deal with contracting budgets, dynamic technology delivery, and changing social needs (Milburn et al. 2010). These changes could be particularly problematic for users of rangelands because rangelands lack the vertical integration and commodity support that provides alternative sources of information for, as an example, traditional row crop agriculture. Some states, such as Wyoming, have transitioned to a multi-county educator model with a higher level of subject matter expertise (i.e., regional specialist). Other states have retained the traditional generalist educator model with broader subject matter expectations (i.e., county generalist), such as Texas and Utah. This paper will examine the impetus and process of the organizational change in Wyoming in the context of rangeland Extension education and outreach. We will also assess these organizational changes relative to our experiences with different organizational types of Extension programs in other states.

Impetus for Change and the Stakeholder Input Process

The impetus for change in most states, including Wyoming, was largely financial driven due to shrinking availability of funds for the existing generalist model. This financial constraint was inhibiting effective program delivery across the state. In response to these stresses, the University of Wyoming Extension (UWE) began to re-consider its organizational model around 2000. The first step was to ask current employees for input and comments on a new organizational model. A draft plan was then presented to county government including commissioners and community leaders and revised. The draft plan then was reviewed by a "Blue Ribbon Task Force" made up of citizens and clients of UWE appointed by the University president. This task force also traveled to other states that had adopted similar organizational changes and additional revisions were suggested. In 2002, UWE re-defined jobs of existing employees to capture the regional specialist model, and in doing so, developed five State Initiative Teams to place this new organizational structure in a team-based leadership model. One of these teams was the Sustainable Management of Rangeland Resources (SMRR) team. After two years, job expectations were ramped up to reflect new job definitions, and after two more years, the expectations began to carry consequences for job-related performance in the context of the new organizational model.

Sustainable Management of Rangeland Resources (SMRR) Plan

The primary intent of the SMRR team was to address the substantial influence of rangelands in Wyoming on local economies, quality of life, and the culture of the state (SMRR Initiative 2015). Because rangelands are critical for agriculture but also for biodiversity, a distinction from more traditional agricultural teams, a clear integration of production and conservation was also articulated in the plan, "*Livestock production is largely dependent upon native rangelands, which also provide critical wildlife habitat, water resources, oil, gas, mineral reserves, and recreational opportunities.*" (SMRR Initiative 2015). The plan had five objectives (summarized): (1) address rangeland resource issues through integrated educational approaches to meet the complex needs of statewide clientele, (2) address rangeland resource issues through participation and leadership in collaborative processes such as coordinated resource management, (3) develop educational programs for non-technical audiences to increase understanding and appreciation for sustainable rangeland resource management, (4) educational programs for agricultural producers, landowners, and other resource managers will promote natural resource sustainability and stewardship, and (5) educational programs will address public policy influences on resource management in the state. Currently there are 8 SMRR Extension educator positions serving Wyoming's 23 counties.

Challenges

Change is always challenging, and the organizational change for UWE was no exception. However, one aspect to the organizational changes that may have minimized the challenge was the maintenance of a youth development presence in every county through the 4H program coupled with the deployment of specialists across multiple counties. In other words, the evolution to a multi-county specialist model was successful in Wyoming because linkages were maintained with the local and general needs of county through youth development and UWE resources housed locally. The perception by UWE administrators was that local stakeholders still wanted Extension and were supportive but the delivery may not have been the most effective — support and criticisms that were part of the impetus for change. Another challenge for organizational models is for the existing employee base to embrace the new model and job expectations. The narrowing of job focus and expectations can be difficult for a generalist educator who has a broad range of interests and abilities. These types of employees likely have a high motivation of service and a desire to respond to every type of issue that can come up — from dying rose bushes to feeding 4H show pigs. However, over time as employee turnover has occurred, UWE has started hiring candidates that were seeking the specialist type of position. These new employees have at least one degree in rangeland ecology and management and all have master's degrees. Once the proportion of teams tipped to a majority of employees desiring the specialist type of position, the new organizational model began to realize many of its objectives.

Advantages and Examples of On-the-Ground Impacts

An advantage has been elevating Extension educators to a higher level of expertise and recognition in the state. Many educators lead cooperative rangeland monitoring and many educators now routinely present at state-wide conferences. The new model has also created a more nimble agency that can respond rapidly and effectively to rangeland issues. For example, we have put teams on the ground, including campus-based rangeland professors/specialists and multi-county educator specialists, to address concerns about larkspur (*Delphinium* spp.) toxicity in the Bridger-Teton National Forest and rangeland monitoring and public allotment grazing management in the Bighorn National Forest. Moreover, this model structure has shifted programming expectations from serving all of the potential needs in a county, to addressing the greatest rangeland resource management challenges across a region. This has led to educators seeking grants to fund applied research on subjects like grazing timing and animal performance and rangeland monitoring. Fourth, the new model has created a more effective state-wide team relative to the evolution of institutional expectations for campus-based rangeland professors/specialists. Finally, the specialist model is optimal for rangeland resource needs because the generalist model may foster educators with a preference for a particular programming areas (such as youth livestock exhibition) yet neglect the complex natural resource issues that occur in every county.

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Pasture and Grazing Management Extension Programing in Northwestern USA

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Key words: Workshop, training, syllabus

Introduction

A needs assessment survey indicated an opportunity to provide education and training in support of improved pasture and grazing management. The highest priority topics, scored from 0= no need to 5= high need, and score in parentheses were: establishment and inter-seeding (4); irrigation and water requirements (3.9); soils, fertility, and nutrient management (3.8); integrating fence and livestock water development (3.8); and weed management (3.8). The target audience was Extension educators; Natural Resource Conservation Service and Conservation Districts personnel; forage seed industry representatives; and other USDA, state, and local personnel. The main objective was to improve extension and USDA personnel understanding and implementation of the principles of management intensive grazing featuring multi-day workshops conducted on demonstration ranches; hands-on workshops on cooperator's operations with a western perspective.

Methods

Five workshops were presented in Idaho, Washington, Oregon, Colorado, and Utah. The seminar / workshop used extension, USDA-ARS, NRCS, forage seed industry, and integrated producer instructors as needed. The detailed class syllabus and program has been revised based on evaluations and experience with the workshops and the needs assessment. The curricula was designed to include about half of the time in a lab or field environment where students get hands-on experience. The program provided 12 hours of classroom lecture and discussion and 10 hours of laboratory and field demonstrations and exercises.

This program provided comprehensive and focused training on genetics and seed certification; growth, development, and defoliation responses of grasses and legumes; irrigation management; forage seed and seedling identification; plant identification and morphology; measuring sward characteristics; soils, fertility, and nutrient cycling; sustainable systems; nutritional needs of grazing animals; insect and vertebrate pest management; weed management; pasture establishment and inter-seeding; optimizing net carbohydrate assimilation; integrating fence and livestock water developments, stocking rate, carrying capacity, and animal performance; inventory and using the grazing wedge; applications of behavioral principles; economics; elements of management-intensive grazing; horse pasture management; allocating forages; and monitoring pastures. This integrated curriculum is not available in land grant universities and not widely dispersed through private contractors.

There are some local or state programs for educating and training producers, but no well-organized or developed training for grass physiology in relation to grazing, plant materials available including legumes in mixes, fertilization, irrigation, and grazing management. It would be difficult for a single state to develop a viable program, but combining the resources and personnel from western universities and USDA provided a viable professional training program in the West.

Outcomes and Impacts

As a result of implementing our professional development program, extension educators and NRCS personnel have a greater awareness of forage agronomy, pasture production, and their relationship to grazing. This will lead to extension of that knowledge and skills to producers who will have a greater awareness and understanding of the economic, ecological, and social benefits of intensively managed permanent pastures.

Accomplishments

Five workshops were completed in regional areas of the Northwest USA and trained a total of 165 professionals with 29% average gain from pre- to post-tests (Table 1).

Table 1. Location, professionals educated, and gain in score from pre-to post-tests by the pasture and grazing management training workshops.

Location	University/ Extension	USDA-NRCS/ CD	Industry	State	Pro-ducers	Total	Gain in score (%)
Salmon, ID	14	12	2			28	33
Ft. Collins, CO	23	17	9			26	33
Dallas, OR						23	25
Mt Vernon, WA	18	29	2	3	5	57	25
Logan, UT	20	10	1			31	30
Total	75	68	14	3	5	165	

Producers who implement managed grazing practices may reduce annual cow production cost by up to $100. Improvement in economic condition will be the result of increased carrying capacity of pastures due to: 1) higher harvesting efficiency and greater photosynthetic capacity due to managed grazing; 2) increased understanding of managed grazing systems; 3) placing higher value on maximizing pasture productivity; and 4) extending the grazing season which can reduce winter feed costs.

Number of Acres/Animals Impacted: The 2007 Ag Census indicates Alaska, Washington, Oregon, Idaho, Montana, Wyoming, Colorado, and Utah have 48 million hectares of pasture and grazing land. Assuming 4 ha per animal unit for a grazing season this grazing land could support up to 12 million AU. If $100/AU savings were realized, this would be a $1.2 billion savings to livestock producers.

Conclusions and Implications

There are portions of our workshops taught at some land grant universities, but not in a comprehensive pasture and grazing management workshop. In addition, many range management and animal science majors do not have an opportunity to learn pasture and grazing management. Further, most forages or range science curriculum merely introduce grazing management but do not cover the important principles. There will be a continuing need to provide workshops in this area in the foreseeable future.

Acknowledgements

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The Impact of Applied Research and Forage Associations Extension Network on the Viability of Alberta Farmers and Ranchers

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Key words: Agriculture, extension, grazing, forage, network

Introduction

Applied research and forage associations were established by Alberta producers to connect agricultural research with local production conditions. Since the late 1900s, Alberta's forage and applied research associations have been delivering information on the most current innovations in forages, grazing and livestock to farmers and ranchers across the province. The maintenance of healthy forages and grasslands have a positive impact on the environment, society and Canada as a whole. The information that has been attained through laboratory and field-scale research on forages and grasslands is extensive, but is that information reaching those who can implement new ideas or practices? Extension to farmers and ranchers is a key component in the viability of agricultural research that is often overlooked. Alberta is home to 12 applied research and forage associations that form a network of extension across the province. Through field tours, workshops, conferences and field schools, these associations bring new ideas and innovations in forages and grazing to the farmers and ranchers who will implement them on their operations.

Materials and Methods

Alberta's forage and applied research associations have a strong extension program at both the individual association level and province-wide. Each association's extension tools vary at the local level, including newsletters, field days, workshops, tours, websites, social media (Facebook and Twitter), conferences, as well as one-on-one interaction with local farmers and ranchers.

Results and Discussion

The results of this network of collaboration are extensive, including:

- Alberta Soil Health Initiative
  - When the United Nations proclaimed 2015 the International Year of Soils, nine regional research and forage associations formed the Alberta Soil Health Initiative. Throughout 2015, these associations hosted provincial, national and international experts on soil at both regional and province-wide events. These events included Peter Donovan of the Soil Carbon Coalition and Dr. Christine Jones, founder of Amazing Carbon.
  - Western Canada Conference on Soil Health culminated the year in Edmonton on December 9th, 10th and 11th 2015. Over 400 producers, industry and academia attended the conference and speakers included Dr. Yamily Zavala, Gabe Brown, Dr. Jill Clapperton, Dr. Allen Williams, Neil Dennis, Jay Fuhrer and Dr. Jeff Battigelli.
- Western Canadian Grazing Conference
  - Held every 2 years, this highly anticipated conference attracts over 200 farmers and ranchers from across Alberta to hear speakers such as Josh Dukart, Dylan Biggs, Jim Bauer and Judith Schwartz.
- Stockmanship Clinics with Curt Pate

  - Curt Pate's personal experience incorporating effective stockmanship principles supports a for-profit mindset and focuses on highlighting the increased economic benefit of handling stock correctly.
- Pasture Walks with Jim Gerrish
  - Jim Gerrish is dedicated to improving the health and productivity of grazing lands around the world through the use of management-intensive grazing practices.
- Perennial Forage Project
  - There has been a gap in perennial forage production knowledge in Alberta and this project, beginning in 2016, will provide farmers and ranchers with performance information on a number of grass and legume varieties by testing cultivars for regional adaptation.
  - A number of field days will focus on the trial across the province and producers will have access to data that is applicable to their local region.
- Improving knowledge and skills of staff
  - Continuing education of forage and applied research association staff is essential to ensure the most accurate and relevant information is provided to Alberta's farmers and ranchers.

Conclusion and Implications

The ability to extend current agricultural research results, new technology and new innovations to farmers and ranchers is an important step in the road to adoption. Alberta's forage and applied research associations provide a valuable extension network across the province and are an established source of unbiased agricultural information.

The Ranching Sustainability Self-Assessment Project

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Key words: Range management, land stewardship, ranching sustainability, self-analysis

Introduction

The California Mediterranean type annual rangelands provide essential ecosystem services and the public with beautiful scenery and economic values through ranching. Ranchers however, come under intense pressure and scrutiny from the public to demonstrate stewardship of the land they manage. The solution often chosen to address these concerns is, put simply, more and more regulations. Regulations impose a financial and philosophical burden on California ranchers; in fact, they threaten the very existence of ranching along with the conservation and economic values it provides.

Materials and Methods

This paper updates the on-going implementation of a self-assessment project that can help ranchers demonstrate their good stewardship. The Ranching Sustainability Self-Assessment (RSA) project was developed by the University of California Cooperative Extension, USDA Natural Resource Conservation Service, and importantly, a group of area ranchers on the California Central Coast as one a method for ranchers to evaluate whether they are managing properly. The mission of the RSA project is to create and implement a voluntary self-assessment program in which ranchers can evaluate all aspects of their operations to ensure the sustainability of their production, lands, and families. In other words, the RSA is a self-help program that enables ranchers to determine what they do well and to find ways to ensure proper stewardship of themselves, their animals, their business, and their natural resources.

The RSA project, is a process that guides the rancher through a series of assessment questions that cover the social, economic, and natural resource aspects of 11 ranch-management categories including: Livestock Management; Soil Management; Forage Management; Biodiversity/Wildlife; Regulations; Family and Professional Relationships; Economics; Energy; Monitoring; Pest Management; and Water Quality. The self-assessment process has a “positive points” philosophy that recognizes existing efforts of landowners and land managers, and motivates them to continually enhance the sustainability of their ranches. Ranching does not lend itself easily to a “one size fits all” approach, therefore, the expertise of the ranchers, and their in-depth, long-term knowledge, of their own lands is vital to this process. There are up to 9 questions per category, 78 total. Users score their practices from 1 to 7, e.g. poor to excellent, (Larsen et.al. 2015). It takes approximately one hour for a rancher to complete this assessment.

Results and Discussion

Essential components for the ongoing implementation of the RSA project have been the strong support of an ad hoc Committee of ranchers, delivery through a series of Workshops, San Luis Obispo County

Cattlemen's Association support, and voluntary participation. Recently, the California Grazing Lands Conservation Initiative (GLCI) has partnered with the RSA to expand this project statewide. The GLCI is using a grant to link key words in the RSA document with sources of further information.

To date many ranchers have preferred to keep their RSA scores for their own use. However, some ranchers have begun to submit their results into a confidential database. Anonymous summary scores allow researchers to compare scoring of individual operations (Figure 1A). As ranchers submit their yearly results, researchers will be able to determine how much improvement is occurring over time. Not only can ranchers track and fine tune their own sustainability progress over time, this will also allow them to compare their results with their peers, and share their success with regulatory agencies, and the public.

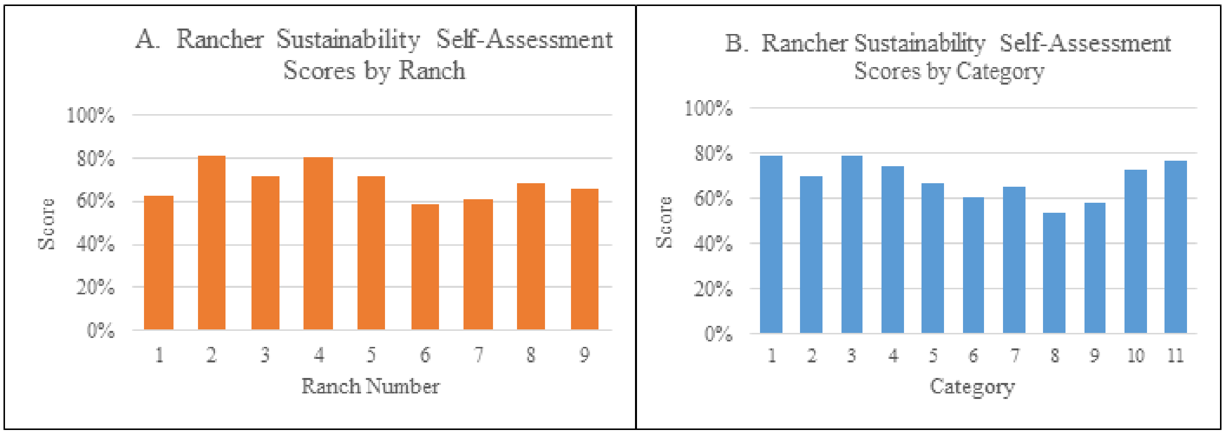

Figure 1. A - Scores from 9 individual ranches, shown as percent of possible points. B -Scores for individual categories from 9 ranches. The categories are: 1-livestock management, 2-soil management, 3-forage management, 4-biodiveristy/wildlife management, 5-regulations and regulators, 6-relationships-family, employee, community, 7-economics, 8-energy, 9-monitoring, 10-pest management, 11-water quality, shown as percent of possible points.

Another important benefit of the RSA is that it reveals to professional Coopereative Extension educators which RSA topics are important for outreach programs such as workshops, field days, and webinars. For example, the early results show that the categories of livestock management, forage management and water quality are scored the highest, while the cateogoreis of energy and monitoring are scored the lowest (Figure 1B). Therefore, an education program on the lowest scored topics may be priority.

Conclusions and Implications

The RSA allows a rancher to evaluate his, or her, own ranch to to improve it's management, thus keepinig their operation sustainable. Scoring within each category, and even each individual assessment question can guide the development of needed workshops. This information will not only help individual ranchers improve management over time, it can also help the ranching industry demonstrate their stewardship to the public and regulators. This process is on-going, and changes to the project can be made as needed. Though the RSA was developed for California annual rangeland ecosystems, it could be easliy adapted to other areas. A copy of the entire RSA document can be found at: **http://ucanr.edu/rsaselfassessment**

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Two Different Approaches to Maintaining the Genetic Purity of Forage Cultivars in Italy

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Key words: Genetic purity, forage cultivars, Italian ryegrass, alfalfa

Introduction

In all industrialized countries, a cultivar for arable species is defined as being Distinct, Uniform and Stable (DUS) and having Value for Cultivation and Use (VCU). Any material that does not meet these two requirements cannot be marketed (Desclaux et al. 2008). Also in Italy all varieties listed in the National Register must maintain genetic integrity. When applying for registration, the breeder, or the holder of the variety, should indicate: i) the name of the maintainer of the variety; ii) where the conservation is carried out; iii) the method used for maintenance. In order to preserve the genetic purity of a cultivar during the seed production phases, it is necessary to know what type of material is being grown. Forage species are generally cross-pollinated and cultivars are synthetics or improved populations from mass selection or recurrent selection. The genetic structure of this type of cultivar can change during the seed production phases because of some genetic events (mutations, segregation), genetic shift (climate changes, environmental selection pressure) and mechanical mixing (during sowing and harvesting). Varietal purity is maintained by following two strategies. The first strategy consists of conservation of the seed foundation by freezing; the amount of this seed must be enough for field establishment to produce certified seed. The second strategy is conservative selection in the field. This paper reports the use of the two different approaches in relation to certain cultivars of forage species (grasses and legumes). The first strategy was carried out on Italian ryegrass (*Lolium multiflorum* Lam) and the second on alfalfa (*Medicago sativa* L.).

Materials and Methods

First strategy: Conservation of the seed foundation of Italian ryegrass varieties by freezing

The seed foundation of fifteen Italian ryegrass varieties was maintained in a freezer (at -18°C) at the Germplasm Bank of the Department of Agricultural, Food and Environmental Sciences of the University of Perugia (Italy). The conservation consisted of several steps: after harvest, the seed was processed and examined for purity and viability. It was then dried at room temperature (20-25 °C) to reach 7-8 % RH (using silica gel desiccant). The seed was then weighed and vacuum packaged and the storage containers were sealed and put into storage at -18°C. The amount of stored seed was approximately 2.5 kg subdivided into ten 250g packets. This type of storage practice allows new fields of multiplication to be established.

Second strategy: Conservative selection of alfalfa varieties in the field

In the spring of 2012 about 1,000 plants, obtained from the seed foundation of four alfalfa varieties, three from Northern Italy and one from Central, were transplanted in experimental fields located in the areas where the varieties had developed. The experimental fields were logistically isolated from other potential sources of alfalfa pollen contamination. In both experiments, plants were established in a spaced plant design with 90 cm between plants in both directions. During the 2012-2013 and 2013-2014 seasons, a negative selection was made by removing out-type plants. Specifically, diseased plants, and those that had yellow and variegated flowers, as well as all those that differed from the ideotype for traits like vegetative regrowth, leafiness, plant habit and flowering time, were eliminated. In July 2014 seed was harvested from the remaining plants. Part of the harvested seed was stored in the freezer and the remaining seed will be used to establish fields to produce certified seed.

Results and Discussion

The two methods described above are used for maintaining genetic purity throughout the entire time that the varieties are registered in the National Register (10-15 years). Specifically 15 varieties of *L. multiflorum* and 4 varieties *of M. sativa* are maintained. These methods are very important to guarantee genetic integrity to growers, processors and consumers. The method described in the first strategy is an *ex situ* conservation in gene banks and supports genetic integrity, the security of varieties, and easy access. The second strategy may be compared to an *in situ* type of conservation, although the elimination of out-type plants allows the ideotype of the variety to be maintained.

Conclusions

The two conservation strategies are complementary and both of them should be used to safely maintain the genetic purity of forage cultivars. This is especially true for Italian ryegrass and alfalfa varieties where the reproduction system influences the genetic structure during the different phases of seed production.

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Improving Producer Profitability and Rangeland Management through Professional Extension Methodology and Technology Transfer in the Australian Gulf Savannas

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Key words: Business performance, cattle, rangelands management

Introduction

The Northern Australian beef industry relies primarily on native pasture systems and studies continue to report a decline in the condition and productivity of important land types in the region (Gobius, 2013). Poor profitability and declining equity are common issues for most beef businesses in the region (McLean et al., 2014). This project examined the complexity of 18 extensive beef businesses in the northern Gulf region of Queensland, Australia. Economic and seasonal pressures drive decision making that impacts on land management and environmental outcomes. We propose that natural resource management programs must be delivered within a whole of business framework to positively influence stocking rate and grazing management practices.

Materials and Methods

This project was conducted from 2013–2015 and included business performance data from the previous five financial years (2008/2009–2012/2013). Expertise was sourced and then assembled through collaborative projects (Tropical Savanna Grazing and Climate Clever Beef) involving Department of Agriculture and Fisheries (DAF), Northern Gulf Resource Management Group (NGRMG) and the NRM Spatial Hub. The consultant-mentor approach used by Coutts and Roberts (2003) was used with 29 businesses, who each manage on average ~ 38,000 ha and ~ 2,680 adult equivalents (AE = 450 kg steer at maintenance), with average business value approaching $10M. On-property sessions were conducted to discuss and analyse sensitive personal and financial information. Profitability, herd performance and greenhouse gas (GHG) emission benchmarks were documented and discussed.

A subset of four breeding businesses was selected to benchmark enterprise GHG emissions. These properties represented a range of regional production efficiencies (weaning, growth and death rates) and turnoff ages. The project estimated tonnes of carbon dioxide equivalents (t CO_2e) per year, per AE and per tonne of live weight sold from each business.

Results and Discussion

All businesses appreciated the targeted on-property approach and embraced the whole of business analysis. The diverse skill base and collective expertise of the delivery team was critical in building the trust and rapport necessary to collect and analyse sensitive information. The study group properties (39) from 18 beef enterprises covered an area of 1.104M ha and represented 29 families and 56 full-time equivalents (FTE). Most businesses operate a breeding enterprise in the Gulf and one or more finishing properties located outside the region. The combined assets and liabilities were in excess of $170M and $54M respectively. On average, each family had assets of $9.4M and liabilities of $3M. Low profitability and significant liabilities led to most businesses negotiating interest-only terms with their respective lenders. Only two businesses were making principal repayments. The mean annual interest rate was 6.1%.

The biplot (Figure 1) displays the results of the principal components analysis (PCA), plotting the first two principal components for 25 variables associated with 18 extensive beef businesses (producers). The biplot reveals a number of inter-relationships between the variables; the most prominent included a cluster (group) of variables related to scale of operation (e.g. many properties, large asset base, large herd size, more staff and more debt). A second cluster of correlated variables show the three 'industry recognised' herd performance drivers of profitability—weaning rates, mortalities (measured as female sales percentage) (F_Sales) and annual average live weight gain (Ann_LWG).

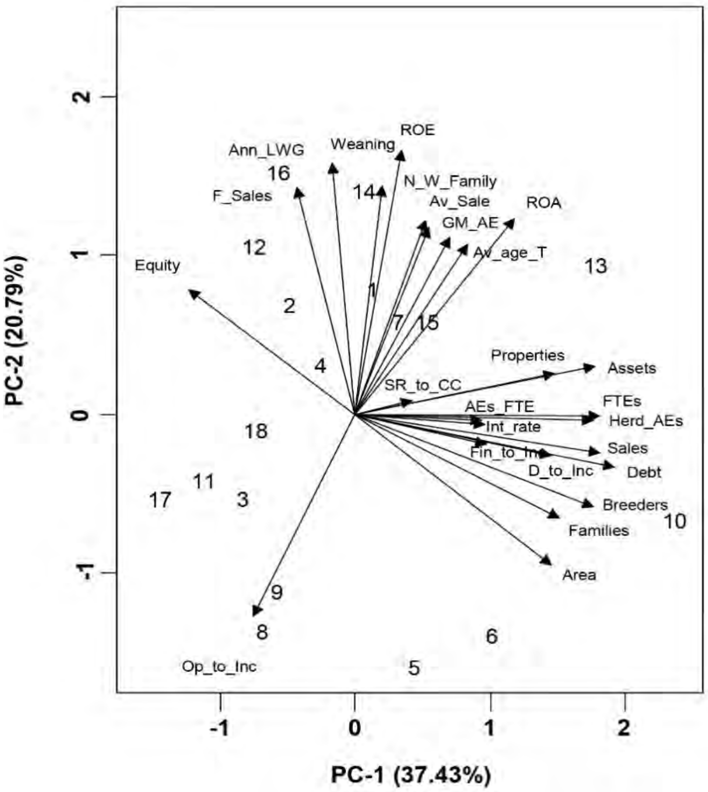

Figure 1. Biplot analysis showing the inter-relationship among 25 productivity, financial and social variables analysed for the study group of 18 beef businesses in the northern Gulf, Queensland, Australia.

The biplot results show some correlation between these three variables and return on equity (ROE). A third correlated cluster displays higher average sale prices, higher gross margin per adult equivalent and higher average age of turnoff, which are all indicative of better return. The longer the vector (arrow) the more variation is explained by that variable. Hence, ROE, Return on Assets (ROA), Assets, Debt, Breeders, operating costs to income (Op_to_Inc), Equity and Ann_LWG explain a similar degree of variation. Conversely, stocking rate to carrying capacity (SR_to_CC) (marker close to origin of biplot) explains less of the variation between producers. Numerous zero or close to zero correlations (perpendicular lines) are indicated on the biplot. For example, the adult equivalents per full time equivalents (AEs_FTE) vector compared to ROE suggests a weak relationship between labour efficiency and profitability amongst the group analysed.

The four case study properties had annual live weight gains in growing cattle ranging from 85–160 kilograms per head across these properties. Total GHG emissions range from 1,764 to 5,442 t CO_2e per enterprise. Herd and FarmGas modelling estimates GHG emission intensity ranges from 11.7 to 23 tonnes of carbon dioxide equivalents (t CO_2e) per tonne of live weight sold or turned off annually.

Conclusions and Implications

The purpose of this study was to explore how business complexity, performance and profitability influence environmental management decisions. The consultant-mentor approach, used by an experienced multi-disciplinary team, proved effective in engaging producers and understanding the business, production and personal intricacies of each enterprise. This study comprised 10% of the commercial beef businesses in the region. Preliminary data provides a clear insight into the diversity and complexity surrounding extensive beef businesses in the northern Gulf of Queensland. Analysis suggests multiple factors drive these production systems. Understanding the complexity of the production system and tailoring changes to individual circum-stances is fundamental to improving technology transfer, producer profitability and rangeland management.

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Teaching the Words "Waterponding" and "Waterspreading" Aus. Aid Style

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Key words: Waterponding, waterspreading, Aus Aid, African trainees, rehabilitation.

Introduction

The global population is set to exceed nine billion by the year 2050 (U.S Census Bureau, 2011), which will test the very fabric of the human existence, food (production). Globally natural resources including arable land are diminishing at rates greater than ever, threatening the agricultural industry (FAO, n.d.). Therefore, innovation in the area of rangeland rehabilitation is vital and the spreading of existing knowledge is essential. This paper will highlight the teaching methods used in the intense hands-on training provided, so that the Aus Aid African trainees could return to Africa to carry out the survey and construction methods of both waterponding and waterspreading rangeland rehabilitation techniques in their own countries.

The conventional land management practices of over-utilisation from grazing in semi-arid rangelands is the main cause for land degradation, resulting in loss of soil organic matter, decreased soil fertility, diminution of soil organic carbon, and increased water and wind erosion (Mekuria et al., 2007). This has resulted in the formation of clay pans once the fine sandy loam topsoil has been eroded away. Clay pans are surface crusts, which are typically 3mm in depth. These surface crusts are also called scalds. Water does not penetrate through the scalded soil surface. The clay pan swells when saturated, sealing cracks in the surface and preventing water infiltration. This results in water erosion and the loss of soil moisture in the landscape. This makes it really hard for seeds to get into the soil and germinate.

Waterspreading is a land management technique used to evenly spread and disperse rainwater flow over land with gentle slopes (less than three percent). The driving mechanism behind the success of waterspreading is the reduction of the energy of water flow, meaning a large reduction in soil erosion and an increase in water infiltration. Waterspreading involves creating a series of small banks to direct water away from eroding drainage lines to areas where it would normally not flow. Each bank is designed to slow and spread water as it continues down slope, increasing infiltration to better suit native grasses and herbage. Waterponding is a land rehabilitation technique used on duplex scalded soils in the semi-arid rangelands. Water is held on the scald in surveyed horseshoe-shaped banks, each covering 0.4 ha. The ponded water leaches the soluble salts from the scalded surface. This improves the remaining soil structure, inducing surface cracking, better water penetration and entrapment of wind-blown seed. The teaching of these two rehabilitation methods to the trainees in three days is a challenge that can be done.

Materials and Methods

The 79 African trainees were from 29 different African countries so the language barrier was considered in preparing all training workshops. The theory in the class room was spoken in a much slower pace than usual. Visuals have no language or cultural barrier, therefore the use of photos to tell the story of the two rehabilitation techniques was a huge success. Waterponding and spreading has been practiced in the Central West Catchment since 1970's and is well documented. The slide presentations gave the trainees a full history of how the two rehabilitation techniques came about and the sequence of the circle that each operation of the rehabilitation technique had to occur.

All the theory has to be backed up with actually doing the work in the field, so step back and start with the staff, level and tripod. How to set up and use the level. Both the waterponding and waterspreading require all the location points to be surveyed. Before the full day in the field with the road graders to construct the earthworks, a half day of practise surveying around old waterponds to understand the correct depth each waterpond has to be and how the ponds fit together to maximise the scald covered with water.

The full day in the field is the real thing. The trainees are taken to a scald that has lost over 30 centimetres of fine sandy loam topsoil. The trainees are then put into groups of no more than four individuals along with one staff, level and tripod. Each group will be required to layout at least five waterponds each. As each pond is surveyed ready for construction they are checked with the vehicle mounted laser system. A road grader is used for construction of the ponds, which each trainee is given the opportunity to get into the cab of the road grader with the driver and is shown how the ponds are built. Each waterpond is then seeded with saltbush seed and native grasses along the inside batter of the bank and across the middle of each waterpond. The trainees are taught on how to do monitoring of the site before the earth works starts and what information should be captured with the photo point and step point along with soil carbon testing of a controlled and rehabilitated sites.

Results and Discussion

The intense theory and skills taught to the trainees were put to test in the field, with each trainee laying out the waterpond using the levels to produce very impressive scald rehabilitation. Waterponding projects are now in full swing back in Sudan, North Africa using the skills the trainees learnt, with impressive rehabilitation results.

Conclusions and Implications

A solid foundation in theory is well and truly important. The theory can be taught in class rooms, however to solve real world problems, one has to be able to apply the theory into practise. During the course of this program, the Aus Aid trainees have not only learnt the theory behind waterponding and waterspreading, but also put the skills they acquired to test so that they will be able to implement rangeland rehabilitation methods in their own country. The last three years of teaching the word on “waterponding” and “waterspreading” has produced satisfying outcomes for the rehabilitation methods. Let’s hope these trainees pass down the knowledge they have attained to their fellow citizens.

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What Have We Learned from Rancher Surveys in the Western US? Preliminary Results of a Systematic Review

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Key words: Rancher decision-making, landowner survey, innovation adoption, conservation social science

Introduction

Rangeland science aims to create knowledge to sustain rangeland social-ecological systems over the long term. Range science has made substantial progress on understanding ecological dynamics of rangeland systems and the management practices that sustain them, and these findings have been systematically reviewed and synthesized in various venues (e.g. Briske 2009). The social factors (e.g. demographics, social norms and networks, institutions, culture, economic incentives) that determine whether sustainable management is implemented have received less attention in the US, and existing research on rancher behavior has not been systematically reviewed and synthesized. We present preliminary findings of a review of quantitative social science surveys that investigate rancher behavior focused on use of rangeland or livestock management or conservation practices. Our goal is to clarify what we know and to highlight key evidence gaps and research needs.

Methods

We reviewed 27 peer-reviewed articles and two MS theses that surveyed ranchers or rangeland landowners in the Western US about their operational characteristics, management practices or adoption of conservation practices or innovations. We limited our review to studies that used quantitative surveys and measured reported rangeland management behavior, behavioral intent, or willingness to participate in conservation programs. We entered each study into a matrix, tallied the target populations, dependent and independent variables, and summarized the main findings. The list of works reviewed is available from the corresponding author.

Results

The 29 studies sampled ranchers, rangeland landowners, and participants in Extension programs targeted to rancher audiences. Studies characterized respondents based on ranch characteristics, age, education level and attitudes, but none considered gender, race or ethnicity. Studies were regionally biased, with the most studies conducted in Colorado, California, Utah, Texas, California and Wyoming, and none specific to the Northwest (Washington, Oregon, Idaho), New Mexico, Nevada, or the Plains (N or S Dakota, Nebraska, Kansas, Oklahoma).

Behavioral outcomes studied ranged from specific practices (e.g. prescribed fire) and suites of practices (e.g. weed control, brush management), to broad indices of practices, to participation in government conservation programs (e.g. Environmental Quality Incentive Program, Conservation Reserve Program), use of conservation easements, intent or willingness to participate in payment for ecosystem services (PES) or to sell the ranch. Use of specific grazing and natural resource management practices and participation in government and other conservation programs were most studied.

Profit, return on investment and cost to implement practices were the most often measured explanatory factors. Profit is seldom a primary motive for staying in ranching. However, return on investment and cost to implement conservation practices can significantly influence adoption of rangeland improvements, practices or conservation programs. Dependence on ranching income can have both positive and negative effects on innovation adoption. Gross income and availability of alternative (non-livestock) on-ranch income sources are associated with proactive and flexible management. Operational scale measured in land area or number of livestock supports greater flexibility and adoption of management practices. Risk orientation and willingness to experiment drive innovation, and often correlate highly with respondent demographics such as higher levels of formal education and younger age. Rancher identity, place attachment, and related concepts (conservation ethic, social bonding), influence decisions such as staying in ranching and placing a conservation easement on the ranch. Access to information, exposure to Extension, social networks, and participation in or presence of collaborative groups or landowner associations can predict conservation behavior. Quantitative studies often explain a small fraction of variation in rancher behavior, and commonly conclude that a tailored approach to rangeland outreach is needed that takes into account differences in ranch scale, tenure, location, or motivation.

Conclusion and Implications

By assuming that ranchers are predominately male and white, quantitative surveys have revealed little about the role that women play in ranch decision-making, and the potentially distinct characteristics, needs and motivations of non-white and non-male ranchers. Given the increasing attention to rancher, place and community identity as explanatory factors, and the potential differences in these attributes among ethnic groups and genders, we suggest incorporating gender, race and ethnicity explicitly in future studies. Although many studies recommend a tailored outreach approach, we wonder whether these results have been applied, and whether we are testing, documenting, and learning from different outreach approaches. Most studies imply that the measured behavioral outcome is beneficial, although the benefits of some practices are not well established (Briske et al. 2009). Further, the outreach approach underpinning most US rangeland survey research is the top-down, one-way "product push" or "tech transfer" model, or at best a "needs-based" approach. As reflected in rancher survey research, the western US rangeland outreach paradigm lags behind Australia, where a more collaborative, social learning model is well established (Keen et al. 2005, Pannell and Vanclay 2011). We included surveys dating back to the 1970s and 80s that may not reflect current rancher motivations and demographics, but which may serve as a baseline for comparative studies of changing rancher motivations and behavior over time. Finally, while quantitative surveys allow for powerful generalizations, they are limited in their ability to capture the complexity of decision-making processes. Qualitative studies may help address this limitation (e.g. Didier and Brunson 2004, Wilmer and Fernández-Giménez 2015). This study highlights the need to systematically review and synthesize existing rangeland social science research to identify key knowledge gaps and ensure that the lessons of four decades of rangeland social science are not overlooked as we renew the quest to understand how and why ranchers make the choices they do, and how best to engage them in creating a sustainable future for rangelands and ranching communities.

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Improving Equine Pastures through Evaluation and Education

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Key words: Horse, pasture composition, ergovaline, fescue toxicity

Introduction

There are over 400,000 horses in the state of Kentucky and the majority are located in central region of the state (KY Equine Survey, 2012). In the spring of 2001, 25-30% fetal losses occurred in central Kentucky due to a syndrome termed Mare Reproductive Loss Syndrome (MRLS) (Thalheimer and Lawrence, 2001). Initially, endophyte infected KY 31 tall fescue (*Schedonorus arundinaceus* (Schreb.)) was blamed and, research at the University of Kentucky (UK) (Webb et al., 2004) eventually linked MLRS to accidental ingestion of the Eastern Tent Caterpillar (*Malacosoma americanum*). Control measures were implemented for severe infestations of this pest, but more importantly this event served to build a new and significant relationship between the Kentucky equine industry and the University of Kentucky. Among several initiatives, programs and incentives that developed was the UK Horse Pasture Evaluation Program. This program is now in its twelfth year of operation and has enjoyed tremendous success and growth over the years. As described in this paper, this program has made on pasture improvements as well as improved the relationship between the University of Kentucky and the horse industry.

Materials and Methods

On farm evaluations are performed by trained technicians and undergraduate students. Evaluations are conducted late March to November on horse farms in any part of the state, regardless of size, breed or discipline. This program is funded 2/3 with grants and 1/3 by fees charged to participating farms.

A detailed soils map of the farm and pasture yield map is obtained using the Web Soil Survey online technology (http://websoilsurvey.sc.egov.usda.gov). Estimated pasture yields for cool season pastures are reported by web soil survey and used to determine carrying capacity of the farm.

Pastures are evaluated for species composition by visual estimation with trained observers of a 0.6 x 0.6 m quadrat placed randomly in 10-20 locations in the pasture (Figure 1). Percentages, rounded to 5%, are recorded for tall fescue, Kentucky bluegrass (*Poa pratensis* L.), orchardgrass (*Dactylis glomerata* L.) and white clover (*Trifolium repens* L.). Individual species of weeds are identified and a collective percentage of weeds is recorded. Finally, a percentage of bare soil, including several warm season grasses, is recorded.

Figure 1. Map of horse pasture in central Kentucky with GPS sample locations.

Tall fescue is abundant in most horse pastures in Kentucky and when infected with the common toxic endophyte *Epichloe Coenophylum* (Morgan-Jones & W. Gams) can cause multiple symptoms of fescue toxicosis, especially in pregnant mares. Farms with equine breeding stock are sampled for tall fescue in two ways. Tillers of tall fescue are collected and submitted for testing to UK Regulatory Services to test for endophyte presence. Grab samples, mimicking the grazing behavior of horses, are also collected and submitted to the UK Veterinary Diagnostic Laboratory for ergovaline analysis.

All data collected is presented in a comprehensive report to participating farms. Additionally, detailed recommendations are made for each pasture individually and summarized on a quick reference chart. These include general pasture management, herbicide applications, seeding guidelines, tall fescue risk analysis, and other farm specific recommendations. A number of UK extension publications relevant to pasture management are also provided. Members the UK Forage Extension team deliver the report to the farm owner and explain the recommendations in detail, providing a one-on-one education and outreach opportunity.

Results and Discussion

Since its inception in 2005, the UK Horse Pasture Evaluation Program has performed over 170 evaluations on 110 unique farms in 21 Kentucky counties. Farms that have utilized this program have regularly shown improved available forage, greater vegetative cover, and reduced risk for tall fescue toxicosis. Some clients have also hosted educational events such as field days and tours to showcase their success in improving pastures.

This program has also strengthened the relationship between the University of Kentucky and the equine industry. This is demonstrated in the large attendance at equine pasture events such as the annual “Pastures Please!!” event held in February of each year and the Equine Farm and Facilities Expo, held in the summer months. The UK Horse Pasture Evaluation Program launched a Facebook page in 2013 and a separate website in 2016. Numerous articles on pasture management are written annually and published online in the Bluegrass Equine Digest (https://equine.ca.uky.edu/content/bed-current-issue).

Conclusions and Implications

The UK Horse Pasture Evaluation Program has increased our ability to reach the equine community and educate them on improving pasture management and reducing the environmental impact of horse operations. It has also served as a vital link between the industry and university. Recently, the UK Horse Pasture Evaluation Program team was awarded a federal NRCS-RCPP grant for over $450,000 to further assist farms in improving pastures through riparian buffer zones, forage establishment, weed control, and other improved management practices.

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Attendance at National Agronomy Competition Leads to Career Opportunities for Undergraduates

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Key words: Undergraduate education, Forage Bowl, competition

Introduction

In the early 2000s, the American Forage and Grassland Council (AFGC) created a contest testing the forage knowledge of undergraduate students, in a Jeopardy! ® style game at their annual conference. In 2014, a group of young AFGC members collaborated to improve the Forage Bowl and turn it into a sought after undergraduate competition. While the first task was to modify the rules, structure and questions of the game, the real goal was to engage a diverse generation of agriculture students and introduce them to forage production and the potential career opportunities that exist within the forage industry. Today's National Forage Bowl Competition is well supported by the AFGC Board of Directors, well attended by schools from across the nation (Table 1) and has had significant impacts on the lives of students and the industry.

Table 1. Schools participating in the National Forage Bowl Competition since 2010.

Asbury University	Wilmore, KY
Berea College	Berea, KY
Kansas State University	Manhattan, KS
Pennsylvania State University	State College, PA
Purdue University	West Lafayette, IN
Southern State Community College	Hillsboro, OH
University of Kentucky	Lexington, KY
University of Tennessee – Martin	Martin, TN
University of Wisconsin – River Falls	River Falls, WI
Virginia Polytechnic Institute	Blacksburg, VA
Western Kentucky University	Bowling Green, KY

Materials and Methods

The new National Forage Bowl Competition committee has worked to improve the rules of the contest to make a level playing field and have expanded the study materials to include 2 textbooks (Ball et al., 2015 and Barnes et al., 2003) and an identification guide (Abaye, 2010). The final round of the competition is now the opening session on day two of the conference. A "Collegiate Room" was established in 2015 as an area for students to gather and interact, enjoy snacks and engage in networking opportunities. Finally, the National Forage Bowl Competition Trophy, the "Baylor Cup," was introduced in 2015 and will travel to the winning school each year. Several schools are now sending teams each year, creating a friendly rivalry among teams.

The 2015 competition was held in Baton Rouge, LA and presented a significant travel cost to schools hoping to send teams. The National Forage Bowl Competition committee, with help from The Forage and

Grassland Foundation and the Samuel Roberts Noble Foundation (Ardmore, OK), were able to assist schools with travel costs by providing funds to support travel and lodging for students.

Results and Discussion

In a recent survey of undergraduate students enrolled in a forage class at the University of Kentucky (unpublished data) found that a forage focused contest held at a national meeting appealed to 75% of students. When asked why she wanted to get involved in the National Forage Bowl Competition, contestant Lisa Baxter replied "*Since I went to a small school, there were few competitive opportunities for agriculture students outside of research. Forage bowl provided a wonderful opportunity to compete on a national stage*. Students are craving non-traditional experiences in college that will benefit them in the years ahead. Several National Forage Bowl Competition alumni are now pursing advanced degrees in forage production or are working in the forage industry (Table 2).

Table 2. National Forage Bowl Competition Alumni

Student	Year	Undergraduate School	Current Position
Katie Hurder	2006	Virginia Polytechnic Institute	Pennington Seed
Jennifer Tucker	2006 (coach)	Western Kentucky University	Research Scientist at University of Georgia
Lisa Baxter	2010 - 2011	Berea College	PhD student, Texas Tech University
Katie Bivens	2014	University of Tennessee at Martin	Seeking PhD position
Veronica Bill	2014-2015	University of Kentucky	MS student, University of Kentucky

Coaching a National Forage Bowl Team also provides valuable experience to young professors. Dr. Ben Goff of the University of Kentucky established a formal class to coach interested students. The team's travel was funded by the department and several local sponsors and they ultimately won the competition. While at the AFGC conference, all of the students also completed the Certified Forage and Grassland Professional (CFGP) test and were certified as Forage and Grassland Apprentices.

The competition is still facing significant challenges such as cumbersome travel expenses. The committee is working with AFGC to identify additional sponsors for the competition in hopes to continue providing support to teams.

Moving forward, the National Forage Bowl Competition committee has several plans to improve the overall student experience including continuing the Collegiate Room, organizing student focused tours and career and networking sessions at the conference.

Conclusion

The National Forage Bowl Competition has proven to be an effective education tool in teaching and challenging undergraduate agriculture students. It has also provided opportunities for many students to attend a national meeting and many of them have chosen to pursue forage production further. There are still many improvements that can be made to the contest and the experience for students. With the help of AFGC and others in the industry, the Forage Bowl Committee hopes to continue to grow the competition and have a positive impact on the lives of students and the industry.

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Monitoring Regenerative Landscapes for a Sustainable Future

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Key words: Landscape regeneration, landscape management, transformational learning, collective learning, monitoring and evaluation.

Introduction

How to establish regenerating landscapes when this requires transformational change in the communities that manage these landscapes are questions asked by many planners, politicians, policy-makers and by rangeland peoples themselves (Thackway and Specht 2015). Dynamic global flows of people, resources, climate and communication are challenging long-standing ways of living, and accepted ways of making decisions (Falk 1999). Taking account of the needs of multiple industries, traditional peoples, established communities and the environment is indeed complex. Despite widespread recognition of the need for collaboration and integration of different perspectives and knowledge systems (e.g. Brown and Harris 2014), conflict often arises between different interest groups.

Managing competing interests, aspirations and needs is integral to supporting change in communities. Yet social change processes are routinely separated from land use planning and management systems (Brown, Harris and Russell 2010). Solutions often require transformational landscape management, calling on both social and environmental change. This in turn requires opening up the boundaries between the "silos" of disciplines and between the power hierarchy of community, expert and organisational knowledge cultures.

The project discussed in this paper trials an innovative process of collective learning as catchment management moves from technological fixes to regenerative landscapes. It is located on the edge of the Australian rangelands, in the Murray-Darling catchment, in a peri-urban community on the outskirts of the rural city of Toowoomba. Communities here are multi-faceted with interests including several agricultural, different mining and equine industries as well as individuals seeking to escape from increasing pressures of urbanisation. Interests reach from the city to the rangelands.

Methods

The methods used cater for this diversity of relationships, interests, aspirations and needs of the individuals and communities are to treat them as mutual learners in a continuing collective learning spiral. Farmers, govern-ment agencies, environ-mental experts, and organisations are brought together in four learning stages as shown (Fig. 1).

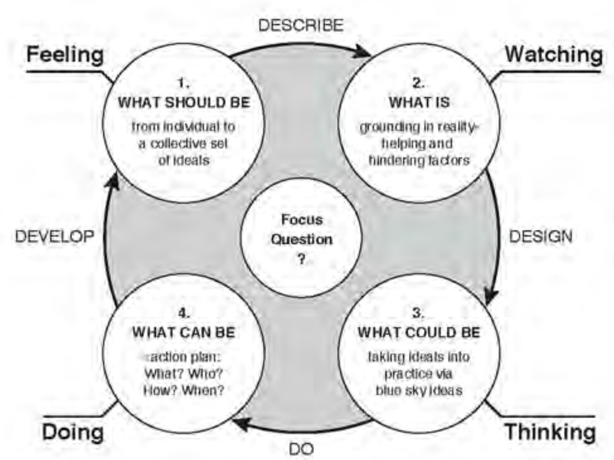
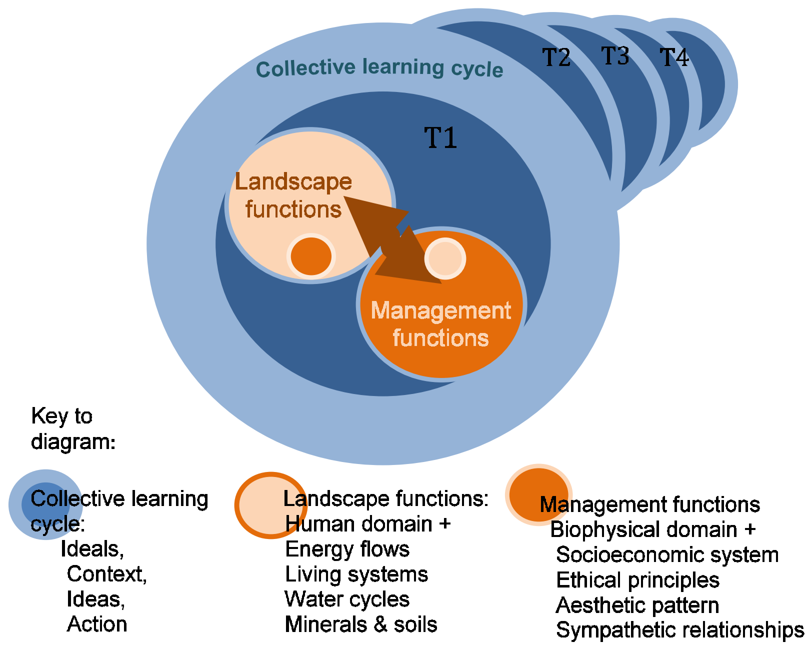


Figure 1. Collective learning spiral.

The mutual learning process takes equal account of the human management functions and the land-scape regenerative capacity functions, functions regularly separated in land-use planning. Together, the full range of interests have the capacity to respond to the full range of the evidence of continuing landscape change. In this process, the multiple interests monitor and evaluate the continuing changes through the biophysical landscape functions of energy flows, life forms, water supply and condition of the soils, and the socioeconomic conditions, ethical relationships, aesthetic response to management styles, and social relationships with neighbours and with the land.



The questioning strategy based around landscape and management functions (Fig 2) were incorporated in the learning spiral (Fig 1) to help break down the barriers between the different knowledge systems and their inherent cultures and power relations.

Figure 2. Collective Landscape Management (Brown and Harris 2016).

Results and Discussion

The collective learning spiral process and related questioning strategy has enabled the research team to engage with the full range of stakeholders in the catchment. Landholders and government officers were enthusiastic to participate. The power of government regulations in helping and hindering management changes will be presented, and the implications of this power on decision-making of other stakeholders will be outlined.

Conclusions and Implications

The eight functions that allow the joint monitoring of the social and landscape change (Fig 2) have the potential to integrate the social and biophysical dimensions of landscape management. The use of these markers as mutual learning did help alleviate the negative influences of the power dynamics between the different constructions of knowledge. These questions proved effective in releasing the participants in landscape management from the social conditioning of their particular knowledge cultures. By releasing people them from the dominant discourses of their cultures, this facilitates a transformative collaborative discussion about future regenerative catchment management.

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Quality Graze Steer Challenge — Engaging Pastoralists in Central Australia

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Key words: producer engagement, research adoption, grazing land management, premium beef

Introduction

The pastoral industry in the Arid Zone of central Australia has a number of strengths which include the ability to achieve significant weight gain on fully cured native pastures from predominantly *Bos taurus* cattle while having access to premium quality beef markets. The production of finished steers for slaughter and premium prices through the Meat Standards Australia (MSA) grading system is one option to take advantage of these strengths. To encourage adoption of research recommendations and to disprove a common perception amongst producers that steers can only be prepared for premium markets in exceptional seasons in the Arid Zone, a Producer Demonstration Steer Challenge (Challenge) was implemented at Old Man Plains Research Station (OMP) near Alice Springs in the Northern Territory of Australia.

This Challenge encompasses the extension component of a long-term grazing trial which tests different grazing strategies, based on a modelled carrying capacity, towards the consistent production of quality beef in central Australia while minimizing the effect of a variable and unpredictable climate. (Materne, 2015). The Challenge provides producers with a neutral venue to compare their steer performance under the latest land management recommendations and investigates the economic and ecological viability of producing quality beef consistently in central Australia. Focus areas of the study include the enhancement of communication and research adoption through participatory learning, monitoring and evaluation using the competitive nature of producers as impetus.

Materials and Methods

Seven central Australian producers representing popular cattle breeds and cross breeds supplied up to eight weaner steers (180-220kg) each for the Challenge. Following quarantine all steers entered a two-paddock 12 month rotation with a capped variable stocking strategy based on a long term carrying capacity of 2.2 Adult Equivalent per km^2. Web based real-time performance updates on weights of individual animals as well as groups are made available to producers while steer performance data such as growth rate, condition score, P8 fat depth and skeletal growth are collected quarterly and results presented to the producers. A Remote Livestock Management System (RLMS) was used to collect automatic weights on a continuous basis during the trial.

At approximately 2.5 years of age, and with a target weight of 575 kg, the steers are sent direct to slaughter and MSA grading with comparable steers from other grazing strategies on OMP. In consultation with the participants in the steer challenge criteria such as steer performance, meat quality and price per kg will be used to determine the winner of the Challenge.

Qualitative data collected through a participant survey at the beginning and end of the project as well as discussions at field days and individual visits are being used to indicate changes in perception on meat quality, grazing land management, MSA grading and steer performance and thereby the effectiveness of this Challenge as a communication and research adoption tool is assessed.

Results and Discussion

Data presented in Figure 1 provides evidence that environmental conditions exert a greater influence on steer growth rates than genetics. This is a most powerful message that emphasizes the importance of grazing land management. In an extremely variable and unpredictable climate this project also demonstrates that steers can achieve a weight of 575kg (Fig.2) with a P8 fat depth of >6 mm by 30 months of age which enables them to achieve MSA grading. The development of a website to provide producers with updated information about the Challenge, as well as other relevant research findings, has the potential to improve communication and contribute significantly to uptake of research recommendations. Observations from two participants after a feedback session: Participant 1: *"But the interesting result so far is that regardless of the starting weights and the breed, they all ended up coming to reasonably consistent weight gain….I certainly didn't expect that, but it does make sense."* Participant 2: *"I have learned that there are many unanswered questions related to animal performance, seasonal conditions and handling that we may have taken for granted without realising there could be perverse financial outcomes from the decisions that have been made."*

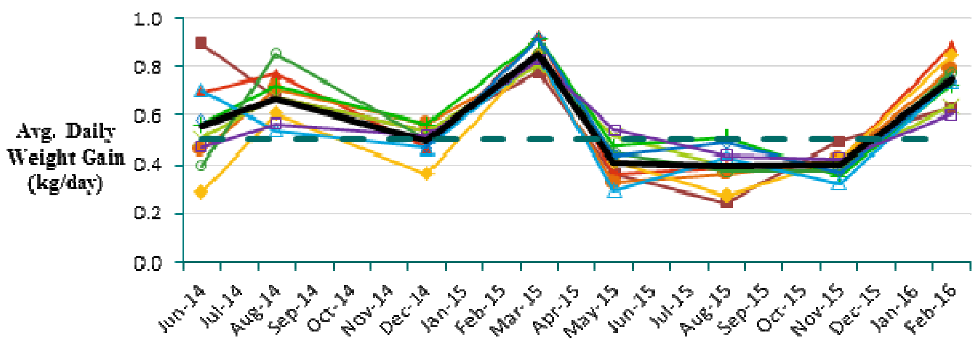

Figure 1. Performance of 10 different steer breed groups showing daily growth rate targets of 0.5kg has been surpassed with the response to nutrition between breeds being similar.

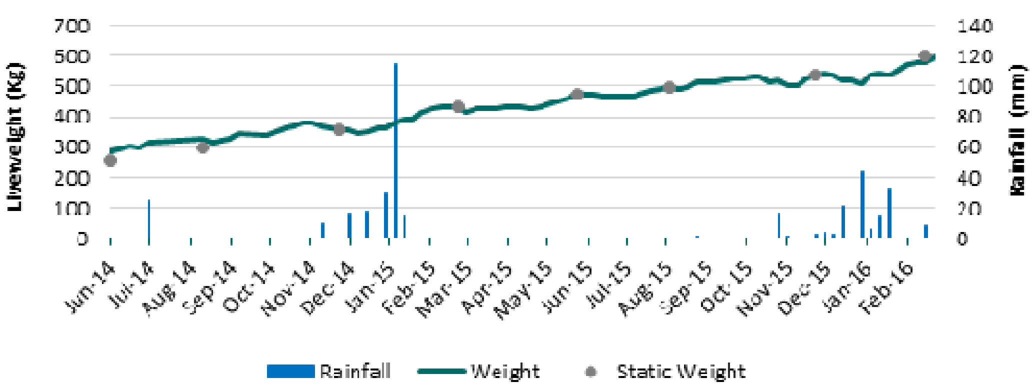

Figure 2. Remotely monitored average steer automatic weight compared to quarterly static weight and rainfall distribution.

Conclusions and Implications

The Challenge participants are experiencing how their steers can meet requirements to access premium markets through applying a grazing strategy and carrying capacity appropriate for the conditions. The Challenge has successfully engaged seven producers with approximately 25% of the Alice Springs region actively following its progress. This is a significant engagement outcome with potential to increase research uptake.

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A Practical Guide to Evaluate Operative Efficiency of Mexican Cattle Ranches/Ejidos

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Key Words: Operative efficiency, balanced scorecard, ranch, ejido, programs

Introduction

For decades, but specially during the current federal government administration (2012-2018) the Mexican Agriculture Department (SAGARPA, 2013) has been calling universities and research institutions to establish innovative technical and methodological proposals to guide extension and technology transfer programs, as well as to improve operative efficiency, productivity and sustainability of cattle ranches and ejidos (a communal rural land tenure system) in Mexico. At Universidad Autónoma Agraria Antonio Narro, Vásquez *et. al.* (2006) have launched a knowledge management proposal to develop operational plans integrating knowledge into 8 programs. Derived from objectives goals and actions (activities) to be attained in the referred programs, a simple and comprehensive protocol has been designed to determine the annual operative efficiency of ranches/ejidos, based on evaluation of several important parameters. We anticipate and welcome opinions and observations of the international range and ranch community.

Materials

Several literature sources were consulted to develop the reference guide. These include:

1. Proposal of Vásquez *et al.* (2006). Strategic Administration applied to Mexican extensive cattle ranches/ejidos, by programs.
   - 1.1 Objectives included or considered on every program of the proposal
   - 1.2 Guides (approximately 40-50 indicators each) to evaluate, diagnose, as well as qualify each program
   - 1.3 Calendars of activities (or actions) of each program integrated into the operation plan.
2. Development Program (2013-2018) established by Mexican Agricultural Department (SAGARPA, 2013).
3. Proposal of Dunn and Etheredge (2005). Key Indicators of Success in Ranching: A Balanced Approach
   - 3.1 Balanced Scorecard for a Ranch.
4. Proposal of Teichert (no date. Internet reference). Key Indicators of Ranch Profitability.
5. Proposal of Doye (2014). Internet reference. Cow-Calf Standardized Performance Analysis.
6. Strategic Administration Concepts. Key financial indicators.

Methods

The following is a suggested methodology to undertake with ranches and ejidos looking to improve their operations. As an initial reference to improve operational plans, we used the proposal of Vásquez *et. al.* (2006), which suggests to integrate the scientific and technological knowledge required to implement the ranch or ejido beef cattle operation plan, in a framework consisting of 8 programs: 1. Administration (Strategic); 2. Reproduction; 3. Range Management; 4. Infrastructure; 5. Health; 6. Nutrition; 7. Forage

Production (Cultivated); and 8. Wildlife. Data corresponding to essential parameters used to evaluate three selected objectives of the eight programs (24 objectives, total), which are outlined in García (2015), is suggested to determine quantitative as well as qualitative results related to the operational plan.

Results and Discussion

Completed by the rancher himself, or supported by technicians of SAGARPA, universities and/or private consultors, Scorecards capture "hard data" to annually assess an operation's efficiency, both quantitatively and qualitatively, in terms of its attainment of the plan's objectives.

For quantitative assessment, each ranch/ejido is scored according to 3-5 parameters outlined by García (2015) which are considered as economic or non-economic indicators, for a set of three objectives for each of the eight programs. For example, selected parameters of the Range Management Program are: 1) stocking rate/year, 2) economic value of the native forage produced/year, 3) total cost of the Range Management Program/year. The same evaluation process is accomplished for the remainder of the seven programs. If the data shows increasing or top values, the objective can be considered as attained.

For qualitative assessment, a set of three objectives for each of the eight programs is scored yes or no. Based on the total number of objectives attained (0-24), the operational plan of the ranch/ejido receives a score of: Very Poor (only 1 to 5 objectives attained), Poor (6 to 10 attained), Regular (11 to 15), Good (16 to 20) or Excellent (20 or more objectives attained).

Conclusions and Implications

We estimate that by using both scorecards, it will be possible for ranchers to achieve improvements in each year. Using the objective attainment scorecard on its own will make it easier for ranchers, as well as Mexican government agencies, to integrate statistical data and evaluate, using "hard" data, the economic impact of the Mexican cattle industry.

Both, ranchers and government agencies, such as SAGARPA, could find a better way to interact and coordinate efforts to promote research, professional extension and technology transfer, in order to keep the cattle industry continuously improving, on a holistic and sustainable basis.

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3.5 Social Justice Issues in Rangelands

Environmental Imperialism and Greening Dispossession: Social Justice Issues in East Africa's Rangelands

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Key words: Social justice, rangelands, conservation, dispossession, East Africa.

Introduction

"First we were dispossessed in the name of kings and emperors, later in the name of state development, and now in the name of conservation."
A statement from indigenous delegates to the Fifth World Parks Congress, Durban, South Africa 2003 (in Dowie 2009

Social justice issues remain a salient topic in rangeland scholarship and advocacy throughout the world.

Rangelands continue their precarious entanglements with globalization, commodification, privatization, and marketization. Ongoing territorial politics and erosions of the commons ensue as a result, with relentless enclosures and dispossessions continuing to adversely affect many pastoral households. This paper considers the "new enclosures" (White et al., 2012) and "new frontiers of land control" (Peluso and Lund, 2011) phenomena that are implicating social justice issues at alarming rates. Certainly, enclosures and dispossessions of rangelands are not *new* social justice issues, but what is often *new* in recent periods is the proliferation of global actors and the substantiating logics implicated. With globalization and the ascendancy of neoliberal orders, the increase of multinational corporate actors and foreign investments has become front and center in rangelands' new territorial politics, social injustice and growing inequalities. Especially pertaining to rangelands in the global south, the "global land rush" and subsequent processes of "land grabbing" have become paramount to land conflicts and struggles (Cotula, 2013; Scoones et al., 2013; Ykhanbai et al., 2014). This paper contends that such processes and corresponding dispossessions are paramount to our consideration of today's social justice issues in rangelands. Using old justifications of underutilized, cheap and available land (Galaty, 2014), new enclosures and dispossessions abound:

> On a scale never before envisioned, the most valued pastoral lands are being acquired though state allocation or purchase for two purposes: by agro-industrial companies or foreign state promising to use it for highly efficient commercial agriculture, and by conservation groups and entrepreneurs who vow to protect wildlife and propagate high-end lucrative tourist ventures. (Galaty 2013, p.143)

Old, erroneous narratives about grazing degradations and misrepresentations of pastoralists' economic contributions to society persist, ultimately amounting to combined processes of "agrarian colonialism" and "environmental imperialism" (Galaty, 2013).

Drawing on a study pursued in partnership between McGill University (Canada) and the African Conservation Centre (Kenya) entitled, Institutional Canopy of Conservation (I-CAN): Governance and environmentality in East Africa, this paper focuses on the latter dimension of global land grabs – the environmental imperialism and land acquisitions arising from global conservation and tourism. With ever-expanding global tourism markets and simultaneously expanding “powerful environmentalisms” (Brockington, 2008), rangelands are more and more entangled in contentious land appropriations often associated with its wildlife resources and subsequent ‘safari business’ potential. Emboldened by green economic logics, foreign actors appropriate the rangelands’ globally-imagined ‘African wildlife’ and corresponding ‘wild lands’ — an ominous “foreignization of space” (Zoomers, 2010).

Subsequently, wildlife conservation and the global demand to photograph, shoot and/or market Africa’s ‘trophies’ is a salient feature of today’s social justice issues. Often referred to as “neoliberal conservation” (Igoe and Brockington, 2007), the outcomes of these rangeland entanglements commonly amount to complete or at least graduated forms of dispossession — e.g. highly regulated environments that ultimately disrupt access and mobility. Drawing on David Harvey’s concerns about today’s globalizing capital (Harvey, 2003), critics argue that such processes amount to “accumulation by dispossession” (Benjaminsen and Bryceson, 2012), or more aptly put, “accumulation by conservation” (Büscher and Fletcher, 2014). In similar fashion, following on the land grabbing literature, some refer to these processes as “green grabbing” (Fairhead et al., 2012). The upshot of such concepts is that wildlife conservation and capital accumulation (e.g. tourism business) are prioritized over pastoral livelihoods, customary land use and systems of management — systems that have historically conserved the rangelands and its wildlife, and which have proven to be most robust forms of social-ecological-systems (Mwangi and Ostrom, 2009). As indicated in the paper’s title, it amounts to processes of what we are calling “greening dispossession” whereby purportedly innocuous processes of conservation and ‘ecotourism’ underpin a growing exclusion of pastoralists from their ancestral lands.

Environmental Imperialism and Greening Dispossession in East Africa

In East Africa, this convergence of global corporate actors, conservation organizations and green discourses is provoking turmoil and conflict in one of the most significant rangelands on the continent: the borderlands of Kenya and Tanzania and the ancestral lands of the Maasai peoples. Situated in the landscapes of so-called “wild Africa” (Adams and McShane, 1992) and inhabited by the globally renowned “big five” (e.g. lion, leopard, buffalo, rhino, elephant), Maasai rangelands have begun to typify processes of environmental imperialism and greening dispossession — a “hotspot” of not only conservation but also growing poverty (Homewood et al., 2012). Whether for shooting or photographing, the rangeland’s trophy animals have become high stakes in the global capital game. Multinational tourism corporations — a “tourism cartel” as described by Norton-Griffiths and Said (2010) — vie for access to the wildlife and the land they reside on. They are often aided by national governments, networks of well-positioned elites and international conservation agencies. Despite the immense national gains of the global tourism industry in both Kenya and Tanzania, the pastoralist households co-inhabiting and displaced by tourism development remain entrenched in higher than average poverty (Homewood et al., 2009; Thompson and Homewood, 2002). Too-often, the rangelands have become “violent environments” (Peluso and Watts, 2001) with conflicts ensuing between state, global business and pastoralist communities.

A brief tour of the rangelands of northern Tanzania and southern Kenya offers many cases in point, beginning at the foot of the iconized Mount Kilimanjaro and leading to the world-renowned heritage sites of Serengeti and Maasai Mara. This is the heart of the popularly termed “Maasailand”, which encompasses 150,000-200,000 km^2 of rangeland from southern Kenya through central Tanzania (Homewood et al., 2009). The borderland landscape is dotted with sites of tumultuous politics, violence and dispossession, while also characterized by “corporate oxymorons” (Benson and Kirsch, 2010) — insubstantial claims by tourism businesses of ecological, sustainable and social responsible achievements in the face of violent conflict, exclusions and protest. More often than not, local petitions hardly reach beyond the walls and desks of local or regional politicians and are commonly stifled by an array of powerful interests at every scale (local, regional, national, and global).

Beginning in Tanzania at the immediate foot of Mount Kilimanjaro, one reaches Ndarakwai Private Lodge & Ranch. Ndarakwai presents itself as a "sustainable ecotourism" venture, "luxury tented lodge" and most importantly, a "success story of land and wildlife rehabilitation."[6] In stark contrast to the peaceful, ecotourism achievements claimed by the company, Ndarakwai was recently burned down by angry pastoralist residents who had been violently chased off the 11,000 acre tourist area, which occupies their ancestral rangeland and a historically important grazing reserve during dry-season periods. One young herder was reportedly shot in the conflict. In immediate defense of the British owner and with desperate attempts to maintain Tanzania's positive foreign investment climate and its burgeoning tourism industry, government officials and military personnel cracked down heavily, blaming a "Maasai mob" for the catastrophe (The Citizen, Nov 16 2014), imprisoning an array of local pastoralists, and all the while praising the foreign investor's contribution to conservation and development. In some bizarre redaction of history, the District Commissioner heralded the beleaguered lodge owners as the "pioneers" of conserving the land (Tanzania Daily News, Dec 29, 2014).

Descending down into the lower rangelands one comes upon Shu'mata Camp – a "luxurious refuge" where "heaven meets earth" and which purportedly demonstrates "a piece of the very magic of which East Africa is made"[7]. The camp's property was occupied in 2013 by an angry demonstration of resident pastoralists who protested the company's maltreatment of the community and, ultimately, its refusal to accept the community's notice of eviction in 2014. Road blocks have been set up by the community on repeated occasions since. In every case, government officials and police intervened with *public* promises to hold the company to account and, allegedly, *private* promises to placate the community at whatever cost. The conflict is now embroiled in a brutal legal battle over the company's entitlement to the land and its wildlife. The case is ongoing and to the chagrin of the local community, a legal injunction was provided to allow the international company to proceed with tourism business during the lengthy proceedings.

Venturing further west into the rangeland's frontiers you'll enter the internationalized rangelands of Loliondo, situated in the Serengeti-Mara ecosystem hosting the world renowned migration of wildebeest and also the key dry season refuge of pastoralists. Before long, you'll reach the wildlife viewing area and luxury lodge of the American-based company, Thompson Safaris, who extol the virtues of "ecotourism" and claim to be "leaders in sustainability"[8]. Rather ironically, the company named the area 'enashiva' (the Maa word for 'happiness') despite the turmoil that pervades the area. The company's property claims, alleged prejudices and exclusions remain hotly contested, culminating in one herder shot for trespassing in 2014. The following statement from one leader captures the contested rhetoric of the company and the intense grievances shared by the local community: "A company can claim to be eco-friendly or socially conscious. But if it fails to gain the consent of the indigenous communities that have traditionally lived on and cared for the land, its customers may be participating in the creation of 'conservation refugees' instead of contributing to sustainable development" (Smallteacher, 2014).

Next door you'll reach the infamous area of "Loliondogate" (Nelson, Gardner et al. 2009) where a similar case of land appropriation amidst public-private collusions and egregious dispossession has captured global attention. Even the popular Avaaz organization circulated a petition in 2012 to "Stop the Serengeti Sell-off" in response to the threat. In the Loliondo crisis, middle-eastern oil barons and trophy hunters

[6] See http://www.ndarakwai.com/. Accessed February 14 2016
[7] See http://www.shumatacamp.de/. Accessed February 2 2016

[8] See http://www.thomsonsafaris.com/giving-back. Accessed Feb 20 2016.

converge with corrupt officials and conservation rhetoric. Much has been written about this conflict (Galaty 2013, Gardner 2016). Suffice it to say here that "The Killing Fields of Loliondo" (Ole Dapash 2002) and "Loliondo is burning" (Intercontinental Cry, 2009) have become common epithets that capture the extent of the conflict. Court cases persist around the land appropriation and the violent evictions that occurred in 2009. While the government's recent threat to restrict all pastoralist access to OBC's 1500 km^2 of hunting area has been sidelined due to local and international pressure, the area remains vulnerable to ongoing dispossessions. Government officials continue employing crisis narratives about supposed over-grazing, degradation and the need to displace pastoralists in favor of so-called, 'conservation hunting'.

Across the border in Kenya, rangelands' entanglements with global tourism and conservation is also ominous. Beginning just north of Loliondo at the Maasai Mara National Park, private conservancies are emerging as one of the biggest threats to rangeland access and pastoral mobility (Homewood et al., 2009; Homewood et al. 2012). Amidst Kenya's long history of sub-dividing and privatizing its rangelands, private conservancies entail newly autonomous, private landowners leasing their property to international tourism companies. While reaping some immediate, individual financial reward, the long-term impacts on households, reduced access to previously common pool resources (e.g. grass, water, and salt) and the cascade effect on rangeland degradation elsewhere is raising much concern. Where it hasn't already, conflict promises to erupt as some elites capture meagre benefits while others bear the burdens of eroded commons.

Further east, the ashes of the Nguruman Ltd property are only beginning to settle. According to one travel company, the lodge was an "artistic wilderness retreat…a group venture with the local Maasai people…[that] aims to create self-sustaining tourism."[9] It is a private, luxury camp that hosts the likes of Bill Gates and "feels as if God installed a private balcony to gaze over creation" (The Africa Report, 13 Aug 2012). Since November 2014, "all that is now no more", as described by one local journalist (Daily Nation, Nov 25 2014). While the conflict has a long history stretching over decades, it recently culminated in violence in 2014 when a group of Maasai youth tore down fences, burnt down cottages and began occupying the area in resistance to Nguruman title claims and recent exclusions from prime grazing and water resources. Today, the ownership and rights to the area remain entangled in court cases with up to 16,000 members of local Maasai facing eviction from over 26,000 ha of the tourism estate (Galaty, 2013).

Returning back to the foot of Kilimanjaro, the rangelands surrounding the world famous Amboseli National Park face a similar fate to those just discussed (Fitzgerald 2013). Given a convergence of privatization and the rapid sales of land to global tourism ventures, the rangeland surrounding the park is a checker board of fragmentation with plans for lodges and private tourism spaces juxtaposed with ever-shrinking rangelands in support of a growing landless population — an invariable geography of the "new scramble for Africa" (Carmody 2011). As in Maasai Mara, private conservancies around the park threaten mobility and patterns of customary use. Despite win-win rhetoric, community conservancies also represent growing concern. As international conservation groups like African Wildlife Foundation (AWF) promise "payment for ecosystem services" in exchange for community grazing areas (Fitzgerald 2013), concerns grow about impacts on future access and mobility regulations.

Concluding Remarks — New Political Spaces, Social Movements and Defying Displacement

The parameters of this paper don't allow a detailed discussion of the above conflicts and their impacts. Suffice it to say that increasing processes of greening dispossession in the face of global environmentalisms and burgeoning tourism markets provoke fundamental concerns for social justice issues in the rangelands — key sources of growing "new enclosures" and territorial politics. In contrast to eco-tourism claims and

[9]See https://www.scottdunn.com/luxury-holidays/africa/east-africa/kenya/maasai-mara-and-southern-kenya/shompole. Accessed Feb 10 2016.

popular win-win discourses, the opportunities and revenues often 'sold' to East Africa's pastoralists rarely benefit the average pastoralist household, rarely offset the costs of committing respective land and resources, and ultimately, represent ominous patterns of new enclosures, private accumulation and dispossession. While pastoralists in these areas are "staying Maasai" (Homewood et al., 2009) and finding innovative ways to maintain their livestock production, ongoing entanglements with global capital and the global land rush besiege households' resiliency at an increasing rate.

Nevertheless, such trajectories remain contested. Concomitant with the deleterious effects of environmental imperialism and greening dispossession, new political spaces and social movements are posing a strong resistance. Concurrent with a proliferation of global corporate actors and conservation organizations, rangelands' political landscapes also include a proliferation of indigenous civil society actors that are opening up new fronts in the land battle – an emerging resistance politics that Dorothy Hodgson (2011) refers to in her book, *Being Maasai, Becoming Indigenous: Postcolonial Politics in a Neoliberal World.* The project underpinning this paper and its authors are cases in point. McGill and ACC's I-CAN project brings together international researchers and sixteen civil society groups that are at the frontlines of resistance to greening dispossession. Co-authors, Edward Lekaita and John Kamanga, are two Maasai advocates entrenched in the conflict. John Kamanga and the agency, South Rift Land Owners Association (SORALO), represent the interests of pastoralist land owners, conducting advocacy and development programs that maintain the integrity of the southern Kenya rangelands and ensure that any wildlife conservation and tourism ventures benefit Maasai communities. As an internationally educated lawyer, Edward Lekaita and the organization, the Ujamaa Community Resource Team (UCRT), have been fundamental to rangeland victories and securing rangeland tenure throughout northern Tanzania[10]. Given the location of the X International Congress meeting in Canada, it's a rather odd twist of irony that one of Edward's recent advocacy achievements includes an unprecedented reparation to the Barabaig pastoralists in Tanzania, who have faced egregious injustices ever since Canada began its joint Wheat Project with Tanzania in the 1970s (Cappelli, 2016). John Kamanga, Edward Lekaita and other I-CAN partners have not only fought their battles in local rangelands but have also carried their messages to international platforms, including the UN Permanent Forum on Indigenous Issues. The upshot of all this: while greening dispossession represents an ominous pattern across many rangelands, indigenous activism and transnational alliances are presenting important resistance and opportunities for defiance.

The Maasai have a saying about the invariable vulnerability of the most seemingly mighty and unstoppable forces. To embolden people vis à vis such forces, they say "even the elephant can trip over a creeping plant". Suffice it to say for the sake of conclusion then, while global tourism and international conservation remain a sizable and mighty force in today's greening dispossession, the likes of this papers' East African authors, and the proliferation of other indigenous civil society groups in East Africa, promise to 'trip it up' as much as possible. The challenge left for international researchers, advocates, organizations and groups, including the International Rangeland Congress, is how we can all build alliances with these groups and support their political struggles accordingly.

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[10] See the following article for information about the prestigious Goldman Environmental Prize, awarded to UCRT's Director, Edward Loure: http://www.theguardian.com/global-development/2016/apr/18/tanzania-land-rights-victory-earns-masaai-leader-goldman-prize-edward-loure

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The Use of the Rangeland NRM Alliance to Overcome Issues Caused by Isolation through Collaboration and Support

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Key words: Network, governance, social justice, regional policy, outcomes

Introduction

An innovative approach to partnerships has assisted the Rangeland NRM Alliance (The Alliance) overcome social justice issues associated with working in Australia's isolated regions.

The rangelands of Australia covers 6.2 million km^2 (1,488 million acres), over 80% of Australia's landmass, however it is home to less than 3% of the population at an average density of less than 0.1 person per square kilometre. Low population, distance from central government, variability of climate, boom and bust cycles, inconsistent and insufficient funding and low political power are some of the defining characteristics of rangeland communities across Australia (Stafford Smith 2008, Chaney 2015). These characteristics are consistent across the rangelands, despite the variation in environments, industries and communities. Stafford Smith and Cribb (2009) argue that a different governance structure, supported by the Australian people with implementation at the regional and local level, is needed.

In Australia regional Natural Resource Management (NRM) organisations have been established to support communities and land managers (NRM Regions Australia, 2016). The 14 rangeland based regional NRM organisations are isolated from one another, policy makers and investors in NRM services. Consistent with the characteristics described above, this distance contributes to incompatible policy design, perverse outcomes from government programs, little influence on government funding, cyclical funding and duplication of work. To assist in overcoming some of the challenges of this working environment the Rangelands NRM Alliance was cooperatively formed.

The Alliance aims to improve the delivery of NRM in the rangelands at a national level to progress sustainable land management. The members see the Alliance as a solution to the difficulties associated with implementing large scale action across regional and jurisdictional boundaries. The driving force behind this group is the recognition that many rangeland issues benefit from a planned national approach.

Materials and Methods

The Alliance operates as a collective, achieving consensus-based decisions and remaining an unincorporated organisation. A chairperson is elected from the membership and the members meet in person up to three times a year (usually in conjunction with other activities) with teleconferences as required. The Alliance is resourced through financial contributions of members and substantial in-kind contributions in time and travel costs for meetings and activities. One of the member organisations takes on the role of administration agent and hosts the part-time coordinator who undertakes an executive officer role.

The Rangeland NRM Alliance commenced in 2007 and periodically revises its strategic purpose and activities. The purpose is broken into four components:

Policy:

- Develop and influence a national approach to rangelands NRM
- Highlight rangelands specific issues and programs for the State/Territory and Australian Governments as they relate to NRM and as a result, influence relevant policy and programs

Projects:

- Provide a forum for developing and facilitating cross-border and / or national projects and partnerships
- Tailor national projects to suit the rangelands

Process:

- Improve operational arrangements through sharing ideas, information and knowledge.
- Develop the opportunities and frameworks for sharing resources and delivering across borders

Partnerships:

- Collaborate and share information among the regional NRM bodies and external partners with a rangelands focus to continually improve practice, performance and outcomes in natural resource management
- Internal — maintain the true collegiate approach to the Alliance
- External — Build and maintain partnerships to have more effective delivery of NRM outcomes.

Results and Discussion

Due largely to a lack of resources the Alliance is limited in the activities it can deliver at any one time. However an assessment of the impact and results of the Alliance highlights that it has achieved across all areas of its stated purpose. Achievements include:

- Gathering information and partners to highlight the need for a large animal management program for feral camels. This resulted in the development of national research project and establishment of a management program accessing $19 million of Federal government funds.
- Collating nationwide data to develop the Australian Invasive Cacti Network, having Opuntiod cacti listed as a Weed of National Significance and supporting ongoing biocontrol activities.
- Working with Meat and Livestock Australia and the CRC for Spatial Information (and its many partners) to develop the Spatial NRM Hub enabling easy access to geospatial tools for land management decisions and land condition monitoring from paddock to national scale.
- Providing a central network to work with scientists in the development of rangeland appropriate climate change information for regional planning and adaptation.
- Supporting other rangelands based organisations and activities including pooling resources to be a major sponsor of the Australian Rangeland Society Conference 2015.
- Driving a national discussion on rangelands policy including partnering with the Pew Charitable Trusts on a forum to raise the profile of the importance of the Rangelands in Australian Parliament.

Less tangible achievements outlined at the September 2013 strategic review included providing a peer support network, providing a single link for government agencies to contact and consult on rangeland NRM issues, and providing an information source.

Conclusions and Implications

The Alliance works to get better traction for the issues important to the people and environments of the Australian rangelands. The combined resources of the Alliance provide investors, policy makers and partners with services beyond the scope of the individual organisations — this includes strategic planning and partnerships that result in the ability to tackle issues which individual groups may find overwhelming. It has been successful, achieving outcomes for the rangelands by collaborating with members and partners to influence policy, programs and deliver projects. As an apolitical group, much of the Alliance's success is a result of the dedication and willingness of members and partners to improve the situation of the people and environment of the Australian rangelands.

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Grazing Land and Herder's Policy — Some Pertinent Issues in Indian Context

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Key words: Grazing lands, nomads, rangeland policy, grazing policy, livestock

Introduction

Grasslands and rangelands occupy approximately 70% of the world's agricultural areas (FAOSTAT, 2013), about two thirds of which are located in developing countries (Boval and Dixon, 2012). These grazing lands are livelihood source for the rural communities especially the nomadic, livestock keepers, etc. They also have historical and cultural relevance and are a key component of ecological sustenance of the zone. The grazing based livestock industry provides livelihoods for about one billion of the world's poorest people (FAOSTAT, 2013).

In India, pasturelands constitute the main grazing resources, available over an area of 12 million ha. The distribution of pasture lands in the states like Himachal Pradesh (36.44 %), Sikkim (13.31 %), Karnataka (6.54 %), Madhya Pradesh (6.35 %), Rajasthan (5.39 %), Maharashtra (5.11 %) and Gujarat (4.49 %). (Bhagmal et al., 2009; Roy and Singh, 2013).

Most of the Indian grasslands are in degraded condition due to various reasons. They need to be restored by suitable management and policy interventions. Managing the grassland / grazing lands on common property resources is a very complicated and complex job. Integration of three main aspects — sustained production, managing livelihoods and desired environmental services for a sustainable management requires active participation of several stakeholders. The public–private partnership, coupled with legal framework and active involvement of local stakeholders like livestock keepers, farmers, nomadic tribes, is essential for its success. As the issues are very complicated, hence decisions should be based on greater understanding of the interaction of these system components. Some of the key issues in finalizing the grassland and grazing resources policy are presented below.

Grassland Productivity

- Productivity of grasslands – whether to an optimum level or at the highest level, keeping in view the long term sustainability and self sufficiency on one hand and economic benefits on the other.
- Introduction of high yielding crops / varieties/ legumes – effect on productivity as well as native species complex; effect on animal health as well as biomass availability.
- Disturbing the natural biodiversity – Interaction of plant species and effect of interventions on below ground and aboveground native flora, fauna, microorganism.
- Removal of unpalatable, alien species like *Lantana*, *Eupatorium*, *Parthenium*, *Prosopis etc.*- cost and working model- labour intensive.
- Trees and shrubs – introduction and management in grassland and common p*roperty* r*esources*- di*fficulties vis-a-vis benefi*ts.
- Effect of climate changes- measures and planning – long term perspectives.

Natural Resource Conservation

- Mapping and assessment of grassland productivity — assessment of carrying capacity on sustainable ecological basis.

- Managing soil and water erosion especially in sandstorm, wind erosion, flood prone areas — planting of crops especially grasses and legumes.
- Planting trees for a wind break.
- Erection of civil construction.
- Watershed development for checking soil, water erosion and enhancing water recharge
- Quality of soil- replenishment of nutrients though fertilization or legumes.

Grassland Sustainability

- Management of animal stocking rates for sustainability-type and number of animals
- Grazing management — deferred, rotational or seasonal etc.
- Grazing duration-days, season, considering the lean period of biomass availability.
- Rejuvenation and renovation of existing grassland while reducing animal productivity cost.

Social andLivelihood — Institutional framework

- Social issues — pride and cultural value; Nomadic tribes/ livestock keepers are discrete groups, each having their own cultural and social value.
- Proper health care, housing and education of children.
- Proper training and availability of technical know-how.
- Shelter houses in traditional migratory routes.
- Proper veterinary care, Insurance of self and animals.
- Market issues in relation to abundance in season and profitability.
- Fodder banks to meet forage shortage period requirement.
- Incentives and subsidies in lieu of environmental services rendered.
- Creating recreational facilities/ tourism spots to supplement herder's income.
- Issues like grazing ban for one year/ season/ rotational grazing etc. should be considered along with stocking rate controls.
- Ensuring supplemental feeding availability.
- Weatherproof roads along the traditional migratory routes.

Education, Dissemination and Awareness

- Mapping and assessment of grasslands productivity, carrying capacity.
- Sensitization and awareness of herders about suitable grazing practices.
- Considering the indigenous technical know of herders and their proper use in policy perspectives - inadequate documentation so far.
- Coordination of research and extension activities across the country
- Development of models applicable for different parts of the country and their proper demonstration and upscaling.
- Economical and suitable conservation practices for surplus fodder for lean period use.
- Impact on ecosystems, productivity, animal health, production, livelihood of pastoral society.
- Rejuvenation and renovation of existing grassland for reducing animal productivity cost.
- Disease forecasting - prevention, monitoring and control of animal diseases.

Policy and Regulations

- Land rights - short term or long term lease of land rights to be transferred to beneficiaries.
- Grazing rights of herders with a cap/ ceiling on the number and type of animals. –grazing with restricted rights distributed among various herders.

- Economic and property rights reforms — issue of private livestock, common pastoral areas needs to be viewed.
- Disaster management especially in hilly and drought - flood prone areas.
- Incentives for abiding by the laws and maintenance of ecological services.
- All inclusive and all participating approach.

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Small-Scale Farmers' Knowledge of Livestock-Rangeland Management Practices in the Gauteng Province, South Africa

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Key words: Feed scarcity, grazing capacity, rangeland condition, socio-demography, questionnaire

Introduction

Small-scale and/or communal farmers own about 5.5 million of livestock (i.e. 40% of the national herd) in South Africa. There is an increasing decline in grazing areas in communal rangelands or small scale farms owing to a variety of factors including excessive stocking rates. In Africa, researchers and development policy experts have overlooked community knowledge and skills when implementing policies and developing plans to improve livestock and rangeland management practices (Vetter 2005). Outside interventions seek to change local livestock keeping objectives and practices without recognizing that these are the consequences of many years of interaction within social and ecological environments, which relies on specific rules and knowledge (Allsopp et al. 2007). As an attempt to better understand local social and economic systems, this study was conducted in the Gauteng Province to document: 1) the local knowledge of small-scale farmers on livestock and rangeland management practices, and 2) the possible constraints related to adoption of these practices.

Materials and Methods

A total of 50 small-scale livestock farmers (i.e. cattle, sheep and goats) were selected from different vegetation types and different administrative boundaries of the Gauteng Province. The selected farmers were interviewed using a structured questionnaire, which was divided into: 1) demographic information, 2) livestock management, 3) rangeland management, and 4) information relating to drought coping strategies.

Results and Discussion

The studied households had an average total family size of 5.54. Eighty four percent of the farmers were over 50 years of age and only 16.3% were less than 40 years. About 63% of the farmers had not received any agricultural training in livestock production and/or rangeland management. The majority of the farmers relied on both livestock and crop farming. Based on the farmers' responses, the major constraints on livestock production included feed and water scarcity, land ownership, animal diseases, stock theft and drought. About 67% of farmers did not know their farm grazing capacity and the stocking rates used. More than 90% of the farmers indicated that they did not conduct rangeland condition assessment (lack of knowledge), which was consistent with the feed shortages during the dry seasons. Only one farmer had grazing management and fodder flow plan which shows the extent of lack of livestock-rangeland knowledge in this province. Current results show farmers in this province to rely on their indigenous knowledge to manage their livestock and rangelands, which agrees with Abule et al. (2005) who found this to be the case for 80% of farmers in Borana of Ethiopia. The current results further indicated that poor grazing practices such as overgrazing may be taking place in this province due to farmers' lack of knowledge and minimal or no training of farmers in rangelands management. The lack of interaction among researchers, extension officers and farmers has been known to result in a "dole-out" mentality among farmers who have been reduced to mere "recipients of new technologies" (Islam 2007). This may lead to rangeland degradation with major economic implications.

Conclusion and Implications

There is a need for training of farmers, particularly the small-scale farmers on rangeland and livestock management. Rangeland management would be effective if government could support indigenous rangeland management knowledge through recognizing and empowering the local management institutions by including them in development planning.

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Will Mongolia's Herders Disappear within 10 Years?

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Key words: Threats to grassland people of Mongolia

Introduction

The challenges related to the preservation of Mongolia's pastureland, its quality and condition are key concerns for the livestock sector. However, scientists, researchers and government agencies tend to focus solely on rangeland ecology and livestock. All too often, herders are overlooked and omitted from the discourse. This is the main reason I want to talk about people of the Mongolian grassland and Social justice issues in rangelands.

Mongolia's herders are the keepers of culture and tradition, passing on their knowledge and wisdom from generation to generation. However, the number of herders has been decreasing each year while the number of livestock has been rapidly growing. By the end of 2015, there were 50 million livestock nationally and just 145,200 herder households. In 2010, herder households numbered 170,300. Sixty percent of herder households have fewer than 200 head of livestock, with only 2 percent of wealthier herders owning more than 1000. According to economists, 200 livestock per household is below the living standard and is insufficient to sustain people's lives. This means that 60 percent of herders, or 87,000 people, are vulnerable to losing their livestock - their key source of income and household security - in natural disasters.

Materials and Methods

"It's the right time to pay more attention to herders, not to the quantity of livestock," said Mr Olzvoi, head of the Mongol Herder agency.

We have investigated several reasons for the drop in herder numbers:

1. **The age of herders:** Statistically, the average age of herders is 45. Young herders between the ages of 20-35 represent just 20 percent of all herders. Hence, the majority of herders are ageing, and there is no government policy or support for the younger generation of herders.
2. **Inadequate social welfare services:** Most herders do not pay social and health insurance on a voluntary basis; therefore, they are unable to access social and health services. Herding is strenuous work, with unlimited work hours and no occupational safety provisions. Herders must work outdoors irrespective of the climatic conditions, and are at risk of disease, with many losing their ability to work or dying at an early age. They are also susceptible to such animal-to-human diseases as brucellosis and parasites (Echinococcus, Cysticercus tenucollis). Diet is an important component of herders' health. Herders` diets are predominantly meat-based, with a general lack of vegetables and other vitamin-enriched food. This had led to high rates of stomach and liver cancer. There is also a lack of other government services in remote areas. The lack of information and means of communication is one of leading causes of rural to urban migration. Overall, the quality of life for herders is poor compared with urban life. In trying to survive in a harsh climate, herders have little time to focus on their living conditions, health, diet and wellbeing.
3. **Six-year-old schoolchildren:** The Mongolian education sector several years ago adopted a 12-year school system. This means children are required to begin school when they are six years of age, which has presented problems for herder households. Young herders with six-year-old children need to have a

separate home in the soum centre where mothers can stay to look after their children. Husbands remain in the countryside to tend to their livestock. This increases households' living expenses and can negatively impact on couples' relationships, prompting some couples to divorce.

4. **Repeated natural disasters:** Multi-disciplinary studies have shown that the degradation and deterioration of pasturelands has significantly worsened with the growth in herd numbers, as well as from human activities and negative changes in climate and the environment. Reduced rainfall and climatic changes have led to declines in grass growth and feed quality, resulting in poor herd productivity. Herders have also lost significant numbers of livestock in dzuds and droughts. Those who have lost their animals tend to migrate to urban areas in search of other jobs.

Conclusions and Implications

According to statistics for the past five years, the number of herders has fallen by 15,400 each year. If this trend continues, in 10 years there will be no more herders. In order to address this situation, the following actions need to be taken:

- Conduct a nationwide survey among herders to ensure there is an accurate database on the herding community, and produce reports or articles to raise awareness of the issue among scientists, policymakers and government agencies.
- Support young herders through education on traditional herding practices, encourage their social participation, and ensure sustainable income sources (such as incentives or bonuses for young herders, income diversification, and compensation for remote herder households).
- Conduct activities nationwide to address the problems herders face in relation to social welfare services (such as improved education, culture, and health services for herders).
- Identify alternative ways to educate six-year-old children from herder households (such as mobile education services, home-based distance education, learning via television or radio, and summer training).
- Conduct a public awareness campaign promoting a positive image of herders and the pride of being a herder.

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Protecting Pastoral Granaries: An Application of the FAO Resilience Model among Households in Northern Kenya

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Key words: Food resilience index, northern Kenya, pastoral households, stages of progress, Turkana, Mandera

Introduction

In the past, food security assessment studies have focused on vulnerability of a household to food insecurity. Although humanitarian support has helped save lives, especially in the Arid and Semi Arid Lands (ASALs), the ability of the communities to withstand future shocks have not been improved (USAID, 2011). It is for this reason that governments and the donor community are shifting their interest to resilience approach. In terms of food security, resilience to food insecurity has been defined as the ability of a household to maintain a certain level of well-being, withstanding shocks and stresses, depending on the options available to the household to make a living and its ability to handle risk (Alinovi *et al.,* 2008). Resilience studies have identified important components contributing to household food security as income, access to basic services, social safety nets, household assets, adaptive capacity and stability. However, the extent to which these components contribute to food security among pastoral communities has not been clearly established. This study sought to investigate how these components vary between poor and non-poor households in pastoral households of northern Kenya.

Methods and Materials

Study setting

The study was carried out in Turkana and Mandera Counties, Kenya. Mandera is situated on the north-eastern part of Kenya and it borders Somalia and Ethiopia. It has three main livelihood zones: a pastoral economy zone on the eastern side of the county, an agro-pastoral economy zone on the western side and an irrigation zone on the northern end along the Daua River.

Turkana County is the second largest County in Kenya. It borders Uganda to the West, Sudan and Ethiopia to the North, Samburu and Marsabit Counties to the East and to the South it borders Baringo and West Pokot Counties. The main socio-economic activity in the County is nomadic pastoralism.

Sampling procedure and data collection

A multi stage approach was used to sample 300 and 360 households in Mandera and Turkana Counties respectively. The first stage of the study involved administration of questionnaires to the 660 households. The questionnaire captured household socio-economic characteristics and data on food security indicators broadly grouped as income and food access, access to basic services, social safety nets, assets, adaptive capacity and stability. The second stage of the study involved carrying out Focus Group Discussions (FGDs) carried in 11 villages and 13 villages in Mandera and Turkana Counties respectively, where the sample households had been identified. FGDs were used categorize households as either poor or non-poor (Krishna 2010). ANOVA was used to test for significant statistical differences between means of interval and ratio indicators, while the Kruskal Wallis test established if there were significant differences in medians of ordinal indicators between the poor and non-poor households. Principal Components

Analysis was used to identify key indicators that could be useful in identifying resilient households, and subsequently for computation of household resilience index.

Results and discussions

Among the 22 indicators of the FAO resilience index model tested in this study, nine of them came out as significant in identifying poor from non-poor households. These indicators were: dietary diversity score, per person daily expenditure, per person daily income, durable index, years of formal schooling of household head, change in expenditure, loss of job, road network and safety net dependency ratio. Further analysis of these indicators using Principal Component Analysis established that diet diversity score, durable index and education level of household head were the most important indicators determining household food resilience. From the Principal Components output, the household resilience score could be computed as:

R = 0.27353DDS + 0.14158DI + 0.12106 SYs where (Equation..... 1)

DDS was the diet diversity score, DI was the durable index score and SYs was the number of years spent by a household head in formal learning institution.

Conclusion

Diet diversity score, durable index and education level of household head are key determinants of household food resilience. These indicators could be useful and targeting non-resilient households and evaluating performance of resilience building interventions among pastoral households.

Recommendations

The significant indicators were all proxy indicators of household socioeconomic status, accessibility to basic services and literacy levels. Resilience of pastoral communities in general could be improved through increased household incomes, improved accessibility to basic services and education.

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A Grazing System Using Solar-Powered Electric Fence to Expand Rangeland Productivity

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Key words: Rangeland, multiple uses, solar energy, Taleghan Research Station.

Introduction

The economic value of rangelands can be increased if they can have more than one use. Multiple use of pasture can raise the income of the land holders and electric fences can be used instead of the shepherd which will reduce the cost of management. As Johnson (2008) reported solar energy is an environmentally friendly source of power for electric fences.

Materials and Methods

The research was conducted at the Taleghan Research Station of the University of Tehran. There are several native species that are both medicinal plants and palatable for sheep grazing in vegetation composition of rangelands of station. The standing crop of medicinal plants was measured using clipping and weighing method. Fashandy sheep were used for grazing; this breed is the dominant sheep breed in the region. The animal weight was recorded when they moved in and out of each paddock. The metabolic energy and palatability of all species were evaluated. Medicinal plants were harvested in flowering stage according to their phenology investigation.

Results and Discussion

Medicinal plants were harvested at the flowering stage and as was reported by (Arzani *et al*. 2004, Askari *et al*. 2010) highest forage quality was obtained before flowering stage and lower quality was found after plant maturity (Figure 1).

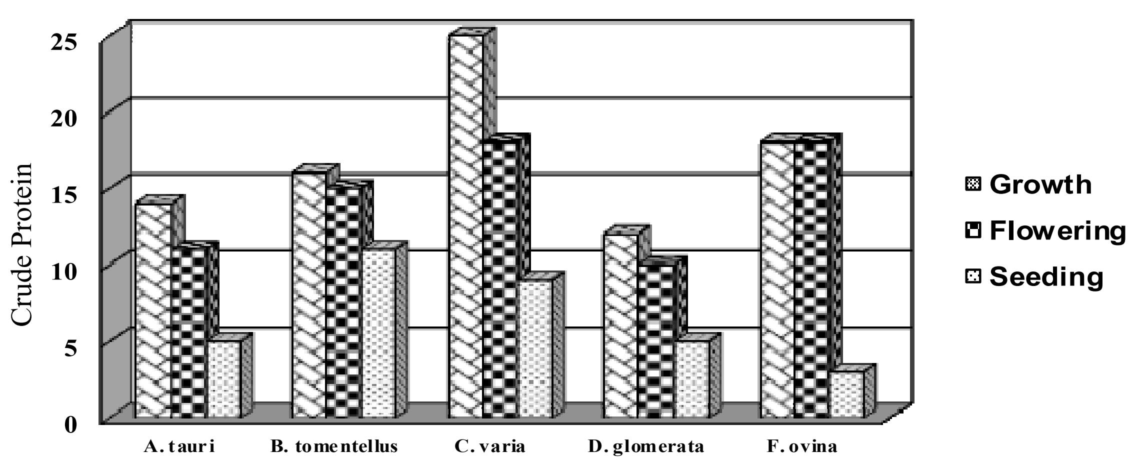

Figure 1. Influence of phenological stages on CP percentage (Arzani *et al.* 2004).

The results showed that multiple use of rangelands promote income of land holders. They can sell medicinal plants and increase animal production because of applying solar-powered electric fencing to control grazing. This type of grazing system also required less energy by the sheep compared with an open grazing system. The solar-powered electric fence also caused changes in animal behavior and reduced labor requirements to manage the animals, the results of animal weight have been illustrated by Figure 2.

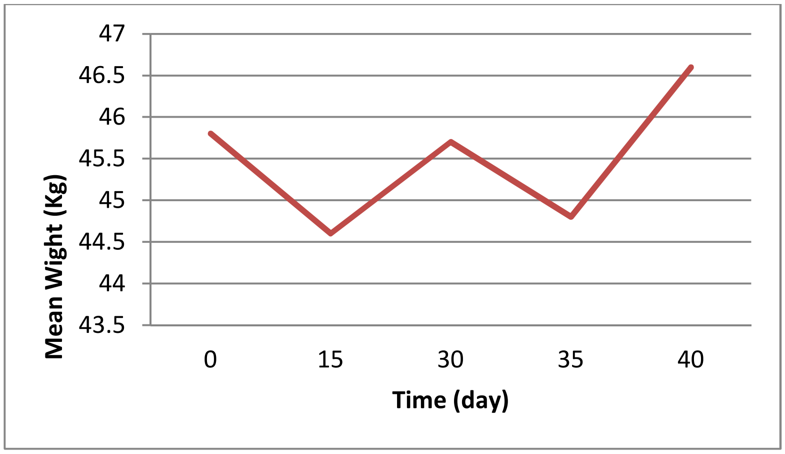

Figure 2. Period of grazing and animal weight of each paddock.

Conclusions and Implications

Generally it was found that it is possible to increase a land holder's income and reduce his or her cost of range management by incorporating solar-powered electric fence and obtaining multiple uses from the land, e.g., animal grazing and medicinal plant harvest.

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Multiple Use of Rangelands

4.1 Energy Development and Reclamation of Industrial Disturbances

Perennial Rangeland Grasses for Bioenergy

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Introduction

The Industrial Revolution established a real synergy between engines used for manufacturing all kinds of goods and for transportation and fossil fuels (coal, oil, and gas). Industrial societies thrived on local or imported fossil fuels and the availability of energy at a stable and relatively affordable price was one of the basic conditions for the development of specific industries, regions, and countries.

Fossil fuel consumption increased steadily from the late nineteenth century up to the 1960s, when environmental concerns became a part of the development agenda. Data gathered all over the world show a strong link between anthropogenic activities and the steady trend in temperature increase, which the International Panel on Climate Change (IPCC, 2014) claims "is due to the observed increase in anthropogenic greenhouse gases (GHG) concentrations". Different GHG emission scenarios show with high confidence that temperature change can be kept to less than 2 °C relative to pre-industrial levels if atmospheric GHG are maintained at or below 450 ppm CO_2eq (IPCC, 2014).Therefore, one of the biggest challenges we are now facing is achieving a substantial reduction of GHG emissions.

This challenge aroused a new interest in renewable energies such as bioenergy, solar, geothermal, hydropower, ocean, and wind energy, due to their potential role in the mitigation of climate change (IPC, 2011). Bioenergy includes electricity, thermal energy, and fuels commonly called biofuels, the most attractive and practical choice for replacing fossil fuels used for vehicle propulsion. Biofuels are classified into different types, according to the feedstock and transformation processes involved in their production: (*i*) first generation biofuels include bioethanol from sugar cane or corn, and biodiesel from oil crops (mostly soybean and canola); (*ii*) second generation biofuels are obtained from lignocellulosic feedstocks such as wood (short rotation coppice, mostly *Populus* spp.) and perennial grasses (e. g., *Panicum virgatum*, *Miscanthus* spp., *Andropogon gerardii*, and *Arundo donax*); and (*iii*) third generation biofuels, including biodiesel, bioethanol, and H_2 derived from microalgae.

Third generation biofuels are still in the lab stage, while 1stgeneration biofuels are surrounded by a lot of controversy (Hill *et al*, 2006; Carroll & Sommerville, 2009) because the raw materials required are commonly used as food and they do not significantly decrease GHG (Salomon *et al*., 2007). However, there is a steady interest in 2nd generation biofuels, though with few truly commercial scale industries devoted to their production.

Energy Crops

Perennial grasses, formerly used for energy when animals were the draft force in farms and transportation, have now come into focus as bioenergy source (Lewandowski *et al*., 2003) due to the following advantages: (*i*) high biomass productivity; (*ii*) high biomass yields in relatively low quality sites; (*iii*) minimal or no fertilizers input requirement; (*iv*) suitability of traditional agricultural machinery for their production; and (*v*) positive energy balance, *i.e.* the energy contained in the biofuel is higher than the energy expended in its production (Fernández, 2003). Furthermore, rising atmospheric CO_2 and drought conditions predicted by climate change models (IPCC, 2014), would not affect their yield (Oliver *et al.*, 2009).

During the last two decades of the 20th century, the U.S. Department of Energy conducted an intense screening for bioenergy crops, analyzing 34 herbaceous annual and perennial species along the crop-producing areas of the country. Annual crops (*e.g.* corn) had the highest yields, but perennial grasses were recommended instead due to erosion risks, and though. *Phalaris arundinacea* was also considered suitable for energy purposes, *P. virgatum* was chosen as the "model energy crop" (Wright &Turhollow, 2010). High biomass production (6-10 Mg DM ha^{-1} year^{-1}) on land not suitable for crops was reported for *P. virgatum*, with variations according to harvest timing, topographic position and fertilization (Adler *et al*., 2006; Lee *et al*., 2009). These high accumulation figures were recorded mostly in soils with low nutrient content and erosion, pH, and drainage problems (Blanco Canqui, 2010). Propheter & Staggenborg (2010) found that annual crops (corn or sorghum) removed more nutrients (N, P, and K) than *P. virgatum*, *Andropogon gerardii*, and *Miscanthus* × *giganteus* during the first two years of establishment. .*P. virgatum* translocate nutrients, storing nitrogen in the below-ground biomass (Lemus, 2013), therefore reducing fertilization requirements. In spite of that, many authors obtained higher biomass yields with low nitrogen inputs (*e.g*., 50-100kgNha^{-1}: Lemus *et al*., 2008; manure: Lee *et al*., 2009).This low nitrogen requirement could explain why although *P. virgatum* produced more biomass in monocultures than in mixtures with no differences across stand ages, the soil under *P. virgatum* contained more organic C than soil under crops and in some cases even than soil under pastures, concluding that long-term studies are needed for determining the net amount of C sequestered, mainly in marginal croplands or degraded soils.

Studies on the production of other energy crops such as *Andropogon gerardii* (Lee *et al*., 2009), *Miscanthus* spp. (Lemus & Parrish, 2009); and *Phalaris arundinacea* (Jarveoja*et al*., 2015) have consistently shown their high nutrient content and water use efficiency, and their advantages over crops for 1st generation biofuels in relation to energy balances and GHG emissions. However, these crops require energy for planting and fertilization for maintaining high yields these managements have associated environmental issues and money cost.

Tilman *et al*. (2006) claimed that low-input high-diversity mixtures of native perennials grasses could contribute more net energy, lower GHG emissions, and less agrichemical pollution per hectare than crops for 1st generation biofuels. They estimated that the C sequestration capacity of these low-input high-diversity grasslands exceeds the release of carbon from fossil fuels used throughout the process of obtaining bioethanol (4.4 ~~Mg~~ vs. 0.32 Mg ha^{-1} year^{-1}); furthermore, as they are obtained in marginal areas and do not require soil removal, biodiversity would not be affected by habitat loss.

Argentinean Rangeland Perennial Grasses

Vast areas of Argentinean land are covered with rangelands dominated, by C4perennial grasses such as *Bothriochoa laguroides, Elyonuru smuticus, Eragrostis lugens, Leptochloa chloridiformis, Panicum prionitis*, *Panicum bergii, Paspalum* spp.*,Setaria geniculata, Sorghastrum setosum, and Spartina argentinensis*. High soil salinity, impeded drainage areas, and severe drought or flood events hinder the conversion of these areas to agriculture. Livestock production has a low efficiency due to poor quality of the forage supply. Controlled fires are frequent because newly sprouted leaves are tender and have higher protein content, but they often become wildfires affecting non target areas. Therefore, these rangelands are huge sources of biomass which so far has not been used for any sustainable productive activities with wildlife conservation. Verón *et al*. (2012) concluded that diverting wildfires to bioenergy could exceed Argentinean power demand.

Our aim was to determine the potential of using two rangeland communities, one dominated by *Spartina argentinensis* Parodi and the other by *Panicum prionitis* Ness (espartillar and pajonal, respectively) as bioenergy feedstock and its initial effect on biodiversity. We had previously carried out studies on the ecological features of these communities (Feldman *et al*, 2004; Feldman & Lewis, 2005; 2007; Massa, 2014), and estimated their bioethanol potential: 240-400LMg^{-1} *S. argentinensis* (Jozami *et al*., 2013). Biomass production of *S. argentinensis* and *P. prionitis* under two different harvesting frequencies (control and every 6 and 12 months; n=4; plots 20m x 20m) was compared with control areas for two years. Cellulose, hemicellulose and lignin percentages were obtained following Van Soest (1963), and bioethanol and potential yield were calculated based on the cellulose and hemicellulose produced per unit area, using the Theoretical Yield Calculator (USDOE, 2009). Both species showed high biomass accumulation after the first harvest, with no differences among harvest frequencies; and although composition of cell wall fibers varied with species and treatment, potential bioethanol production per hectare was not affected (Fig. 1). Therefore, in order to minimize economic and energy cost one annual harvest is recommended for both plant communities. As *P. prionitis* had higher initial biomass and *S. argentinensis* accumulated more biomass after the first harvest, different management approaches should be considered for each species. Anyway, our aim is to combine using these feedstock for both bioenergy and livestock production, *i.e*. harvesting biomass and then using the area as usual for livestock production for a 3-4 year period, therefore with no impacts due to land use change (IPCC, 2014). Soil organic carbon was determined and no statistically significant differences due to treatments were evident during the experimental period.

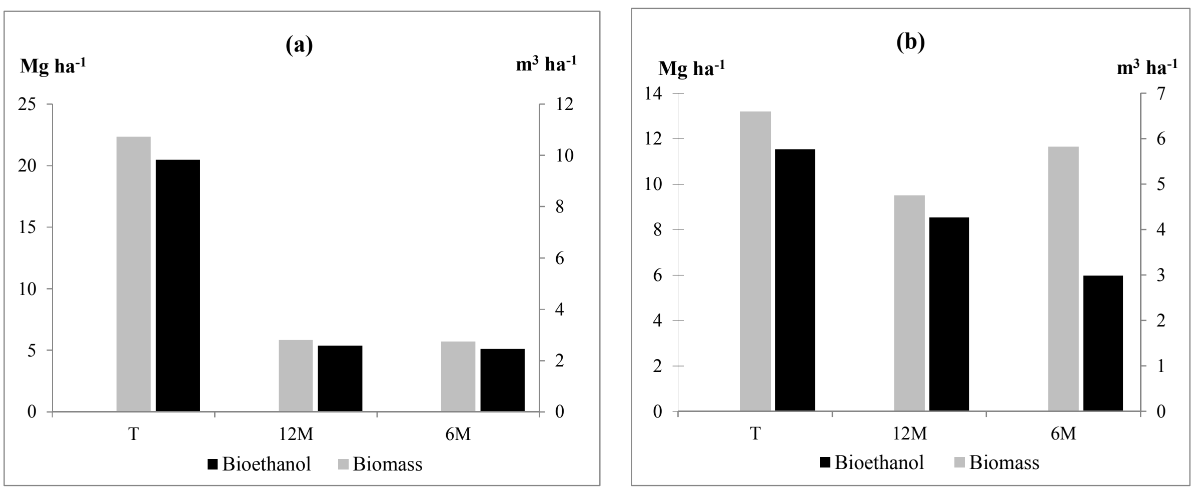

Figure 1. Biomass and potential bioethanol production of *S. argentinensis* (a) and *P. prionitis* (b) under different harvest frequencies

Biodiversity changes were determined by censing vegetation (Braun Blanquet, 1979) in randomly placed plots (n= 4; 4 x 4m) and by capturing soil arthropods with pit-fall traps (n=16; 250 ml of 5% ethanoic acid and 2.5% methanal solution) in each community. Full plot × species matrixes were constructed for each community (vegetation and arthropods of the espartillar and pajonal) for each year. Data were analyzed by multivariate methods (Principal Component Analysis and Multiple Response Permutation Procedure) for synthesizing information. The vegetation and arthropod biodiversity metrics considered (richness, evenness, abundance, and diversity) were not affected by either treatment, showing that these are resilient communities and that using them for bioenergy poses no risk of biodiversity loss.

Considering that in C4 grasses lignin is the main barrier to the efficient hydrolyzation of cellulose for bioethanol production, we evaluated different pretreatments for its removal: phosphoric acid, ligninolytic enzymes and supernatants of native Fungi species *Trametes hirsuta* (Wulfen) Pilát, and *Pycnoporus sanguineus* (Fr.) Murr. Supernatant of *P. sanguineus* culture was the best pretreatment for lignin degradation of *S. argentinensis* green or senescent leaves, allowing the release of near 60% of glucose for fermentation (Larranet al., 2015). We are continuing these researches in order to optimize this process and analyzing *P. prionitis* lignin removal as well.

Another bioenergy approach that we considered was gasifying pellets of *S. argentinensis* for combined heat and power (cogeneration), assessing the energy balance of the whole process. We designed a model considering biomass harvest with a self-propelled chopper, shipping to plant, drying and conditioning, pelletizing, pellet storage, and gasification for combined heat and power (fig. 2). Our calculi show an energy return on investments of 5.43, a promising figure when compared with other feedstocks (unpublished data).

According to Tilman *et. al.* (2009), we are now facing "the food, energy, and environment trilemma". Society demands food, so diverting croplands for bioenergy would not be a wise solution, energy requirements continue growing, and environmental issues include GHG and pollution. Our approach of using perennial rangeland species for bioenergy and livestock production could contribute to this trilemma solution, while helping to improve life quality due to the development of new economic activity.

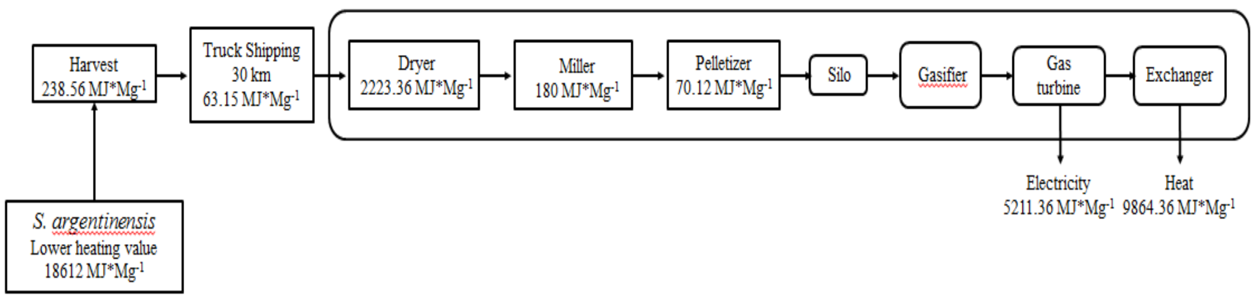

Figure 2. Schematic flow diagram of cogeneration process with energy inputs and outputs.

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Factors Regulating Long-Term, Large-Scale Grassland Community Assembly

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Key words: Community assembly, compositional data analysis, rangeland, restoration, shrubs

Introduction

Considerable research is currently focused on restoring degraded grasslands by introducing species from seed. Much of the research involves small plots seeded, otherwise treated and measured over a few years. Over these short periods, seeded plant abundances remain sensitive to numerous factors including seeding rates, precipitation and priority effects. Owing to a lack of long-term data, it is unknown if the short-term abundance differences these factors cause tend to persist. Longer term studies are needed to better quantify lasting effects of restoration inputs on plant communities.

Extending restoration research to longer measurement periods necessitates working at larger spatial scales because, over time, tiny populations in small plots become unrealistically vulnerable to demographic stochasticity. Measuring outcomes of real-world restoration projects can provide some of the needed long-term data without the prohibitive expense of performing large-scale experiments. In recent years, considerable practical knowledge has emerged through study of restoration in practice (e.g. Knutson et al. 2014). In this study, we investigated grassland restoration outcomes at nine Great Plains surface coal mines. The top restoration priority for degraded Great Plains grasslands is shifting compositions away from weedy species toward seeded species. Another priority is boosting abundances of shrubs, the plant group often most difficult to restore to grasslands.

Materials and Methods

We studied 327 fields occurring on coal mining lands in Montana and Wyoming. Prior to seeding, crushed rock extracted during mining was deposited to reconstruct pre-mining topography, and topsoil was spread over the rock. Fields were then tilled and seeded with native grasses, forbs and shrubs.

In 2011 and 2012, between 5 and 27 years after seeding, we measured plant cover in 20 frames (20 x 50 cm) evenly spaced along each field's longest possible transect. We analyzed cover of: 1) seeded grasses, 2) exotic perennial grasses, 3) exotic annual grasses and forbs (hereafter annual weeds), 4) native forbs, and 5) native shrubs. We transformed to relative cover (cover of each plant group divided by total plant cover) to better investigate factors allowing certain plant groups to outperform others and used compositional data analysis techniques to account for the resulting sum to 1.0 constraint (Egozcue et al. 2003).

Results and Discussion

On fields seeded with the low grass seed rate range (i.e. >0.0 to 4.0 kg pls ha^{-1}), the ratio of annual weed to seeded grass cover averaged 1.5 (0.7, 3.3) (point estimate with 95% CI), compared to 2.8 (1.1, 6.7) on fields not seeded with these grasses. There was little evidence increasing the grass seed rate above the low range further suppressed annual weeds (Fig. 1).

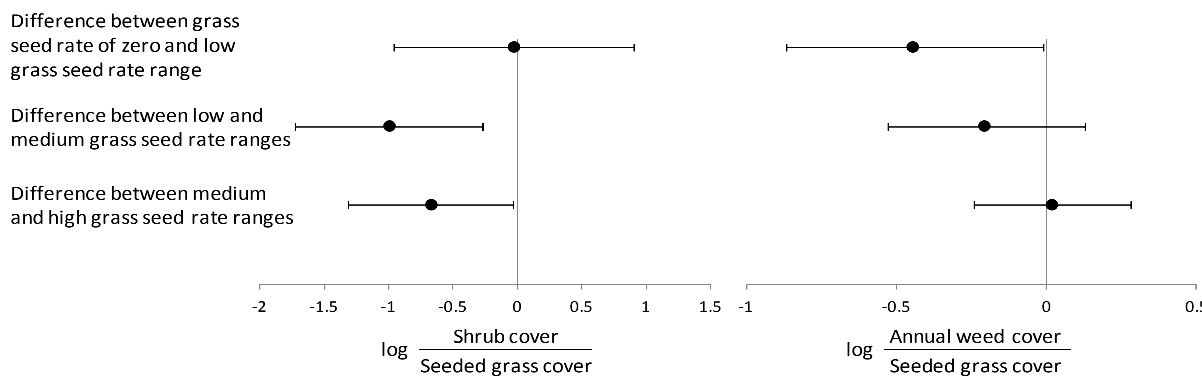

Figure 1. Point estimates (dots) and 95% CIs (lines) estimating differences between effects of four grass seed rate ranges. The top left CI indicates inconclusive, potentially minor effects on shrub abundances of increasing grass seed rates from 0.0 to the low range (i.e. >0.0 to 4.0 kg pls ha^{-1}). The middle and lower left CIs indicate reduced shrub to grass cover ratios for the medium range (>4.0 to 8.0 kg pls ha^{-1}) compared to the low range and the high range (>8.0 kg pls ha^{-1}) compared to the medium range, respectively. Increasing the grass seed rate from 0.0 to the low range decreased exotic annual weed cover (top right CI), but the data were inconclusive about weed responses to further grass seed rate increases.

Unlike annual weeds, shrubs were not detectably suppressed by the low grass seed rate range (i.e. >0.0 to 4.0 kg pls ha^{-1}) (Fig. 1). Another contrast between annual weeds and shrubs was that shrubs became increasingly suppressed as grass seed rates were elevated above the low rate range (Fig. 1).

Crested wheatgrass (*Agropyron cristatum* L.) and smooth brome (*Bromus inermis* Leyss.) were the only exotic perennial grasses observed, with the latter observed only rarely. Exotic perennial grasses tended to colonize around the time of seeding. Averaged over fields where exotic perennial grasses were detected, the ratio of exotic perennial grass to total plant cover increased 0.6 (0.14-1.9) % per year.

Conclusions and Implications

Regardless of seeding rate, first growing season precipitation and other factors determining starting densities, seeded grasses appeared similarly abundant long after seeding, suggesting convergence to constant final yield. Conversely, starting conditions regulated native shrubs: Though generally rare, shrubs were exceedingly rare where grasses were sown at high rates. Lowering grass rates would reduce costs, benefit shrubs and pose minimal risk of grass establishment failure. In fields where present, crested wheatgrass increased through time, so preventing this species from establishing is critical, especially around seeding time. These findings exemplify the practical knowledge that can emerge from studying restoration in practice.

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Dynamics of Vegetation, Biological Soil Crusts, and Seed Banks along Pipelines in Southern Alberta's Mixed Grass Prairie

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Key words: Alien and invasive species, community dynamics, disturbance, seed bank, soil crust

Introduction

Oil and gas infrastructure negatively impacts ecosystem function, increases habitat fragmentation, increases susceptibility to invasive species, and has been linked to decreases in biologically fixed carbon, productivity, and grazing capacity (Allred *et al*., 2015). In the Northern Great Plains, disturbed sites can exhibit dominance by seeded cool season grasses, native ruderals, and volunteer alien species, many of which rely on the seed bank for dispersal and persistence (i.e. *Agropyron cristatum*, *Melilotus* spp., etc.). Biological soil crusts (BSCs) are functionally important in grasslands for stabilizing the soil, fixing nitrogen, increasing available phosphorus, retaining soil moisture, and regulating both seed bank formation and seedling recruitment; however, BSCs are sensitive to disturbance and recover slowly (BLM, 2001). Further, invasive species like *Melilotus* are deleterious to grasslands by altering soil microsites and vegetation structure resulting in shading and changes to moisture and nutrient availability (Ripper and Larson, 2009). A relationship between soil crusts and seed banks has been acknowledged in the literature, particularly in deserts (Clements *et al.,* 2007); however, there is limited research exploring these relationships in Mixedgrass Prairie, especially divergent management and disturbance regimes. Our objectives are to quantify the impact of pipeline disturbance (i.e. time of installation, pipeline width, distance from disturbance, etc.) on plant communities, seed banks, and BSCs. Foliar and soil crust cover will be related to seed bank formation.

Materials and Methods

We sampled 18 pipelines in SE Alberta at the University of Alberta Mattheis Research Ranch. Along each pipeline 16 linear transects were placed perpendicular to the edge of the trench every 5 m. Sampling resolution (for 15 distances) was higher near the disturbance up to a distance of 55 m, replicating methods employed by Hansen and Clevenger (2005). Seed bank was sampled on all transects up to a 6 cm depth then bulked by distance. Foliar and basal cover were recorded for a third of transects. Biomass and 15 cm of mineral soil were collected for a subset of sampling distances (n=5); detailed BSC cover data were collected at this time. Germinable seed bank was recorded in the greenhouse over 1 year. Community data was analysed in R using multivariate techniques like NMDS and PerMANOVA.

Results and Discussion

Aboveground 120 plant species were observed while seed bank richness was lower with only 96 species; grasses occurred infrequently in the seed bank. Hence, invasive grass *Agropyron cristatum* was detected during vegetation surveys along pipelines, but occurred infrequently from the germinable seed bank (Compare Figure 1A and 1B). BSC richness overall was low with 12 species, this could be explained by the disturbed nature of our sites as 57.6% of plots lacked BSC and 19.4% contained fragments (cover <5%). Foliar cover, seed bank, and BSC composition responded to pipeline disturbance (Fig.1). Near pipelines there was a shift towards plant communities and seed banks dominated by introduced species, primarily *Melilotus*, and native ruderals. Two grasses, *Elymus trachycaulus* and *Nassella viridula*, indicative of native reclamation seed mixes, were more abundant near pipelines. Pipelines had more bare ground and lower BSC cover (NMDS gradients, $p<0.05$). PerMANOVA indicated that plant communities on the pipeline up to 3 m from the trench were significantly different from the native community 55 m away ($p<0.05$). This effect was much weaker for seed bank composition, with the trench only marginally different than the native community ($p<0.1$). Basal cover was significantly different than the undisturbed community up to 1 m ($p<0.05$); at 5 m where there was near significance ($p=0.096$).

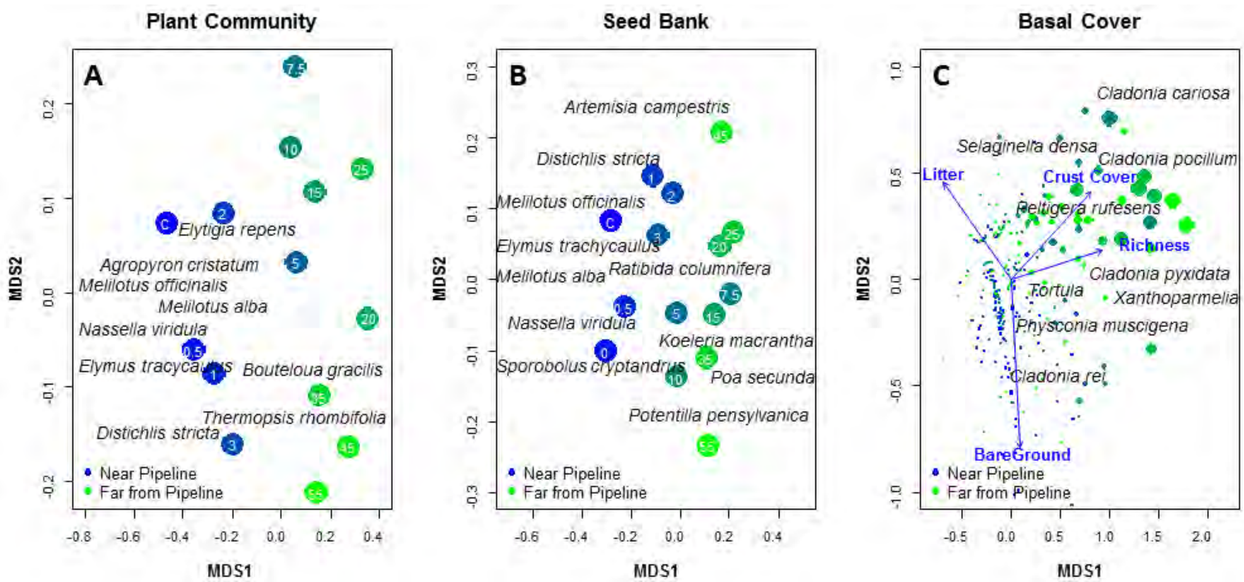

Figure 1. NMDS of community composition along pipelines. Darker blue symbols indicate composition near pipeline trench; lighter green symbols indicate a greater distance from the pipeline center. A) Plant community, with centroids of species composition by distance. B) Seed bank, with centroids of species composition by distance. C) Basal cover including lichens, mosses and spikemosses. Larger symbols indicate greater BSC cover.

Conclusions and Implications

Shifts in plant communities due to pipeline construction were more pronounced than the corresponding seed bank. BSCs exhibit high sensitivity to pipeline presence, achieving higher cover and richness in undisturbed grassland. Evidence of pipeline seed banks containing native ruderal and seeded native grasses indicates favorable successional trajectory. Abundance of invasive legume *Melilotus*, deleterious to native grasslands and facilitates invasive species (Riper and Larson, 2009), is of concern.

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Landowner, Operator Perspectives on Energy-Related Impacts to Natural, Agricultural, and Social Resources in the Bakken Oil Patch

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Key words: Bakken energy development, landscape industrialization, North Dakota oil production

Introduction

Energy production in North Dakota has increased dramatically since 2007, driven primarily by development of petroleum deposits in the Bakken shale formation. Oil production has long been a feature of the working landscapes and rural communities of western North Dakota, but new technologies such as hydraulic fracturing and horizontal drilling have led to unprecedented landscape industrialization. North Dakota is currently second to Texas for state-level petroleum production. While production in Texas is triple that of North Dakota, production in North Dakota is much more spatially concentrated, with approximately three-quarters of statewide oil production contributed by just four counties centered over the Bakken shale.

Increased density and productive capacity of wells has increased the footprint of energy development in almost every sense: more traffic; more land given to pads, pipelines, and novel infrastructure such as saltwater disposal; and large increases in local populations (Fig. 1). All of these changes affect the natural and social resources of rural communities, but the nature and extent of these impacts have yet to be documented. We sought insight on energy development-related impacts in the Bakken region from those who depend on natural and agricultural resources for their livelihoods in an effort to identify locally-relevant research priorities.

Figure 1. Energy impacts directly impact natural resources by degrading (Top) and occupying (Bottom) rangeland, but the social impacts of population growth and a changing local workforce affect rangeland users and their communities, as well.

Materials and Methods

To identify—and determine the prevalence of—issues that affect residents of the Bakken region, we conducted focus groups and a mailed survey of local landowners and farm/ranch operators. Focus groups were comprised of at least five community and agricultural industry leaders in each of the top three oil-producing counties of North Dakota. Each focus group consisted of two hours of discussion following six fixed, open-ended prompts given by the moderator. These discussions were recorded, transcribed, and qualitatively analyzed to identify emergent themes, which were ranked by their frequency of mention and re-shaped into questions with Likert-type responses for a landowner/operator survey conducted by mail. This two-part process provided in-depth perspective and ranked interest in various topics and issues from the focus groups, which was tested for broad community support through the mailed survey. Survey respondents were also asked to characterize and quantify their experienced impacts and note their experience with energy-related companies as per problems identified by focus groups.

Results and Discussion

Across all three focus groups, three major categories of energy development-related concerns emerged: Impacts to farm/ranch management and operation; Impacts to local social resources and communities; and Business relationships with the energy industry, particularly with respect to easements, contracts, and compensation.

From an agricultural perspective, focus group participants were most concerned about fugitive dust impacts on crops and livestock, traffic-related disruptions to farm operations, and restoring productivity following reclamation of pads, pipelines, and spills. From a business perspective, participants expressed concern about terms of easement contracts, ability to rent or lease land in high-impact areas, and adequate compensation for time spent managing development impacts. From a community perspective, participants expressed concern over limited resources for local services, stress on social networks, and demands of itinerant populations on schools and churches.

We found no clear relationship between survey respondents' stated level of energy-related impact and their affected land area, suggesting attitude and level of disruption are more important than actual footprint. There was a high degree of agreement with issues identified by focus groups among survey respondents, particularly with respect to state and local policies on energy taxes and revenue-sharing, and the terms offered by energy companies in compensation for impacts. However, with the exception of having difficulty understanding jargon-laden legal documents, relatively few survey respondents reported experiencing many of the acute, negative impacts described in focus groups (Fig. 2).

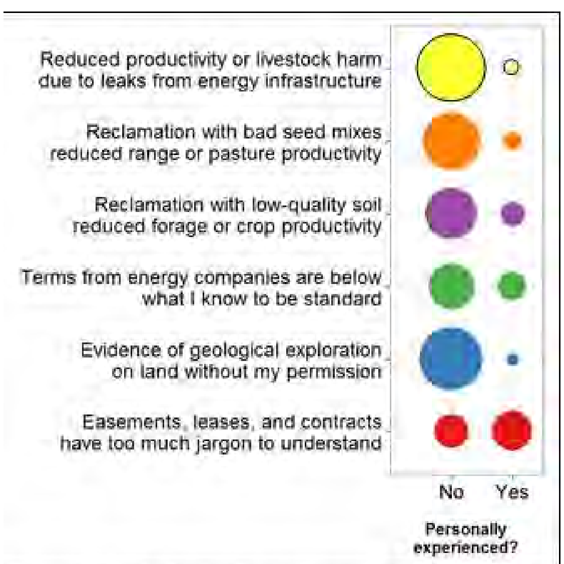

Figure 2. Bad stories from the early boom seem less common, which suggests natural resources might be under less of a threat than perceived, and attention to public relations could improve industry relationships.

Conclusions and Implications

Agricultural landowners and operators see and welcome the advantages of Bakken energy production. Survey responses suggested that local and state revenue policies, urban planning, and better public relations by energy companies could improve quality of life and reduce tension in North Dakota's working rangeland landscapes.

The Range Supply Review: A Management Strategy for a Landscape with Multiple Users

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Key words: Forage inventory, energy development, GIS mapping

Introduction

In the Peace District, located in northeast British Columbia, the provincial government manages 106,280 AUMs of forage on 226 grazing tenures. Range tenures are seldom used solely for range activities. Tenured resource extractions, such as oil and gas development or timber harvesting, and alternative uses, such as recreation or First Nations' values, also impact how the landscape needs to be managed. The different land uses and values are not always complimentary to each other and the cumulative impacts of such activities do not always increase ecosystem health or the carrying capacity of the range tenures.

Of the 621,766 ha of total grazing tenures approximately 22% of the available land base is also used for some kind of resource extraction. As a result, it was necessary to develop a large scale mapping and inventory system to better visualize the forage type, accessibility, management features, and carrying capacity of the range tenures. The new system, called the Range Supply Review, helped to aid in measuring the cumulative impacts on the landscape.

Materials and Methods

Within every range tenure each plant community was identified using Stone et al.'s guide to plant community types (2007). For each different plant community the carrying capacity was estimated using a combination of clipping data, visual estimates, and suggestions from Stone et al. (2007). Clipping data was collected by setting up three transects of ten 0.5x0.5m Daubenmire plots within representative portions of the plant communities and by removing all vegetation from within the plots. The clipped vegetation was then separated into three categories: grasses, forbs, and shrubs. Each category was further separated into palatable and non-palatable species. The species were then dried and weighed to calculate the kilograms per hectre of palatable forage. From here the acres per AUMs were calculated for each sample site. Clipping data was collected for all the different plant communities at numerous sites in the region providing the statistical range and average of AUM productivity on unutilized plant communities. To take the clipping data further, stands of 25%, 50%, 75%, and 100% utilization were also measured to provide a carrying capacity at different levels of utilization.

The sheer number and size of tenures in comparison to staffing levels made assessing every range tenure impossible. Instead, visual estimates were made and GIS forage inventory exercises were completed using the results of the clipping data to create Range Supply Reviews for every individual tenure. This allowed the maximum carrying capacity and the useable carrying capacity to be calculated by factoring in accessibility and actual percent utilization of available forage for each range tenure.

Discussion

The resulting maps showed in detail the different plant communities on each range tenure and the carrying capacity for the specific site. The visual representation of the distribution of AUMs within a range tenure would allow land managers to graze specifically, and intentionally, based on the plant community and available forage thus decreasing overgrazing and increasing range health.

The maps also become very important in predicting how additional land uses will impact the range tenure. When the location of a proposed development is known the impact to the available AUMs can be predicted by looking at the plant communities and carrying capacity of the specific polygon in which the development is located. Decisions can then be made, based on the remaining available forage, on how to proceed with managing the tenure. In some cases, industry is required to replace any AUMs that are lost through development activities. In other cases, where AUM replacement is not required, it may be necessary to expand the range tenure area in order to ensure the tenure holder has access to the number of AUMs guaranteed by the province.

There are also cases where different land uses may increase the amount of AUMs available. Removal of natural range barriers, such has heavily forested areas, through logging can increase livestock access to previously inaccessible areas. Revegetating areas with tame grasses can increase the AUMs produced per acre. These changes, although positive, may affect cattle distribution within the tenure and result in areas of overgrazing, especially on the tame grasses, and other areas of underutilization.

While these maps are valuable management tools the usefulness of the resource is limited by its accessibility. Currently, the information is only available on maps with access limited to internal staff. The next step is to digitalize the data and upload it as a series of shape files to the DataBC spatial database. This will make the information accessible to all users.

Conclusions and Implications

British Columbia has a long history of multiple uses on rangelands. The range supply process allows for the impact of overlapping tenures to be properly managed to ensure a healthy and sustainable ecosystem. It also provides an accurate estimate of the acres per AUM on each individual tenure to prevent over allocation and ecosystem degradation from overlapping tenuring.

Development of the electronic database would improve information access to all users and ensure that their priority areas for use are taken into account before a development is allowed. The data should be used to guide the location of development away from areas of high utilization and forage production to areas of low utilization and forage production to minimize the negative impacts to range tenure holders.

Finally, because the carrying capacity calculated was based on site conditions the information needs to remain current. Tenures should be re-examined regularly to determine if any changes in condition, species composition, or utilization have occurred as a result of resource extraction or range management activities. Having this information accessible to all tenure holders and resource managers should help parties to manage the landscape while respecting the other uses of the land.

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Access Mats Reduce Mixedgrass Prairie Soil Physical Responses to Industrial Traffic

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Key words: Compaction, infiltration, penetration resistance, rangeland, soil moisture

Introduction

Access mats, three ply wooden mats, are used to minimize industrial construction impacts on rangelands, and are routinely recommended by the Alberta government (ASRD 2010) as a best practice conservation strategy despite limited data testing their effects (Dollhopf et al. 2007, Mitchem et al. 2009). Mats redistribute the weight of heavy equipment thereby creating a temporary buffer for prairie soil and vegetation. In the absence of mats, vehicle traffic is thought to create soil compaction, increase soil bulk density, negatively impact plant growth, and alter hydrologic function. Here we report on a controlled field study testing the initial effects of industrial traffic, with and without underlying mats, on Mixedgrass Prairie soil penetration resistance (PR), moisture content (SMC), and water infiltration (WI).

Materials and Methods

This field study was conducted on the Mattheis Research Ranch, 40 km N of Brooks, Alberta, Canada, in the Dry Mixedgrass Prairie. The area has mean annual precipitation of 348 mm and temperature of 5.3°C. Soils range from Orthic Brown Chernozems (sandy sites and uplands) to Brown Solonetz (lowlands). Four sites were used for the experiment, two with loamy soils and two with sandy soils, with 1-3% organic matter. At each site, in a randomized block design, we tested industrial traffic impacts with and without mats over time. Mats weighed approximately 1500 kg and were in place for 12 weeks (April 30 – July 22) during 2015. Traffic consisted of 8 passes by a 28 ton loader, split into 4 passes on April 30 and another 4 on July 22, 2015. PR measurements were taken immediately after mat removal (July 23) and again 6 (September 03) and 12 weeks (October 15) later. PR was sampled using a DICKEY-john Soil Compaction Tester (Dicky-john Corp., Auburn, IL, USA) with a 1.27 cm^2 cone tip. Resistance was measured to a maximum of 4200 kPa, while penetrating to a depth of 15 cm. SMC was assessed immediately after treatment completion (July 23) on the control and mat treatments, but not traffic only areas as soil was too compacted for the moisture probe to penetrate. A TDR 100 Turf Soil Moisture Meter probe was used to quantify SMC in the top 15 cm, on the same dates as above. WI was assessed on July 25 by installing a 21.2 cm diameter plastic ring at least 7.5 cm into the soil, and recording the length of time necessary to infiltrate 2.5 cm of water. PR, SMC and WI data were analyzed separately for loam and sandy sites using Mixed Model ANOVA, with treatments as fixed effects and site and block as random. Significance was set at 5%, with *post-hoc* comparisons done on treatments with significant responses. As SMC and PR were collected at several intervals, time was included as a repeated measure.

Results and Discussion

Penetration resistance was highest under the traffic treatment, followed by the control, and lowest where mats were used (Fig. 1). Six and 12 weeks later, PR was similar in the control and matted treatments, with both lower than the traffic only. Overall, WI took longer on loamy soils, and 1.5 (sandy) – 1.8 (loamy) times longer on traffic treatments, with loamy soils 1.25 – 1.5 times longer to infiltrate compared to the mat treatment and controls (Table 1). Initially, SMC was greater (2.5 times) where mats were recently removed than in controls, but there was no difference 6 and 12 weeks later (data not shown). Industrial traffic results in compaction and increased PR, likely limiting root growth. This effect persisted to the end of the growing season even though mats were moved in late spring. It remains unknown how long this effect will persist for, and may require many freeze-and-thaw cycles to correct.

Use of mats with traffic resulted in no increase in PR, and therefore mitigated the impact of traffic on soil compaction. Mats increased SMC likely due to the conservation of winter snow melt through reduced plant water use or reduced evaporation. After mat removal, SMC declined quickly to levels similar to controls. Plots with mats had reduced litter and vegetation and the loss of these insulating layers likely led to increased evaporation. Loss of moisture may also explain the increase of PR in the matted treatment over time. Post-construction management of sparsely vegetated matted prairie will be important to their future recovery. WI rates help understand the effect of heavy equipment on soil hydrologic function. Matted treatments had much faster WI rates relative to the traffic treatment. Slower WI can lead to increased runoff or evaporation before water enters the soil, reduced water availability for vegetation, and increased risk of erosion on tracked areas.

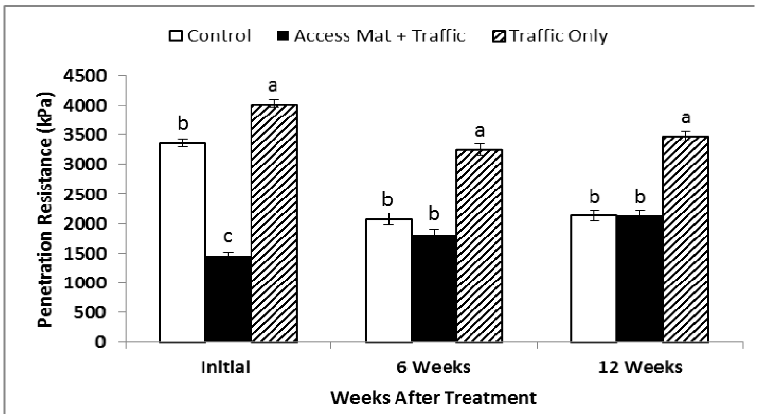

Figure 1. Comparison of mean (±SE) penetration resistance among treatments at 3 times. Within a date, means with different letters differ, p<0.05.

Soil	Treatment	Infiltration Rate (minutes)	Soil Moisture (%)
Loamy	Control	9.98 b	10.5 b
	Mat + Traffic	10.49 b	29.0 a
	Traffic	17.99 a	-
Sandy	Control	8.25 B	3.9 B
	Mat + Traffic	8.17 B	11.6 A
	Traffic	12.14 A	-

Table 1. Comparison of mean infiltration rates and soil moisture among treatments.

Conclusions and Implication

These results indicate best management practices for maintaining soil physical characteristics during industrial construction activities on Mixedgrass Prairie should include reducing or minimizing direct traffic impacts to grassland ecosystems, a process that can be at least partly achieved with access mats.

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Switchgrass Quality and Biomass Suitability over Fertilizer Type and Rate and Maturity

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Key words: Forage, nutrient management, chlorine, potassium

Introduction

Switchgrass (*Panicum virgatum* L.) is a warm season bunch grass native to North America (Casler et al., 2004). It has recently become a crop of interest as it can be used as a renewable energy source in addition to forage for livestock (Vogel, 1996). Bio-energy from switchgrass can be produced in the form of ethanol or by co-firing with coal. Switchgrass is ideal for biomass production and co-firing because it can be grown on marginal soils (Sanderson and Adler, 2008) and has high yields compared to other warm season grasses (Vogel et al., 2002). The objective of this project was to determine the effect of fertilizer type and rate and plant maturity/age on switchgrass yield, quality and mineral residues.

Materials and Methods

Two hectares of "Kanlow" switchgrass were established in 2008 on each of three private farms in Campbell, Nicholas and Rowen counties of northern Kentucky, USA. Fertilizers were applied in May of 2010 and 2011 and included a control (no fertilizer), urea (46-0-0), composted chicken litter and biosolids (Louisville Green^{tm}) applied at rates of 33, 67, 100 or 134 kg N ha^{-1} on an actual N equivalent basis. These 15 treatments in 4 replicates were organized in a randomized split block design.

In June of each year, material was hand collected from each plot to evaluate forage quality, but yield was not measured to avoid a destructive harvest. Whole plant material was harvested in November and March of the following year and analyzed for yield, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) using Near Infrared Spectroscopy (NIRS). Yield was determined by harvesting 1m^2 grid of material cut at a 15 cm cutting height using a hedge trimmer and weighed on-site. A subsample of approximately 1 kg was then shredded, dried and ground through a 1 mm screen for NIRS analysis. Selected treatments, 67N, 134 N, and the control, were further analyzed for Cl and K residues.

Results and Discussion

Data was analyzed in SAS 9.3 using Proc GLIMMIX. Harvest month, rate and type were considered fixed effects. Only yield and nutrient residues (Cl and K) are reported here. Yield was significant for both rate (P<0.0001) and type (P=0.0761) with urea producing significantly more yield than chicken litter. Biosolids were no different from either other type. A rate by harvest interaction (p<0.0001) was observed for Potassium (K), driven by a rate effect in June (Figure 1).

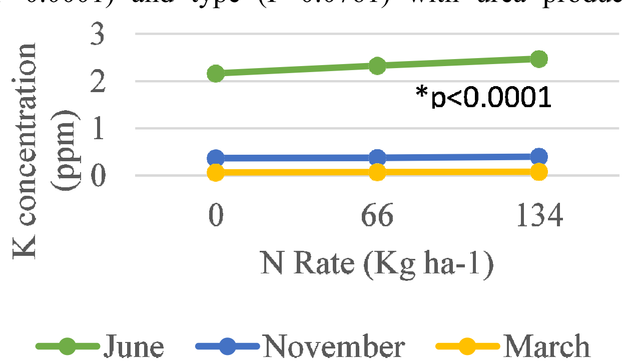

Figure 1. K Concentration by rate and harvest date over three locations.

A three-way interaction (rate * type * harvest, p<0.0001) was observed for Chlorine (Cl) concentration (Table 1). In June, significant linear trends were observed for chicken litter and urea treatments with increasing fertilizer rate. The biosolids treatment in June had a significant quadratic trend. Additionally, chicken litter had a significantly steeper slope in June, indicating a higher increase in Cl with increasing rate for chicken litter when compared to the other treatments. In November, only chicken litter had a significant trend (quadratric) with increasing rate. In March, no difference was observed between treatments.

Table 1. Cl concentration by fertilizer rate, type and harvest month, sorted by harvest month, over three locations.

	June			November			March		
N Rate Kg ha^{-1}	**Urea***	**Bio Solids***	**Chicken Litter****	**Urea^{NS}**	**Bio Solids^{NS}**	**Chicken Litter***	**Urea^{NS}**	**Bio Solids^{NS}**	**Chicken Litter^{NS}**
0	1400	1400	1400	261	261	261	14	14	14
66	1800	2326	2541	237	321	329	5	6	0
134	2907	2281	4094	316	339	637	0	25	3

^{NS} indicates no statistical significant trend.
***indicates a statistical significant regression.**
****indicates a significant difference in slope of the trend when compared to other fertilizer types by rate within that month.**

Conclusions and Implications

Data presented here suggests that switchgrass stands being harvested for biomass should be harvested in early spring. Over-wintering does not significantly reduce total biomass yield; however it does allow nutrients such as K and Cl to leach back into the soil. This reduces the amount of essential nutrients like K removed in plant material and decreases the amount of salt residues (Cl and K) that can cause corrosion in power plant boilers. Alternative fertilizers (chicken litter or biosolids) did not result in additional nutrient residues compared to urea at equivalent rates, however, high rates of urea (100 and 134) did result in the highest yields.

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Contrasting Access Mats and Conventional Powerline Construction Impacts on Mixedgrass Vegetation

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Key words: Seedbank, mycrophytic crusts, baresoil, revegetation

Introduction

Industrial activities such as powerline construction can alter vegetation and soils in the Mixedgrass Prairie of western Canada. Re-establishment of vegetation is critical to restore ecosystem function and meet regulatory compliance. Two different methods of high-voltage powerline tower construction are sod-stripping prior to construction followed by soil replacement and revegetation, or laying wooden access mats to minimize heavy equipment impacts to the underlying prairie (ASRD. 2010). Access mats are thought to reduce direct damage to soil and vegetation by limiting physical disturbance, but subsequent recovery depends on regrowth from surviving plant material or the seed bank (Dollhopf et al. 2007 Mitchem et al. 2009). While the use of access mats is widely recommended on public land in Alberta, little data exists on their effectiveness in facilitating vegetation recovery, or on how this varies with soil texture. We contrast the first-year vegetation recovery of tower sites constructed in Mixedgrass Prairie using two contrasting construction methods, specifically those done with access mats versus conventional sod-stripping.

Study Design and Field Measures

This study examined 15 high voltage tower sites associated with the ATCO Eastern Alberta Transmission line crossing the University of Alberta's Mattheis Research Ranch, 40 km north of Brooks, Alberta, Canada. The powerline was constructed between September 2013 and September 2014. Sites ranged from Orthic Brown Chernozems dominated by *Hesperostipa comata* on loamy prairie to Rego Chernozems on sandy soils dominated by *Calamovilfa longifolia*. Towers were constructed with either low disturbance (LD; n=8) where access mats were placed up to 4 months during construction and vegetation recovered naturally, or high disturbance (HD; n=7) where soil was stripped, piled, and replaced 8 months later, and hydro-seeded in October 2014. At each site, we collected plant biomass by growth form (litter, grasses, forbs, shrubs) from 4, 0.25 m^2 quadrats and estimated ground cover in another 10 quadrats. A nearby (< 50 m from tower) patch of undisturbed grassland on the same ecosite was sampled as a control. All data were collected during July and August of 2015. Data were analyzed using mixed model ANOVA with ecosite and disturbance level as fixed effects and tower site as random.

Results and Discussion

High disturbance sites were colonized by forbs leading to an increase in biomass even though grasses almost disappeared from the site (Fig.1). Grass biomass was higher in LD sites where access mats were used to reduce direct damage to vegetation. It should be noted that control sites were markedly different from each
other, possibly indicating a construction bias in where different tower installation methods were used, with LD techniques being done on flatter, loamy prairie (Fig. 1). Low and high disturbance sites also differed markedly in their cover of litter (HD 0%, LD 82%; P-value <0.001) and microphytic crusts (HD

0%, LD 12%, P-value 0.05), both of which were completely lost when the site was stripped. The latter could have consequences for the long term function and recovery of these sites.

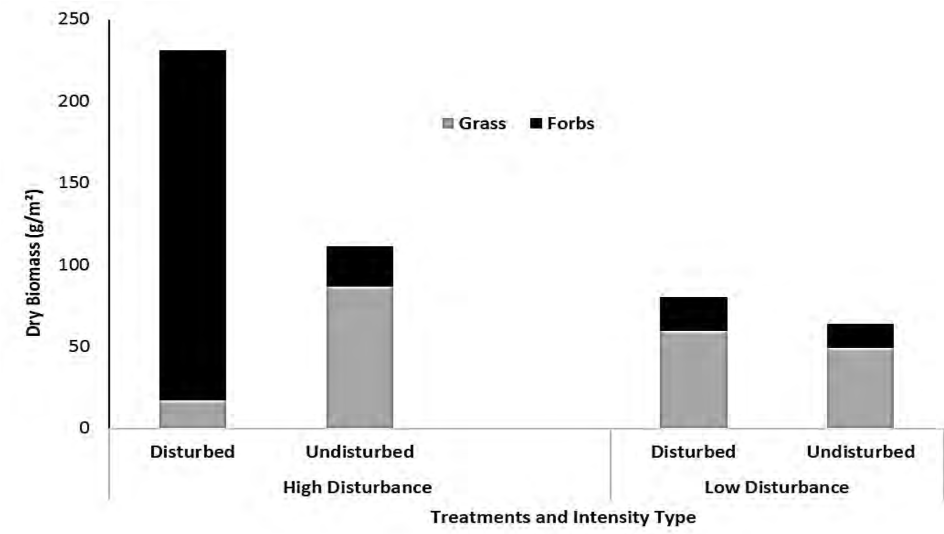

Figure 1. Biomass of grass and forb in communities receiving different levels of industrial disturbance.

Conclusion

Industrial activity in grasslands is extensive, but our results show that low disturbance construction using access mats can limit negative impacts on Mixedgrass Prairie. We found no impact of access mats on plant biomass one year after construction while removal of topsoil altered the plant community.

Acknowledgements

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4.2 Fire Management and Restoration in Rangelands

Restoring Fire to Grasslands: An Overview

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Introduction

Fire is a natural disturbance in most rangeland types. For purposes of this paper I shall use the definition and distribution of grasslands (Dixon et al., 2014) as synonymous with rangeland. The distribution of grasslands worldwide would be very different without fire (Bond et al., 2005). C4 grasslands seem to have evolved under regular fire regimes and fire control may contribute to a shift in woody species. The distribution of grasslands is primarily determined by climate, but fire may allow a broader distribution than would be expected from climate (e.g. the Cerrado savanna of Brazil). Many grassland species are hemicryptophytes or geophytes with growing points that would be at least partly protected from the relatively brief pulse of heat that results from burning fine fuels. The shrubs and trees characteristic of grasslands often have adaptations that allow rapid regeneration after fire or are somewhat fire resistant. Many grasslands contain species that are facultative pyrophites, (having serotinous seeds whose germination is stimulated by heat shock) while Mediterranean shrub lands contain obligate pyrophites (having seeds that respond to smoke or char).

The global distribution of actual fires (Bond et al., 2005) shows that most fires occur in C4 grasslands. It is interesting that the density of fires in the C4 grasslands in the northern hemisphere is much lower – perhaps because of greater investment in fire control. This seems to justify restoring fire in North American at least to C4 grasslands. Also while we have conducted much research on the effects of fire on grasslands in North America, given the extent of C4 grasslands in the southern hemisphere, more research needs to be conducted in Africa and S. America to determine if fire is being used in an effective way. Pastoralists have a great deal of traditional knowledge about how to manage vegetation using fire. Though there may be valid concerns about the traditional use of fire these must not be used to further justify the widespread 'Conservation land grab' happening in for instance Africa (Galaty, 2014). The challenge is to find out what is working well and develop the science around good practices. A good place to start is to look for commonalities in fire response of North American and African grasslands (Knapp et al. 2004). Also, along with the conference theme of future management of rangelands in a high-tech world, remote sensing and GIS could be used more widely to study grassland fire at the landscape and global scales.

Fire and Climate Change

As we become more concerned about climate change, we cannot ignore that burning grasslands can contribute to global warming.

Direct burning of grassland vegetation can release gaseous pollutants, many of which are potent GHG. The majority of the C volatilized in a flaming fire is as CO_2 but in a smoldering grass fire some CO and CH_4 are released (Goode et al., 1999). Also 50- 90% of the N in plant materials may be released (mainly as NO and NH_3) into the atmosphere during combustion. NO reacts with O_2 or O_3 in the atmosphere to produced N_2O which is a potent and long-lived greenhouse gas.

Particulate matter from fires influences climate change. So called 'black carbon' or soot is produced by incomplete combustion and is present in smoke from grassland fires. Black carbon is resistant to decomposition and may be involved in the accumulation of C in grassland soils but when it is transported to other ecosystems it causes problems. Black carbon in the smoke plume from any grass fires can rise to the lower stratosphere and be carried great distances. Grassland fires produce smaller particles than forest fires (Janhall et al., 2010) and are therefore more likely to be transported. Deposition of black carbon from grassland fires has been implicated in melting of arctic and Antarctic ice (Bond et al., 2013) although some constituents of smoke may also have a cooling effect. It was estimated that black carbon (mainly from stubble and pasture burning) was responsible for 30% of Arctic warming. It is interesting that most of the black carbon originates from countries where there is a great deal of unregulated grassland, pasture, and crop residue burning (such as parts of the former Soviet Union, Africa, and South America).

Charred plant material from grassland fires reduce soil albedo and thus contribute to warmer soils. This warming can enhance the mineralization of soil organic matter by soil microbes. This releases CO_2 and mineral N release. There can be an alteration of CO_2, CH_4, and N_2O fluxes following burning but this is not sustained over a protracted period (Castaldi et al., 2010). In tallgrass prairie burning usually increases plant productivity (C fixation) offsetting increased C flux and increasing uptake of mineral N (Bremmer and Ham, 2010). Still, they suggested that reducing the frequency of fires may better ensure that grasslands remain a C sink.

Many of these problems can be reduced by altering the timing of burning, so that combustion is more complete and optimizing the recovery of grasses to take up the nutrients released. It seems prudent to reduce frequency to the minimum required to get desired effects. Another way to reduce fire emissions is to invest in education of farmers to adopt conservation tillage to manage crop residues and to reduce unnecessary pasture burning. Patch burning could be promoted as an alternative to burning the whole landscape. A comprehensive scientific review is needed to address the question 'does managed use of fire in grasslands add to the already considerable contribution of agriculture to global warming'?

Invasive Species and Fire Frequencies

While in North America the aims to have been to reduce fire frequency and severity, in certain ecosystems, establishment of invasive species has increased fire frequency. The spread of invasive species and their effects on fire regimes may be exacerbated by climate change. The most affected grassland types are the Great Basin shrub lands and California chaparral. A synthesis paper (Brooks et al., 2004) cited many examples from around the world of how invasive alien plants can alter the fuel characteristics of plant communities, altering the fire regimes and degrading native plant diversity. On the positive side they summarized management options for breaking the invasive plant fire regimes cycles and restoring the pre-invasion fire regimes. As a rule, prescribed burning alone is not effective in controlling invasive alien species but fire may be usefully combined with other restoration treatments (e.g., herbicide use and reseeding).

Fire Restoration in 'Conservation' Grasslands

Conservation grasslands are increasingly common partly as a response to the threat of land conversion. Where this is leading pastoral use of grasslands is another question. With reduction or exclusion of livestock fire is the main agent of disturbance. Initially, frequent early-season fire may improve the representation of native grasses, but once they predominate, biodiversity of these grasslands may decline due to the lack of disturbance. A combination of competitive exclusion and excessive buildup of litter reduces the abundance of lower growing species. Invasion by shrubs or trees may also occur in the moister microenvironment that results mostly from litter buildup. An interesting aside is that without disturbances, range reference areas also become atypical and some advocate that they be burned periodically. Once an advanced seral stage has been reached, more intense, growing season fires can be used in at least part of the landscape to mimic natural fire regimes. Some combination of fire and 'native' graziers such as bison in the landscape can increase Beta biodiversity in extensive protected areas such as Canada's Grassland National Park. Diversity can also be managed over large areas by providing a mosaic of conservation and 'working' landscapes. For example, fire and grazing may both favour biodiversity but do not have exactly the same effects. Fire favors grasses and a 'pole' form for shrubs while grazing alone favors forbs and a 'cage-like' form for shrubs (Bond and Keeley, 2005). Excessive use of fire can also be deleterious possibly leading to soil erosion and nutrient loss, as are often observed following summer wildfires. Fire frequency and seasonal timing are two factors implementing to be considered when planning prescribed burning regime. Few studies have evaluated the long term effects of fire regimes, most of these have been conducted in the Flint Hills of Kansas. The Konza prairie fire study (Bremmer and Ham 2010) has compared annual vs. biennial burning for over 16 years. Another Konza study looked at long term effects of season of burn (Towne and Craine, 2014).

Fire Restoration in 'Working' Grasslands

In the vast majority of 'working' grasslands the major economic activity is grazing by domestic livestock. But on the portions that are public lands, multiple uses and maintaining biodiversity are also promoted. Moderate grazing prevents the buildup of litter and loss of species diversity so that prescribed burning may not be necessary. However heavy grazing can shift species composition to more tolerant grasses and forbs and if applied extensively can lead to under representation of the dominant native grasses that optimize ecosystem function. Other undesirable effects are shrub and tree encroachment. Prolonged very heavy grazing can be extremely deleterious to biodiversity, and lead to replacement by invasive annual grasses, as has occurred in parts of the Great Basin (Knapp, 1996) and Pacific Northwest. Thus, while livestock grazing remains the most cost effective tool to provide disturbance to grasslands careful management is required. Grazing does not mimic all the desirable effects of fire. Generally fire impacts shrubs and small trees more strongly than herbaceous vegetation, and when combined with altered grazing management can improve the representation of grasses. The heat pulse, altered soil albedo, and in some cases combustion by products may stimulate seed germination and the flush of mineral nutrients may help in establishment. Periodic fires definitely are useful in pasture rejuvenation. When we wish to implement prescribed burning in a grazed landscape there is often inadequate fine fuel to get sufficient fire heights and continuity to control shrubs or trees. Two ways to increase fine fuels are to defer grazing and cutting or dozing (Wink and Wright, 1973) all or some of the undesirable shrubs and small trees so that they dry and provide fuel. Grazing management and fire can be synergistic in pasture rejuvenation or in improving grassland species diversity. Fire may be more effectively used to increase grassland heterogeneity when used at a fine scale, i.e., patch burning. Graziers are highly attracted to burned patches where forage 'greens up' earlier, is more accessible, and more nutritious. Rotating burned patches within a pasture may provide a 'shifting mosaic' of seral stages (Fuhlendorf and Engle, 2004). Burning of lesser used patches can cause graziers to shift focus away from 'grazing lawns' and allow improvement in their seral stage (Archibald et al., 2005). By using fire to alter the distribution it may be possible to reduce fencing. The era of rotational grazing saw a great deal of investment in infrastructure to produce pasture homogeneity some of which we may not be necessary when increasing pasture heterogeneity with patch burning.

Ecosystem Restoration of Savanna

Degeneration of savanna ecosystems due to fire exclusion, overgrazing, high grading lumber, and perhaps increased atmospheric CO_2, is best documented for North America but similar problems exist in Africa (Smit, 2004), South America (Junior et al., 2014) and Australia (Prober and Thiele, 2005). Restoring the understory vegetation to savanna using a long term fire regime can increase soil organic carbon (Dai et al., 2006). Reintroducing fire is a key part of maintaining a desirable stand structure during the restoration process. A starting point for such work is to determine historical fire frequency. In many pine savanna ecosystems a process called *Ecosystem Restoration* is being practiced that may involve thinning smaller trees, pruning larger trees, prescribed burning, and fuel management. Given adequate fuel loads, a medium intensity burn alone can be effective at thinning smaller trees and pruning larger trees (Ducherer et al., 2009) but weather conditions must be right to prevent a canopy fire.

There may be multiple objectives such as focusing growth in fewer larger trees, removing 'ladder fuels' to prevent stand loss and increasing understorey forage production for cattle and wildlife. Key to any restoration of savannah ecosystems is enhancing the herbaceous understory. Restoring an open savanna can be a costly process as restoration treatments may need to be repeated periodically. There are few long-term studies of the effectiveness of restoration treatments one of which was conducted in Arizona (Moore et al., 2006). This study indicated that a thinning alone was as effective as thinning and burning at increasing understory production. Season of burning can affect understorey response, especially if C_4 grasses are present. As in open grasslands, spring burning encourages C_4 grasses while fall/winter burning may encourage C_3 grasses. Response of the understory may take several years, longer with lower than average precipitation. Because of more effective use of soil moisture recovery of C_4 grasses to canopy thinning may be less affected by droughts.

Planning for an Operational Burn

A review of both the published and 'grey' literature is prudent while planning to implement a burning regime. Fire can be an effective restoration tool but like any tool it is most effective when used wisely. Pyke et al. (2010) provided a decision framework for predicting the control or enhancement of particular plant species to a planned fire regime by considering many factors such as life form, reproductive strategy, resilience and vitality.

The more local the information the better as fire effects vary from site to site. Agency reviews can be very useful to bring together diverse information (e.g. Knapp et al., 2009). There are useful generalities that can arise from such reviews, such as the observations that fire may improve yield in a moist grassland but not in a dry grassland, fire is more effective at altering plant species composition in a mixed grassland than in a primarily C3 grassland, and the severity of damage by wildfire varies with the moisture regime during and post fire. Scholarly reviews are also very useful because scientific rigour can sometimes question the basis of accepted 'truths'. For example a review by Baker and Shinneman (2004) called into question the belief that low severity surface fires were frequent in the pinon juniper woodlands and used to restrict shrub encroachment. Another important point is to include unburned controls along with operational burns to monitor effects. While before and after comparisons are useful without controls there is always the confounding effect of weather. Planning for an operational burn can be a lengthy process. The many steps include; know the land resource,), acquire permissions, protect infrastructure (fences), smoke plan, ignition plan, adequate resources for 'mop up', and monitoring effects. During the fire, record weather conditions (temperature, wind speed, RH), fuel characteristics (mass, moisture content) as well as fire behaviour (rate of spread, backfire or head fire, etc.). Every fire had somewhat unique circumstances that contribute to results and should be added to the local body of knowledge.

Conclusions

We have come a long way from the era of fire prevention (i.e., 'Smokey the bear' was our mascot). In North America over the past 50 years there have been many research and management projects related to grassland and savanna fires. Today prescribed burning for well-defined purposes is an accepted range management practice in most constituencies. However legislation to reduce wildfires and improve air quality has generally reduced the formerly widespread spring ritual of pasture burning. More research on use of fire in grassland management in Africa, Asia, and South America is needed. While traditional pasture burning may be widespread there is a lack of scientific knowledge on how to use prescribed fire in grassland improvement.

Climate change may cause more frequent and severe lightning storms, increasing the risk of wildfire. Though grassland burning can contribute to climate change, prescribed burning remains one of the most effective means of wildfire prevention. There are also the many well-documented benefits of using prescribed burning to enhance grassland biodiversity and function. We may need to modify our burning practices and/or combine burning with other management techniques to minimize harmful emissions while attaining the desired effects.

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Fire Seasonality and Return Interval Effects in Northern Mixed Prairie

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Key words: Fire frequency, litter, prescribed burning, weeds, wildfire

Introduction

Fire is understood to be an important process in the development and maintenance of rangelands. Less clear are the ramifications of alterations in the seasonal timing and frequency of fire. Most wildfires occur during summer in the northern Great Plains, but most research is based on spring and fall fire. Without timber to assess fire scars, it is also difficult to estimate historical fire return intervals for open grasslands and shrublands. Effective use of prescribed fire in managing rangelands requires improved understanding of how fire seasonality and return interval affect rangeland productivity and species composition.

Materials and Methods

The first eight years of a long-term experiment were analyzed as a factorial experiment plus controls with three fire seasons (summer, fall, spring) and three return intervals (1, 3, 6 years) applied to 36, 15 x 20-m plots in eastern Montana (2006-2013) to assess fire effects on plant productivity and species composition. The annual fire treatment was expected to exceed the sites' capacity to carry fire and was intended to identify the most rapid return interval possible under conditions of the study period. To assess mean responses over time and simplify data presentation, year was treated as a random variable. Biomass by key species and functional groups were clipped each year at peak biomass then separated into current-year and old standing dead material. Litter cover and bare ground were measured annually with point intercept transects.

Results and Discussion

Fire season and return interval had interacting effects on most plant response variables. Fall fire with a 6-year return interval had the greatest current-year biomass (1476 kg ha^{-1}) and summer annual fire had the least (1044 kg ha^{-1}). Only the summer annual fire differed from biomass with no fire (1324 kg ha^{-1}). Perennial grass biomass was greatest with fall annual and 3-year return intervals and least with annual summer fire, but all treatments (1098 kg ha^{-1}) were similar to non-burned controls (1073 kg ha^{-1}). Although fire had little effect on productivity, it caused considerable shifts in species composition. Frequent fall or summer fire increased C_3 grass dominance (burned 69 vs control 54 ± 6%) and reduced non-native plants (8 vs 24%), primarily *Bromus japonicus*, *Bromus tectorum* and annual forbs. Litter cover was positively related to and explained 61% of the variation in non-native composition. Fire reduced litter with all fire treatments except 6-year fall fire. Annual fires reduced standing dead material about 66% whereas 3- and 6-year return intervals had similar standing dead compared to non-burned sites.

Conclusions and Implications

On average, 2 years was the fastest return interval these rangelands would support. Total biomass was resistant to fire seasonality and return interval, but species composition was sensitive to both. Fire effects were complex and species-specific. Spring fire shifted composition toward *Hesperostipa comata* and *Bouteloua gracilis*, fall fire toward *Pascopyrum smithii* and *Carex filifolia*, and summer fire toward *Pascopyrum smithii* and *Bouteloua gracilis*. Burning every two years on average reduced *Hesperostipa comata* and non-native annual bromes and increased *Bouteloua gracilis* and *Carex filifolia*. Fall and summer fire at short intervals favor rangeland integrity by reducing litter and non-native species. The period of study was representative of a wide range (54-317% of 77-year average) of precipitation years, spanning dry, near-average and wet growing conditions. Data support use of fire to maintain northern mixed prairie.

The Need for Grazing Fine Fuels after Wet Periods

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Key Words: Cheatgrass, fire, weather, dormant season grazing

Introduction

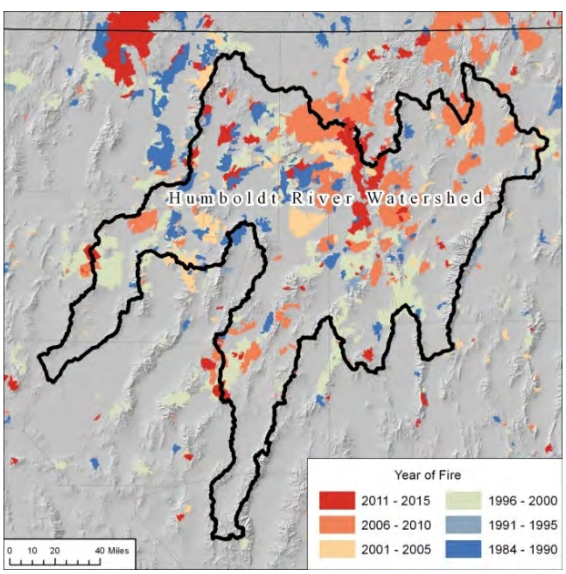
Cheatgrass (*Bromus tectorum* L.) is a highly flammable invasive winter annual abundant in many drier North American sagebrush (*Artemisia* sp.) ecosystems. At higher elevations, perennial grasses historically fueled rangeland fires along with shrubs and trees where they became dominant in the absence fire. Where management allows landscape expanses of accumulated fine fuel or woody fuel, mega fires create homogenous vegetation. This fails to provide habitat for wildlife that requires a patchy mosaic of sagebrush and grass. Resistance and resilience of sagebrush rangelands depend on proactive fire and fuels management. The focus on fuels management has recently been elevated by the Interior Secretarial Order 3335 which mentions appropriate livestock grazing for management of fine fuels. Variation in production make sustaining forage for livestock difficult in dry years and create excess fine fuel in wet years. Is there time to harvest the fine fuel with grazing before it burns?

Methods

The State and Federal agencies have mapped burned areas each year. The United States Geological Survey records surface water flow of the Humboldt River at various locations including near Imlay Nevada.

Results and Discussion

Figure 1 shows the area of the Humboldt River watershed and the area burned. Figure 2 shows the relationship between river flow and area burned in the Humboldt River Basin.



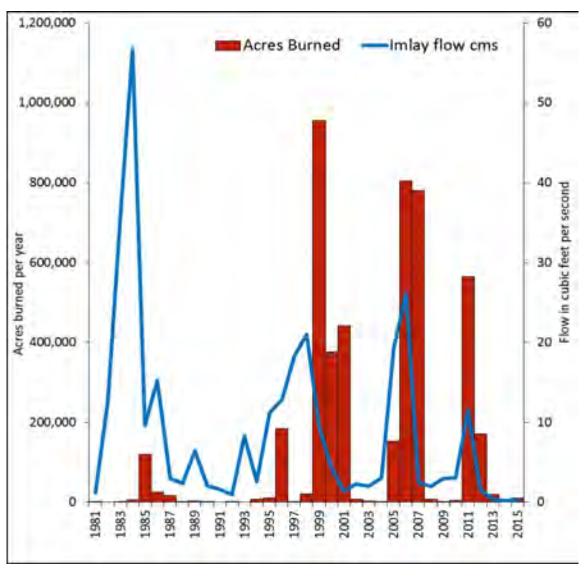


Figure 1. Fires in the Humboldt River Watershed. Figure 2. Humboldt River discharge and area burned.

Since the 1980s big fire years come after one or more very wet years. This lag time provides a window of opportunity to use fall grazing to consume residual fuels (Schmelzer et al. 2014). Grazing during summer-winter dormancy greatly reduces risks to perennial plants needed for rangeland resistance and resilience. The misperception that cheatgrass is only desired forage while it is green may stem from Aldo Leopold's discussion of the cheatgrass problem in A Sand County Almanac more than half a century ago. Some literature linking grazing to increased cheatgrass (Reisner et al. 2013) and actions to reduce public land AUMs in Nevada by 16% between 1980 and 1999 ((Resource Concepts Inc. 2001) suffer from missing some key concepts. Management of the timing, duration, and recovery from grazing are all critical determinants of vegetation responses in addition to the intensity of grazing. With strong management, grazing can be a tool for good rather than simply a land use to be restricted for less bad.

Some tools and strategies could include: Focused grazing in fuel breaks; Stockmanship; Herded sheep; Protein supplements in a line; Water hauled to troughs placed in a line; Electric fences or permanent fencing; Grazing some pastures more intensely so that fires burn only other smaller areas; Temporary nonrenewable (TNR) grazing AUMs preapproved with forage production criteria based decisions; Using existing AUMs in targeted grazing; Stewardship contracting; Retaining calves after weaning or purchasing stockers and supplementing them with protein to encourage energy (dry grass) consumption; Retaining cull cows until spring when prices are higher; Growing season grazing with care for perennials by following the green up the mountain;, Rotating off pastures in the spring when cheatgrass turns purple and unpalatable in comparison to green perennials.

Conclusions and Implications

Dependence on cheatgrass noted for variable forage production is not economically easy for ranchers. Management to concentrate grazing into linear fuel breaks in years of overabundant cheatgrass requires management that requires effort and expense. The expense of proactive management is warranted by loss of forage after fire and tremendous fire control costs, expense born by ranchers and agencies. The challenge for agencies, ranchers and other stakeholders is to find solutions to mega-fires after very wet years. An ecologically, economically and socially acceptable solution could provide for sagebrush habitats within resilient ecosystems using feasible livestock grazing for fine fuels management that is socially dependable and sufficiently flexible to be effective. Recent drought environmental assessments have missed this larger problem. It may be time to plan for climate variability and the fire problem that is even more consequential than the problem of drought. Finding durable solutions will require cooperation among diverse stakeholders. Collaboration will produce better decisions, improved relationships, and sustainable communities and habitats.

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Factors Affecting the Use of Intensive Prescribed Fire by Landowners in the Southern Great Plains

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Key words: Fire suppression, woody plant expansion, prescribed fire, legal and social constraints

Introduction

Perceptions that applying fire on rangelands is risky have contributed to conversions of grasslands to woodlands, higher fuel loads, and increasingly destructive wildfire in the western USA. Recognition that fuel accumulation under fire suppression policies has resulted in greater wildfire risks has led to calls for greater use of prescribed fire to reduce woody plant encroachment and fuel loads. Recent studies found that liability concern is a major reason for landowner reluctance to use prescribed fire (Kreuter et al 2008). Such concerns are driven by a state's legal statutes governing the use of fire and by a lack of knowledge, labor and equipment to apply fire safely. More hectares were burned in counties with more lenient gross negligence liability standards than in those with typical simple negligence standards suggesting the need to promote gross negligence liability standards to increase the use of prescribed fire (Wonkka et al. 2016). Other studies found landowner attitudes towards prescribed fire are strongly influenced by perceived support from family members and neighbors for the use of this management tool (Toledo et al 2013). Prescribed burning associations have helped promote more positive attitudes about prescribed fire by reducing landowner concerns over liability and lack of skills, labor and equipment and have led to increasing use of fire in the Southern Great Plains (Twidwell et al. 2013). Current research is exploring interactions between social and regulatory barriers to the use of prescribed fire on private land. Integrative frameworks for illuminating these barriers and opportunities for promoting the wider use of prescribed fire are presented.

Integrative Frameworks for Understanding Factors Affecting the Use of Prescribed Fire

Figure 1 shows the mortality of juniper under different fuel load and fuel moisture conditions. The area above the juniper mortality threshold represents the combination of conditions that result in sufficient fire intensity to collapse juniper woodlands. Traditional burning conditions rarely result in sufficiently intense fires that overcome mortality thresholds and current "socially unacceptable" risks (risk threshold) associated with the use of fire prevent burning under conditions that result in significant juniper mortality (ecological threshold), such as those used by the Edwards Plateau Burning Association (EPPBA). Over time, the adaptive capacity of the social-ecological system can shift these constraints (represented by arrows) to the benefit or detriment of each social group as a result of emergent ecological, economic, or social pressures; these may include the increased risk of wildfire with elevated fuel loads and social pressure to reduce fuel loads. The ability to shift social constraints to achieve the "desired social group position" depends upon knowledge about ecological dynamics of these systems and the value that society places on properly functioning fire-dependent ecosystems and embraces the use of intense fire to exceed the mortality threshold of woody plants.

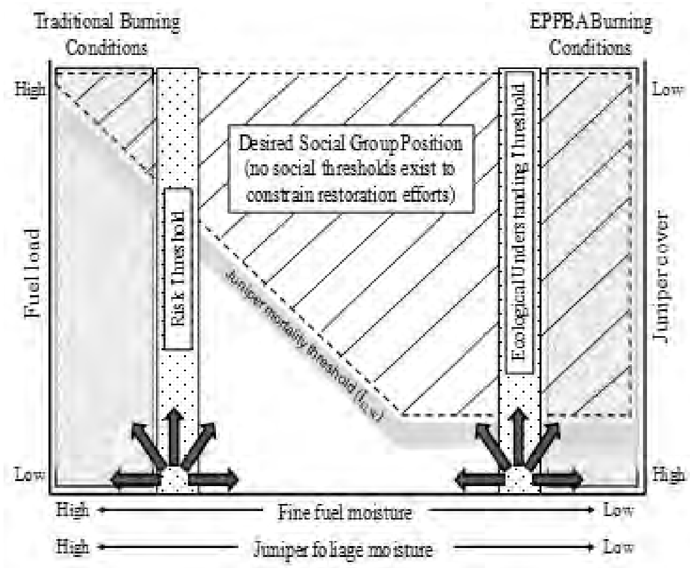

Figure 1. Multifaceted framework that integrates the ecological and social constraints that drive the application and effectiveness of fire in juniper woodlands in the Southern Great Plains.

Figure 2 shows the influence of federal and state regulations regarding fire on state agency support and county commissioners' attitudes towards prescribed fire and resulting constraints imposed on the use of prescribed fire. Its also shows the relationship between information source and county commissioners' and extension agents' attitudes towards fire and, in turn, the effect these have on skills and resources available to landowners for applying prescribed fire. Additionally, it shows the influence of public perception, as influenced by media coverage, on attitude among social networks and in turn how those attitudes affect skills and resources and landowners' subjective norms; these factors together with legal constraints on burning affect manager's attitudes towards fire. Finally, Figure 2 indicates opportunities for using three intervention strategies to influence the attitudes towards prescribed fire of county commissioners, agency personnel, landowners, and social networks with which landowners are affiliated.

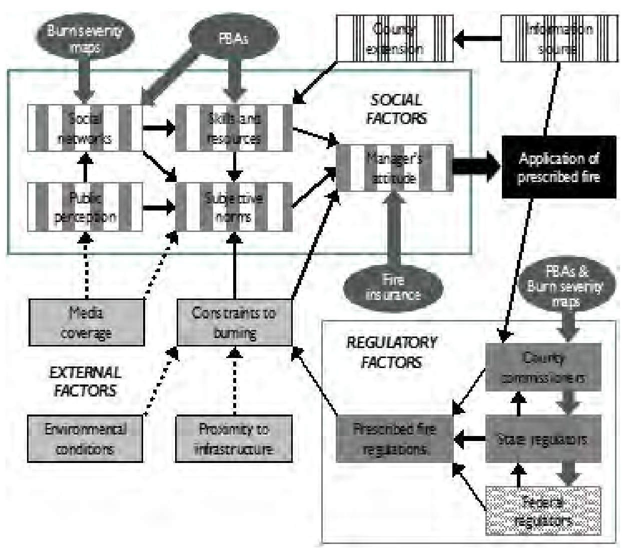

Figure 2. Framework of social and regulatory factors affecting the use of prescribed fire by landowners and intervention opportunities for increasing the use of this management tool.

Discussion and Conclusions

Despite the increasing body of literature illuminating the influence of various factors on the use of prescribed fire by private landowners, there remain significant knowledge gaps regarding ecological and social thresholds that need to be exceeded in order for sufficiently intense fire to be applied over large enough areas to arrest and reverse woody plant expansion and to reduce elevated wildfire risks. For example, imposition of blanket burn bans by some county commissioners present a regulatory constraint for landowners to use prescribed fire under conditions that result in high levels of woody plant mortality. Furthermore, misperceptions about fire are created by media coverage of wildfire disasters leading to misunderstanding by landowners about the critical ecological function of fire and the ecological and social risks of long-term fire suppression. Additionally, the effectiveness of alternative strategies to increase the use of prescribed fire on private land, such as the use of remote sensing tools to illustrate burn severity or the provision of fire liability insurance, has not been comprehensively studied. An integrative assessment of current knowledge, knowledge gaps and the potential efficacy of alternative wildfire avoidance and mitigation strategies is needed to reduce the risk of loss of life and property damage from wildfire emanating from or traversing across private land due to increases in flammable woody plants. Addressing these knowledge gaps is critical to restore healthy fire-dependent ecosystems and reduce the social risk of wildfire on private land.

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Targeted Grazing to Manage Wildland Fuels and Alter Fire Behaviour

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Key words: fuel treatments, wildlife fire, prescribed grazing

Introduction

The grasslands, shrublands, and woodlands that characterize more than half of the landscapes in western North America are maintained and influenced by forces of climate, grazing, and fire. These powerful natural forces are inherently important components of the health and productivity of rangeland ecosystems. Wildfires occurring in rangeland ecosystems are becoming larger and more frequent across North America in recent decades. Strategically applied targeted grazing is an important tool that can change the type and amount of wildland fuels (Strand et al. 2012).

Livestock grazing can influence herbaceous fuels including the: (1) amount of herbaceous biomass, (2) relative abundance of herbaceous and woody fuel, (3) live/dead fuel mix and (4) continuity of fuel at a patch and landscape scale. Fire behavior is also determined by weather factors (e.g., daily and seasonal fire weather conditions including temperature, relative humidity and wind), which determine fuel moisture. Landscape features (e.g., degree of slope and aspect) influence how fire moves across landscapes.

On a yearly basis, grazing can reduce the amount and alter the continuity of fine fuels changing wild fire spread and intensity. However, how grazing-induced fuel alterations affect wildland fire depends on weather conditions and plant community characteristics. As weather conditions become extreme, the influence of grazing on fire behavior is limited especially in communities dominated by woody plants.

Targeted Grazing to Fuel Loads

Fuel management objectives in grassland and shrubland systems aimed at reducing flame lengths and fire spread could be accomplished by altering the fuel bed depth, fine fuel loading, cover and continuity such that the flame length never reaches four feet (Nader et al. 2007). Livestock grazing primarily impacts small diameter fuels (< 0.2 inch diameter) including grass and small woody stems that equilibrate with the ambient humidity and temperature within 1 hour (i.e., the 1 h time lag or 1-htl fuels). Livestock can also impact larger fuels (0.25 inch) diameter or 10-htl fuels) through browsing and trampling (Davison 1996; Nader et al. 2007). Hence grazing could be a useful management tool for reduction of grass and shrub biomass (1-htl and 10-htl fuels).

Grazing Affects Continuity of Fuels

Besides reducing the amount of fine fuel biomass, grazing can also create fuel load heterogeneity across a landscape and thereby decrease the risk of large wildfires (Fuhlendorf and Engle 2001; Kerby et al. 2006). Sheep or cattle might preferentially graze certain habitats while avoiding others. At landscape scales this depends on stocking rate, animal husbandry practices, and the resulting livestock use patterns. Fire modeling in the tallgrass prairie of Kansas revealed that fires are smaller and have more complex shapes in heterogeneous landscapes with a variety of vegetation types and biomass attributes (Kerby et al. 2006). Alternatively, grazing management practices aimed at creating spatially uniform patterns of biomass and utilization may reduce vegetation heterogeneity and increase the risk or extent of fires (Fuhlendorf and Engle 2001). Although heavy grazing has been attributed to reducing biomass and fine fuel loads, light grazing can produce patchy burn patterns in continuous fuels (Bunting et al. 1987). Light grazing can remove sufficient fuel as well as break up fuel continuity to significantly reduce fire spread (Bunting et al. 1987). Patchy burn patterns are particularly important in shrub steppe regions where maintenance of shrub cover (e.g., for wildlife habitat) is a management objective. Patchy burns leave islands of unburned sagebrush, thereby creating a seed source for reestablishment of sagebrush plants across the steppe.

Opportunities for Strategic Targeted Grazing

There are several ways that contemporary livestock grazing practices can affect the consequences of fires in grassland and shrubland ecosystems. Carefully managed grazing can reduce the amount of fine fuels created by grasses, including annual grasses, and forbs and small twigs of woody plants. Grazing can reduce the potential for fire ignition and spread by removing understory vegetation, reducing the amount of fuel, and accelerating the decay of litter through trampling. Grazing can further alter the continuity of fuels to slow rates of spread and intensity and create a naturally patchy burn that results in unburned islands of vegetation providing a seed source for re-establishment of plants after the burn. The effects of grazing could result in fires that burn at lower fire-line intensity, increased patchiness, decreased rate of spread, and increase subsequent survival of plants after fire. Finally, grazing can be applied in specified ways across landscapes in combination with fire breaks to compartmentalize fires and improve the effectiveness of fire-fighting activities. Though targeted grazing can be an important tool to manage fire behavior and effects, the effectiveness of targeted grazing depends on the fire weather conditions and the structural composition of the plant community.

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Fire as a Management Ecological Tool for Restoration of Degraded Rangeland Ecosystems for Livestock Grazing in Uganda

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Key words: Fire, livestock, grazing, rangeland, restoration

Introduction

Large areas of rangelands in Uganda that are important for livestock grazing have been seriously invaded by *Acacia* bush leading to reduced forage and animal productivity (Mugasi *et al*., 2000). This alarming trend requires attention to find sustainable ecologically friendly management technologies to reverse the declining trend. This paper is a review of the limited research work that has been done in the rangeland ecosystems for sharing with other international scientists working under similar or related ecological systems.

Materials and Methods

Relevant published and unpublished literature were reviewed and analyzed, thus the basis for this presentation.

Results and Discussion

Effects of fire regimes on Acacia savanna dynamics in rangelands

The *Acacia* /savanna ecosystems have over the years been maintained by regular fire and browsing regimes, especially by livestock and wildlife for browsing impact. However, following the ban on bush burning by government in 1970s, there has been an increase in bush encroachment in these rangelands.

Limited research studies indicated that annual fire regimes influence the regrowth of grasses. Fires of high intensity during late burning produced significant herbage yields containing high crude protein contents as a result of subsequent rains that followed after late burning (Table 1). Also the bushes and *Acacia* saplings were significantly killed by high intensity fires, thus reducing competition for light and other growth requirements.

A number of research studies indicated that annual fire regimes and browsing by goats influence the growth of *Acacia* seedlings and sapling regrowth (Table 2). Seedling survival appears to be high in treatments of fire and browsing. Fire stimulates the germination of hard seeded *Acacia* seeds and also promotes coppicing. Fire and browsing significantly reduced *Acacia* sapling regrowth. Several years of annual burning with high intensity fires led to significant *Acacia* sapling mortality and promoted grass recovery and production (Sabiiti and Wein, 1991; Sabiiti and Wein, 1988).

Table 1. Effect of fire regime on total regrowth herbage yield (DM g/m²) and on crude protein of a natural grassland in southwestern Uganda (n=10).

Year of burning	1986			1987			1988		
Season of burning	No burn	Early burn	Late burn	No burn	Early burn	Late burn	No burn	Early burn	Late burn
Fire intensity (KW/m^2)	---	2772	3276	---	2808	4590	---	2340	4536
DM (g/m²)	60 ± 0^{a}*	540 ± 18^{b}	864 ± 15^{c}	145 ± 5^{a}	675 ± 22^{b}	1200 ± 14^{c}	85 ± 17^{a}	983 ± 206^{b}	1520 ± 10^{c}
CP (%)	8.3 ± 1.2^{a}	9.0 ± 1.4^{a}	11.8 ± 1.1^{b}	7.9 ± 1.7^{a}	9.5 ± 1.1^{a}	12.6 ± 2^{a}	6.3 ± 2.0^{a}	9.8 ± 1.5^{b}	13.7 ± 1.2^{c}

*[abc]Means within a row having different superscripts are significantly ($P<0.05$) different
Source: Sabiiti and Wein, 1989; FI= Fire Intensity

Table 2. Post-browsing response of *Acacia hockii* coppice shoots and seedlings after termination of grazing treatments in Mbarara, Uganda.

	No fire + No browse	No fire + Browse	Fire + No browse	Fire + Browse
Shoots/stumps	6 ± 4^{a}	4 ± 1^{a}	18 ± 6^{b}	8 ± 2^{ac}
Shoot height	380 ± 15^{a}	92 ± 12^{b}	38 ± 7^{c}	16 ± 4^{d}
Seedling survival (m²)	4 ± 2^{a}	2 ± 1^{a}	3 ± 1^{a}	2 ± 1^{a}
Seedling height (cm)	76 ± 9^{a}	30 ± 6^{b}	15 ± 4^{c}	6 ± 2^{d}
Seedling survival (m²)	2 ± 1^{a}	2 ± 1^{a}	19 ± 5^{b}	24 ± 2^{d}

[abc]Means within a row having different superscripts are significantly ($P<0.05$) different
Source: Sabiiti and Wein, 1991; *Nf = No fire

Conclusion and Implication

Bush encroachment can be managed easily through annual late-burning which appears to be more effective in controlling *Acacia* regeneration by killing saplings and promoting high herbage production of high quality (high CP %). Exclusion of fire from the *Acacia* /savanna systems could partly explain the increased bush encroachment in the rangelands of Uganda.

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Reclamation of Gullies in the Arid Karoo Region of South Africa

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Key Words: Practical study for reclaiming gullies

Introduction

The arid Karoo region of South Africa mainly receives rainfall in summer in the form of intense thunder showers. This usually happens after a dry winter and very vulnerable rangeland. The effect of these thunder showers on the sparse veld causes erosion gullies and if not treated soon enough it becomes huge gullies (Photos 1 and 2). There are a lot of studies and methods on how to reclaim bare patches, but not many on how to stop the formation of gullies.

Photo 1. Gullies seen on an aerial photo.

Photo 2. Very active gullies.

Materials and Methods

Once a site is identified you need to do a survey with a global positioning system (GPS) or similar device to, 1) determine where the water accumulate, 2) the slope of the valley, 3) the position where you want to build the structure, and 4) the height of the structure, etc. After you have done the survey you draw contours to get a picture of the water flow dynamics. This survey is done once.

You also need to identify the catchment and do run-off calculations to determine the peak flow in the gully. This is done once, because it is a fixed landscape and is not supposed to change.

From the survey you now can decide what type of structure you are going to design and build. If you have a meandering gully you will design groynes, if you have a lot of gullies on a flat surface you will design a spreader bank, if you have a lot of gullies coming together at the same point with the gully less than 1.2 m deep you will design a buttress weir and the same scenario, but the gully deeper than 1.2 m you will design a multi-arch weir (Photo 3). The reason for this is cost, because these weirs are usually built from concrete. You use less concrete in multi-arch weirs the higher you go than for buttress weirs. The shape of the multi-arch weir allows it to be stronger with less concrete.

Photo 3. Typical concrete multi-arch weir.

After you determined the estimated peak flow using empirical formulas and you know where you want to position your structure and what type of structure will suit the conditions best you can start to design the structure.

These structures can be quite expensive so you need to calculate the cost and compare it to the return you will get on it. If it is intensive farmlands that you are rehabilitating then you can build a more expensive structure than extensive sheep farms with a low carrying capacity.

Results and Discussion

Recovery is dependent on available soil-, run-off availability and intensity and occurrence of rain fall.
Usually the sediment in the water coming from upstream will be deposited against the weir. With each rain incident, sediment will be deposited until the weir is filled to the top. Plants will establish and grow on the sediment and the gully will be in a rejuvenated and pristine condition. In areas with less incidents of rain the gully will take longer to recover and grow vegetation, since sediment comes down the river/ gully occurs fewer times each year. With lower rainfall opportunities, there is less potential vegetation recovery and lower grazing capacity. The grazing capacity is used along with the production value of the area to determine what type of weir will be build. This is done to determine if the weir will be cost-effective or not. The type of soil and slope of the valley also plays a role. The flatter the area, a larger area will be influenced by the structure, thus being more cost-effective. The slope is determined by the GPS-survey. With this information available you can determine with empirical formulas how far upstream the reclamation will happen. With this information in hand you can determine the area that will be rehabilitated and the cost-effectiveness of the weir.

Conclusion and Implications

Any gully can be rehabilitated, but you need to determine if it will be cost-effective.
The best option is to stop the erosion before it becomes a huge gully which is too expensive to rehabilitate.

References

Google Earth Imagery

Compounds in Plant-Derived Smoke Affect Seed Germination

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Key words: Germination, seedling growth, plant-derived smoke, karrikinolide

Introduction

Fire is a selective force in the evolution of seedling establishment traits. Fire cues, including heat, ash, and smoke, have different mechanisms to trigger seed germination. Plant-derived smoke produced during burning of native stands contains active compounds that stimulate seed germination (Van Staden et al., 2000). It is not certain whether smoke associated with burning of different plant materials has unique active compounds that in turn have differ in their impact on germination responses. In this study, active compounds in smoke produced from burning alfalfa (*Medicago sativa*), prairie hay (*Festuca hallii*), and wheat straw (*Triticum aestivum*) were compared. Objectives of this study were to: 1) determine whether unique active compounds exist in smoke pro-duced when burning different plant materials, and, 2) determine the effects of active compounds in smoke derived from burning different plants on seed germination of three native and one non-native species in Fescue Prairie.

Materials and Methods

Each smoke stock solution was produced by smouldering wheat straw, prairie hay, or alfalfa. The procedures for separating the active compounds involved in smoke solutions were based on modifications of Flematti et al. (2008). Germination responses of three native species, including *Artemisia frigida*, *Artemisia ludoviciana*, and *Conyza canadensis*; and a non-native species, *Cirsium arvense*, were tested after priming in serial dilutions of active fractions obtained from alfalfa, prairie hay, wheat, and karrikinolide (KAR_1) (a known active compound produced when burning prairie hay and wheat straw) in darkness for 24 h. For each of species, a randomized-complete-block-design was used with five priming treatments for each of the four different types (Table 1), and four replicates within 10/0°C or 25/15°C in 12h light /12h darkness or 24 h darkness. The experiment was repeated with four new replicates of four different solutions as the second run. Germination data were arcsine square root transformed before analyzed using ANOVA using the mixed model procedure in SAS version 9.3 software.

Results and Discussion

KAR_1 was in the smoke produced from prairie hay and wheat straw, but was not in that from alfalfa (Fig. 1). This is the first time that KAR_1 is absent as an active compound produced with burning of plant material.

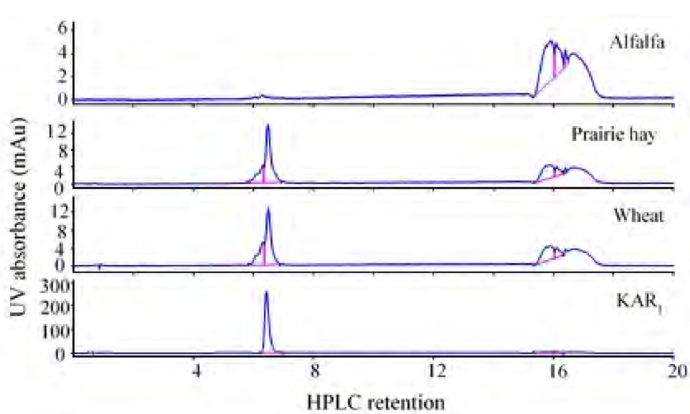

Figure 1. Chromatograms of the active fractions obtained from alfalfa, prairie hay, wheat, together with KAR_1 standard.

Effect of priming treatment on seed germination was dependent on species and environmental conditions, which agrees with previous findings (Ghebrehiwot et al., 2009); significant effects are described in Table 1. Priming with 1/1 v/v active fraction from prairie hay significantly increased seed germination of *A. frigida*. Seed germination of *A. frigida* was 62% and 67% higher for the seeds primed with 1/10 v/v and 1/1 v/v KAR_1 solutions, respectively (Table 1). Priming with 1/1 v/v fractions from prairie hay and wheat straw increased seed germination of *A. ludoviciana* by 37% and 27%, respectively. Seed germination of *A. ludoviciana* was 38% higher for seeds primed with 1/1 v/v KAR_1. Priming with the 1/10 v/v fraction from prairie hay increased seed germination by 96%. Priming with 1/1000 v/v fraction of wheat increased seed germination by 114%. Seed germination was 73% and 68% higher for seeds primed with 1/1000 v/v and 1/100 v/v of KAR_1 solution, respectively. Priming in various dilutions of fractions from alfalfa had no effect on germination of tested species compared to the control. Priming treatments had no significant effect on germination of *Cirsium arvense* under any germination condition.

Table 1. Total germination (%) of *Artemisia frigida*, *Artemisia. ludoviciana*, and *Conyza canadensis* seeds after priming in serial dilutions of separated fractions from alfalfa, prairie hay, wheat or KAR_1.

Species	Germination Condition	Dilution	Types			
			Alfalfa	Prairie hay	Wheat	KAR_1
Artemisia frigida	10/0 °C Light/Darkness	DW	28 ± 5 a	28 ± 5 b	28 ± 5 a	28 ± 5 b
		1/1000	33 ± 4 a	33 ± 5 ab	28 ± 4 a	34 ± 4 ab
		1/100	25 ± 5 a	27 ± 5 b	28 ± 2 a	38 ± 5 ab
		1/10	29 ± 4 a	40 ± 3 ab	37 ± 5 a	45 ± 4 a
		1/1	32 ± 4 a	49 ± 6 a	39 ± 6 a	46 ± 3 a
Artemisia ludoviciana	25/15 °C Darkness	DW	47 ± 4 a	47 ± 4 b	47 ± 4 b	47 ± 4 b
		1/1000	55 ± 5 a	55 ± 5 ab	58 ± 6 ab	52 ± 6 ab
		1/100	56 ± 4 a	51 ± 3 ab	57 ± 4 ab	52 ± 6 ab
		1/10	50 ± 4 a	53 ± 4 ab	52 ± 7 ab	55 ± 4 ab
		1/1	56 ± 5 a	64 ± 5 a	59 ± 4 a	64 ± 5 a
Conyza canadensis	25/15 °C Light/Darkness	DW	38 ± 8 a	38 ± 8 b	38 ± 8 b	38 ± 8 bc
		1/1000	57 ± 8 a	61 ± 10 ab	80 ± 8 a	65 ± 3 a
		1/100	49 ± 8 a	38 ± 10 b	76 ± 9 a	63 ± 2 a
		1/10	57 ± 10 a	74 ± 7 a	58 ± 12 ab	60 ± 8 ab
		1/1	44 ± 10 a	60 ± 10 ab	62 ± 10 ab	33 ± 9 c

Only the germination data that was significantly affected by the priming treatments was shown. Means with different letters indicate total germination of primed seeds were significantly different ($P \leq 0.05$) among dilutions within fractions. DW=Distilled water. Bars represent means ± SE.

Conclusions and Implications

Burning different plant species produces unique active compounds. Unidentified active compounds may be involved in the smoke made from alfalfa. KAR_1 is the major stimulant in the smoke made from prairie hay and wheat straw and has the potential to improve seed regeneration of native species in the Fescue Prairie.

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Application of the Sample Point Photo Monitoring Methods in Mongolia for Monitoring Short Term Grazing Management Impacts

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Key words: Resilience based rangeland management, digital photographs, short term monitoring, soum, Association of Pasture User Groups

Introduction

According to the National report on Rangeland Health of Mongolia, 2015 (Green gold. 2015), vegetation data indicate that changes to grazing management could result in recovery, or progress toward recovery, for more than half of Mongolian rangelands within ten years.

A new, comprehensive approach called resilience-based rangeland management (RBM) was developed to initiate management changes. Resilience-based management circumscribes science, management, policy, and governance that sustain ecosystem services in the face of global change (Chapin , Kofinas et al. 2009). Using ecological sites mapping and state and transition models, yearly grazing plans are developed by local government and herders, including stocking rates, seasonal use schedules for herder families, and other restoration actions. Plans are implemented over the subsequent grazing year, but there is no monitoring system suited to short-term monitoring that is simple enough to be applied by people who do not have a strong botanical background. The aim of this study is to test the sample point photo monitoring method (Booth and Cox 2008) using digital photographs for short-term impact monitoring of grazing management.

Materials and Methods

Monitoring plots were established in 15 soums in active grazing areas where planned changes to the existing management regime were implemented. Photo images were collected at 5 meter intervals along the two parallel 50 meter long tapes before and after the management change by soum land managers and the leader of the soum Association of Pasture User Groups (APUG) who were trained in the Sample Point photo monitoring method and provided field tools. SamplePoint is a free software facilitates manual, pixel-based, image analysis from nadir digital images of any scale, and automatically records data to a spreadsheet (J. Cagney, S. E. Cox and D. T. Booth, 2011).Photo images were analyzed using Sample Point software and cover was estimated for key functional groups.

Results and Implications

After indoor trainings and field demonstrations, soum land managers and APUG leaders became skilled at monitoring plot selection, photographic image collection, and analysis using the sample point software. They created soum-level short term monitoring databases. Photos were able to represent changes in vegetation cover due to management interventions (short term deferment associated with rotational grazing) such as significant improvements in rangeland productivity and health (Figure 1) in relatively favorable climatic conditions like the forest steppe region and the yearly fluctuations due to climate condition that is familiar in dry regions (Figure 2).

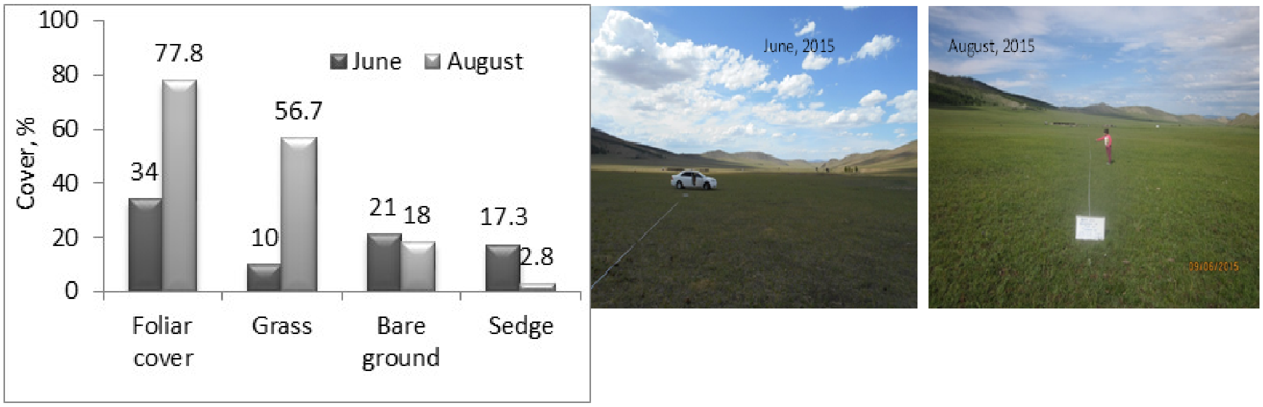

Figure 1. The effects of pasture rest on vegetation cover in winter/spring pasture in Teel bagh, Erdenemandal soum of Arkhangai aimag where the species composition is improved significantly through increase in grass and decrease in sedge cover.

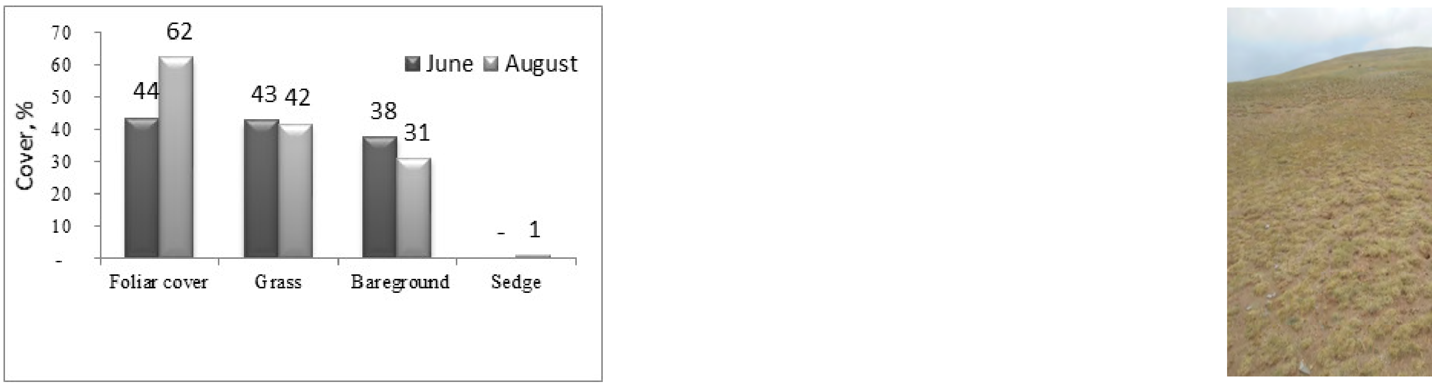

Figure 2. The effects of rainfall on vegetation cover in a spring pasture in Chandmani soum of Gobi Altai aimag where just a canopy cover increase is observed.

Comparing to other traditional methods based on visual estimation, the sample point photo monitoring method showed advantages compared to other methods such as line-point intercept due to less labor cost and by adequately documenting rangeland health changes in a way that pasture users and local decision makers could see and recognize. Furthermore, the sample point method is more repeatable and precise than ocular vegetation estimates. Based on the progress in the 15 selected soums, the Administration of Land Affairs, Geodesy and Cartography (Administration of Land Affairs 2015) that is responsible for the land management issues made a decision to adopt this method and implement it nationally as a basis for evaluating management impacts.

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Can Degraded Rangeland in Mongolia Be Restored through Better Management?

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Key word: Rangeland degradation, restoration pathways, alternative states, recovery class

Introduction

A vast majority of monitoring sites representing more than half of Mongolian rangelands suggest that changes to grazing management could result in recovery, or progress toward recovery of vegetation and soil characteristic, within ten years (National Report on the Rangeland Health of Mongolia, 2015). This study is aimed to test the restoration pathways between alternative states of *Stipa krylovii – Cleistogenes squarrosa*-forb rangeland in sandy loam alluvial fan soils that represent one of the main ecological site groups (ESGs) in steppe zone of Mongolia.

Based on field data collected in 2014, sixty-five percent of monitoring sites were judged to be altered relative to the ecological potential (reference condition) of the soils and climate zones for those sites. Only forty eight percent of the sites, however, would require more than three years for recovery to occur with altered management and seven percent of sites have experienced highly persistent degradation or desertification.

Materials and Methods

Vegetation cover data using the line-point intercept method were collected in and adjacent to two exclosures, one is set up in 2009 and another one is set up in 2013. These sites represent two alternative states of *Stipa krylovii–Cleistogenes squarrosa*-forb rangeland of sandy loam alluvial soils in Undurshireet and Argalant soums of Tuv aimag, steppe zone, Mongolia. Vegetation inside the exclosures had been rested for most of the growing season and grazed only at the end of the summer grazing season, and outside the exclosures were grazed year round.

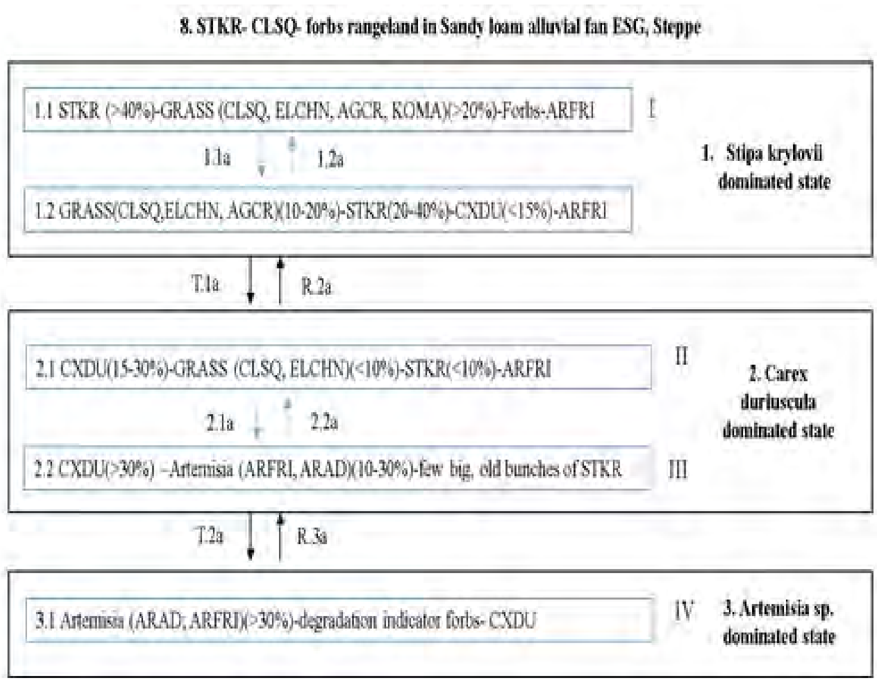

Figure 12. The Stipa Krylovii-Cleistogenes squarrosa-forb STM in steppe zone of Mongolia (National Report on the Rangeland Health of Mongolia, 2015). Species name abbreviations in boxes: STKR-Stipa krylovii; CLSQ-Cleistogenes squarrosa, ELCHN-Elymus chinensis; AGCR-Agropyron cristatum, KOMA-Koeleria macrantha, ARFRI-Artemisia frigida, CXDU-Carex duriuscula, ARAD-Artemisia adamsii. I-IV are recovery classes describing constraints to

recovery. T1a, T2a are transitions, R2a, R3a are restoration pathways.

Results and Discussions

Between 2013 and 2015, , *Stipa krylovii* cover in the initial *Carex duriuscula*-dominated state increased in the exclosure from 9 to 29 percent but it is decreased in the outside area from 9 to 3 percent. Concurrently, there was a reduction of *Carex duriuscula* cover from 17 to 6.0 percent and a decrease from 17 to 12 percent outside of the fence (Figure 2).

In 2009 – 2015 in, unpalatable *Artemisia species* fluctuated and in the same period foliar cover increased and bare ground has been decreased (Figure 3). *Stipa Krylovii* increased significantly up to 6 percent in *Artemisia sp* dominated state (Figure 3).

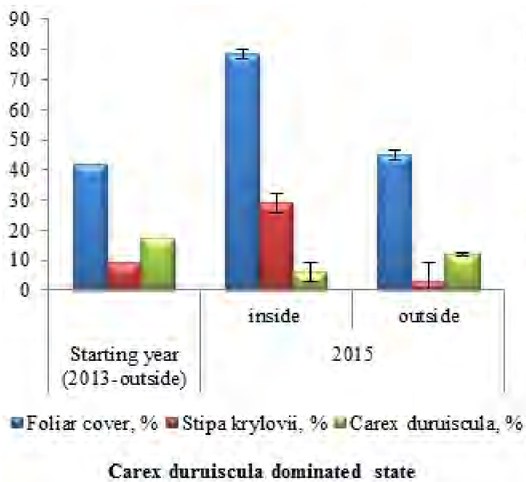

Figure 13. Vegetation changes in Carex duriuscula dominated alternative states of the Stipa Krylovii – Cleistogenes squarrosa-forb rangeland.

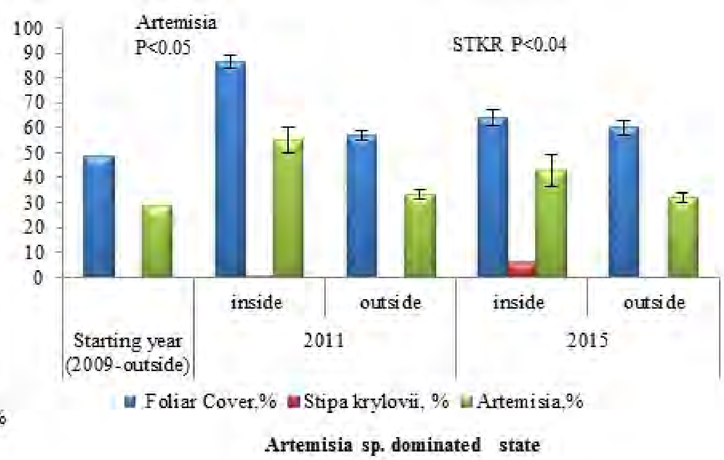

Figure 3. Vegetation change in Artemisia species dominated state alternative states of the Stipa Krylovii – Cleistogenes squarrosa-forb rangeland.

Conclusion

Through this study our hypothesis and concepts for restoration pathways of State and Transition Model and recovery classes for *Stipa krylovii – Cleistogenes squarrosa-forb* rangeland in Sandy loam alluvial fan ESG were supported. According to the result there are ample opportunities for changes in management and policy that improve rangeland health, that enable adaptation to climate and land use changes, and that secure the future of pastoral production and food security in Mongolia. Those *Carex duriuscula* dominated state can be recovered after 3 years off, but *Artemisia sp* dominated state was difficult to recover after extensive grazing. But it is important to act decisively and promptly before those opportunities are lost.

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Waterponding the Rangelands

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Key words: Rangelands, rehabilitation, scald, waterponding

Introduction

Bare, scalded semi-arid areas in western New South Wales Australia are being transformed into biodiverse native pastures, thanks to the waterponding technique which is returning clear profit to the landholder and benefits to the environment. Waterponding is a land rehabilitation technique used on duplex scalded soils in the semi-arid rangelands. Waterponding is the holding of water on the scald in surveyed horseshoe-shaped banks, each covering 0.4 ha. The ponded water leaches the soluble salts from the scalded surface. This improves the remaining soil structure, inducing surface cracking, better water penetration and entrapment of wind-blown seed. In the 1960s, it was estimated that tens of thousands of square kilometers of sites on duplex soil in the rangelands of New South Wales had been denuded and were moderately or severely bare or 'scalded' as a result of wind erosion of their sandy top soils. (A 'duplex soil has sandy loam topsoil and clayey subsoil) (Cunningham, 1987). This was a consequence of past severe droughts and overgrazing of the native vegetation, allowing wind and water to erode the sandy loam topsoil. This left bare and relatively impermeable subsoil which prevents water penetration and is very difficult for plants to colonize.

Materials and Methods

The Marra Creek Waterponding Program was established at Nyngan NSW Australia in 1984 located between the Bogan River and the Macquarie River to refine and establish the waterponding technique as a recognized rehabilitation method for scalded rangelands. It involved the Soil Conservation Service of NSW and 18 landholders in the Nyngan Marra Creek District. It showed that success of waterponding in rehabilitation of scalded country depends equally on: bank construction to specific dimensions; correct survey techniques; suitable construction equipment; and appropriate management of banks to allow establishment of native perennial pastures. In 1984, Thompson (Soil Conservation Service, NSW) mapped 100 000 ha of scalded country in this area that had potential for waterponding Thompson (2008).

The most productive and effective waterpond shapes for relatively level sites were a horseshoe shape (on scalds with slopes up to 0.4%) and complete circles (on flat scalds). These enclose an area of approximately 0.4 ha within each waterpond (Rhodes, 1987). The horseshoe-shaped and fully enclosed circular waterponds rely on the rain falling directly into the pond allowing very little external catchment to enter the ponds. The ends of horseshoe-shaped banks should be surveyed to ensure that they are level. This enables any overflow water to escape around both ends rather than concentrating it in one direction. A maximum depth of 10 cm of ponded water was found to be ideal as any deeper would damage native grasses and shift the vegetation to more wetland species. This depth is achieved by the correct survey method, then construction of the waterpond bank with a road grader to a minimum height of 45 cm and 1.8-m base width. An important lesson learned is that the size of the pond needs to be limited to ensure that the area of pond and the catchment which feeds it are able to be held by the waterponding banks without fear of breaking. This leaves space for the borrow areas and the lateral banks. Ten cm of ponded water is ideal to induce deep cracking, germination and growth of grasses and saltbushes. The wave action problem is worst in exposed situations where ponds are larger than 0.4 ha and where the banks have been built with insufficient freeboard and base width.

Before 1983, waterponding banks were surveyed using a surveyor's level and staff. This operation required three people and was inefficient. The survey system was replaced in 1985 with a laser level transmitter and an elaborate vehicle-mounted laser receiver. In addition, a vacuum tine marker was fitted to the rear of the survey vehicle which can be raised and lowered from inside the vehicle. This system enables one person to survey and mark waterponds from a single vehicle, with up to 50 ha surveyed and readied for construction in a day.

Over time, a wide range of machines have been used to construct waterponding banks including standard road graders (ridged frame and articulated) or similar. Pre-1985 road graders were generally too small to construct banks of sufficient size, which resulted in too many breached banks. Over a four-year period, the Marra Creek Waterponding Demonstration Program, backed by committed landowners, researched different horsepower road graders, constructing different size banks, winning the dirt from different locations, and evaluating the economics of construction methods. The results showed that the higher-powered articulated road graders exceeding 200 HP proved to be the most economical and efficient for waterpond construction. This type of machine has the power to form the bank with one pass on the inside of the bank and two passes on the outside, achieving a bank with well over 2 m base width and over 50 cm in height.

Results and Discussion

The land managers that undertake incentive projects to rehabilitate scalds carry out yearly photo and step point monitoring, commencing before the waterponding takes place. This highlights the dramatic landscape change that has taken place after the waterponding rehabilitation technique has been applied. Photos and pasture measurements were undertaken on 'Billabong' Marra Creek NSW, commenced October 2005, waterponding in November 2005, and monitored to 2014. This Billabong paddock waterponding site has increased ground cover from 1% in 2005 to 84 % in 2014 (Thompson, 2012).

When the waterponds modify the soil structure, improve water infiltration, increase soil moisture and decrease soluble salts, an increase in vegetation occurs on the ponded sites, with organic carbon beginning to accumulate in the soil. Research has found that the scalds store approximately 18.7 t/h of soil organic carbon to a depth of 30 cm. Once the landscape has been restored by waterponding and revegetation, we have found there is a rapid increase in soil organic carbon up to 25 t/ha within five years (Read *et al*., 2013). The result of waterponding is indicating that land in the rangelands that has been rehabilitated using waterponds does sequester carbon. This could lead on to waterponding being eligible for a carbon abatement activity and hopefully lead to Carbon Farming Initiative activity for carbon credits.

Conclusion

The increase in native pasture yield has made the waterponding technique an economic method of increasing production and reinstating functioning native vegetation communities on previously scalded lands.

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Wildfires Cause Long-Term Plant Community Conversion in a Western Great Plains Steppe

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Key words: Grassland, Shrubland, Shrub encroachment, Threshold, *Bromus tectorum*

Introduction

Long-term impacts of wildfire vary dramatically across rangeland ecosystems. Frequent fire can promote productivity and biodiversity in some locations (Fuhlendorf et al. 2006), but in other regions this same disturbance can cause catastrophic ecosystem shifts, including the loss of dominant plant species and invasion by exotic plants (Davies et al. 2011). Understanding the short- and long-term effects of fire is critical for the successful management of rangeland ecosystems. However, in many regions the role of fire is still poorly understood.

Here we describe associations between wildfire and plant community composition in the Thunder Basin ecoregion, which covers more than 800,000 ha in northeast Wyoming. Nestled within the larger Powder River Basin, Thunder Basin is located in the ecotone between northern mixed grass prairie to the northeast, shortgrass steppe to the southeast, and shrub steppe to the west. In this region, livestock producers, energy developers, and conservation interests are struggling to co-manage a spatially extensive, biophysically complex, and water-limited landscape. Wide variation in soil types, topography, and the abundance of both shrubs and grasses makes it difficult to understand and predict the long-term effects of wildfire in this landscape. To advance our understanding of wildfire in complex landscapes and to help inform management, we asked three questions: How does wildfire influence plant community composition? Are the effects of wildfire on plant communities short-term or persistent? and Does wildfire interact with other environmental factors to influence community composition?

Materials and Methods

From a database of perimeters for wildfires that burned between 1988 and 2012, we identified regions in the Thunder Basin that had burned only once since 1988. We also used local knowledge to identify burns that occurred in 1937 and 1974. For each ecological site within each fire, we randomly placed a 30 m-long transect which was paired with an unburned transect located outside the burn but within 1000 m of the fire perimeter. Paired transects were matched based on grazing allotment, ecological site, slope, aspect, elevation and topographic wetness index. We sampled 79 transect pairs across 32 fires. For each transect aerial cover of each species was determined within a 50 x 20 cm quadrat at ten systematically spaced locations, end of growing season biomass was clipped by functional group, and shallow soils cores (0-30 cm deep) were collected for determining surface soil texture. We used nonmetric dimensional scaling ordination to investigate variability in plant community composition and determined whether community-level variability was associated with historical wildfire, soil type or other factors. We also used linear mixed models and model selection to investigate the responses of key plant species and functional groups to wildfire and landscape context.

Results and Discussion

Historical wildfires in Thunder Basin induced both short-term and long-term shifts in plant community composition. Compared to paired, unburned sites, burned sites had lower shrub cover, higher perennial grass cover, lower cactus cover, and higher forb cover (Fig. 1). Effects of wildfire on cactus and forb cover diminished over time, but effects on shrubs and perennial grasses were persistent. Inside the oldest fires, shrubs had not recovered and perennial grass cover remained significantly elevated. Historical wildfires were not associated with invasion of *Bromus tectorum* (cheatgrass) or *Bromus arvensis* (Japanese brome). Aside from fire, we found that soil texture, cover of other plant species, and microclimate (slope and aspect) were key drivers of annual brome abundance. Soil texture, slope and aspect also had important impacts on plant community composition and functional group biomass.

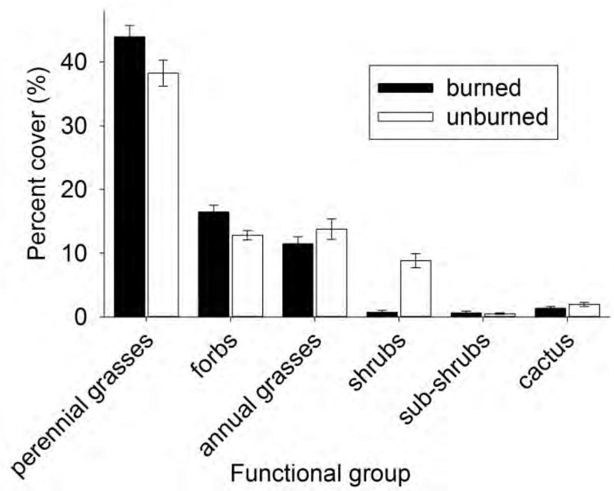

Figure 1. Impacts of historical wildfire on the relative percent canopy cover of different plant functional groups.

Conclusions and Implications

Wildfires induced plant community shifts that persisted for over 100 years in Thunder Basin. Long-term losses of shrubs from burned sites may be problematic for managers attempting to maintain sagebrush habitat for sage grouse (*Centrocercus urophasianus*) and other important wildlife species. Conversely, increased cover of forbs and perennial grasses in burned sites suggests that these areas may provide important forage resources that are less abundant elsewhere in the landscape. From the perspective of annual brome invasion, infrequent fires may be a safe strategy for influencing plant communities and wildlife habitat in Thunder Basin. In ecotonal environments such as Thunder Basin, plant communities may respond to wildfire and other disturbances in unexpected ways. Enhancing spatial heterogeneity (e.g., a mosaic of burned and unburned sites) may be an effective land management strategy to optimize biodiversity, livestock production, and other ecosystem services in this ecosystem.

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Burning and Growing Season Influences on a Semi-Arid Grassland

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Key words: Fire, burning, grassland, recovery, season

Introduction

Fire effects on grassland plant communities may depend on season of burning (i.e., timing) and growing season climatic conditions (Erichsen-Arychuk, 2002). Climatic variability is indeed inherent to semi-arid regions (Sala et al., 1988), and results in pronounced inter-annual variability in plant productivity (Smoliak, 1986). This variability may in turn influence both fire effects and plant community recovery. This experiment studied the effects of burning and growing season on a Dry Mixedgrass plant community in southeast Alberta, Canada. Questions addressed included (1) how does burning season influence plant community composition as well as herbage mass and quality? (2) How do these parameters recover over time? And (3), what is the influence of different growing season weather conditions on both plant community recovery and burning season effects? This information is timely considering the potential effects of climate change. Climate in the northern Great Plains is already variable, but growing seasons, on average, are longer and warmer conditions occur more frequently (Wheaton et al., 2014). This means that fire may occur more frequently, earlier or later in the growing season, and over a longer period. Climate change is also increasing the intensity of weather (Fischer and Knutti, 2015), which may further increase inter-annual climatic variability and fire frequency due to lightning.

Materials and Methods

This was a 6 year experiment (1997-2002), where 3 different trial replicates were initiated over a 3-year period, and plots were surveyed for another 3 years thereafter. The study site was at Onefour, Alberta. Treatment combinations, applied to plots (9 x 7 m) in a randomized complete block design, included burning (early spring, late-summer, or unburned control) and growing season (97/98, 98/99, and 99/00). A propane torch and wet lines were used for burning. Vascular plant foliar cover was assessed in three subplots (20 x 50 cm) in late-August. Standing herbage was clipped, dried at 60°C for 48 hrs, and weighed. A grab sample was sorted into green and dead (litter) portions and the green portion was tested for percent nitrogen.

NMS ordinations were used to assess plant community composition changes. Ordinations combined data collected for different growing seasons (97/98, 98/99, and 99/00) but were stratified for each year of recovery (1, 2, and 3 growing seasons post burning). For perMANOVAs and ANOVAs, burn treatment and growing season were fixed factors. Univariate responses included herbage mass, percent nitrogen and green portion, and Shannon's diversity. Least significance difference was used for significant ($P < 0.05$) effects.

Results and Discussion

Growing season precipitation ranged between 28% below to 90% above average and drought occurred in 2000-2001. For community composition, early-spring and late-summer burning resulted in different communities ($P < 0.003$) after one post-burning growing season. Late-summer burned communities diverged further than spring burned from unburned controls. After 3 growing seasons of rest late-summer burned communities still differed from controls ($P = 0.007$), but early-spring burned communities did not ($P = 0.11$). This suggests that late-summer burning has a greater effect on plant community composition and prolongs recovery to the original community. Burning reduced *Hesperostipa comata* ($P < 0.037$) and *Selaginella densa* ($P < 0.002$), and promoted *Koeleria macrantha* ($P = 0.002$). Communities burned in different growing seasons always differed ($P < 0.001$) from one another at similar stages of recovery and there were no interactions between burning and growing season ($P > 0.42$). Burning did not influence plant diversity ($P > 0.38$), but there were annual differences in plant diversity 2 and 3 years post-burning ($P < 0.002$). This suggests that although different climatic conditions within growing seasons strongly influence plant community composition from one year to the next, they do not influence burning effects or community recovery.

Herbage mass dynamics in response to burning followed this same trend. Burning markedly reduced herbage mass ($P < 0.001$), partly by eliminated standing litter. However, regardless of growing season, herbage mass recovered within 3 growing seasons post burning despite that litter remained reduced ($P < 0.001$). There were no burning and growing season interactions for any stage of recovery ($P > 0.48$), indicating that climatic conditions within individual growing seasons did not influence recovery. Burning also altered herbage quality. After 1 rested growing season, late-summer burned communities had higher percent nitrogen in the green portion ($P < 0.004$), suggesting that late-summer burning may be used to increase forage quality for the following growing season.

Conclusions and Implications

Results suggest that although this plant community responds to growing season conditions and is more sensitive to fire later in the growing season, growing season conditions (including drought) do not influence burning season effects on plant community composition, productivity, or recovery. This suggests that this plant community is resilient to the interactive effects of both increasing climatic variability and wildfire. This highlights the importance of semi-arid grasslands as a forage resource in an increasingly variable and extreme climate.

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Grass Morphology and Fire

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Key words: Grass, morphology, traits, combustion rate, ecosystem

Introduction

Many grasslands rely on fire for their existence and without fire, would be in danger of bush encroachment (Bond and Midgley, 1995). The identification of how traits such as leaf size relate to flammability is still under investigation. Therefore, we aimed to determine how grass morphology affects the rate of combustion (flammability) of various grass species. Our research questions were 1) How does morphology vary between and within grass species and 2) Does morphology affect the rate of combustion? Our predictions were that grass species with a similar morphology would experience similar rates of combustion.

Materials and Methods

We collected data from three different sites along an altitudinal gradient, the Coast near Scottburgh (30° 15' S, 30° 43' E, elevation 159 m), Ukulinga Research Farm, Pietermaritzburg (30° 24' S, 29° 24' E, elevation 850 m), Highmoor Rest Camp in the KwaZulu-Natal Drakensberg (29° 19' S, 29° 37' E, elevation 1850 m). The species sampled were *Aristida junciformis*, *Themeda triandra*, *Sporobolus africanus*, *Digitaria eriantha*, *Diheteropogon amplectens*, *Alloteropsis semilata* and *Festuca costata*. At each study site, ten mature tufts were selected randomly and the following data collected; tuft diameter) (cm), tuft circumference (cm), height to tallest extended leaf (cm), leaf table height (including 80% of the leaves) (cm), pseudostem %, inflorescence % and leaf %. Leaf measurements were done on each leaf; leaf length (cm), maximum leaf width (cm), wet mass (g), leaf dry mass (g) and leaf area (cm^2). I used a LI C3000 portable area meter to determine the leaf area. The leaves were dried at 70°C for 48 hours until completely dry and then weighed. Specific leaf area (SLA in cm^2g^{-1}) was then calculated using the formula:

$$\text{SLA} = \frac{\text{Leaf area}(\text{cm}^2)}{\text{dry mass}(\text{g})}$$

To determine rate of combustion, comparable amounts of grass from each tuft were ignited using a gas flame. Mass loss rate was recorded as the material was burning.

Results and Discussion

Physical traits for *A. junciformis* and *T. triandra* were different on average between all the study sites (Table 1) and along an altitudinal gradient (Fig. 1). SLA was highly correlated with flammability (Fig. 2)

Table 1. Permutation MANOVA test of differences in mean trait values among locations of different elevation for *Themeda triandra* and *Aristida junciformis*.

Species	Df	SS	MS	P (perm)
Aristida junciformis	2	145.75	72.873	0.0001
Themeda triandra 2	227.79	113.9	0.0001	

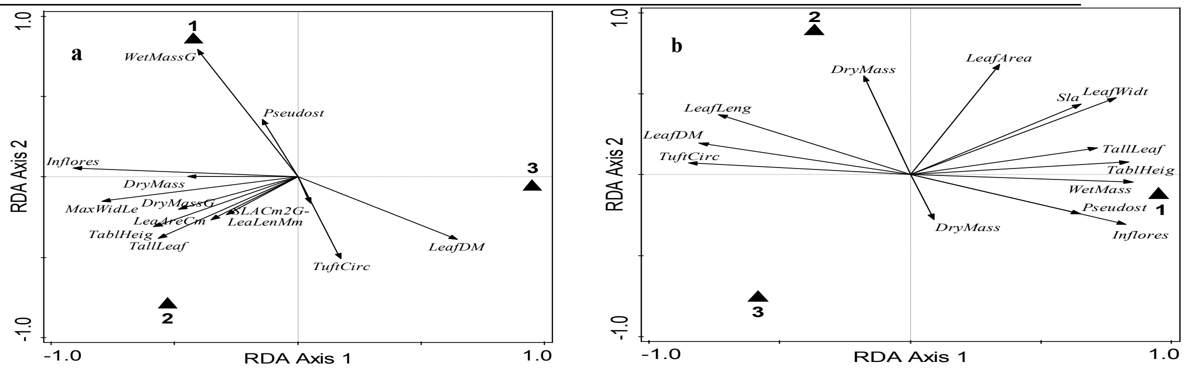
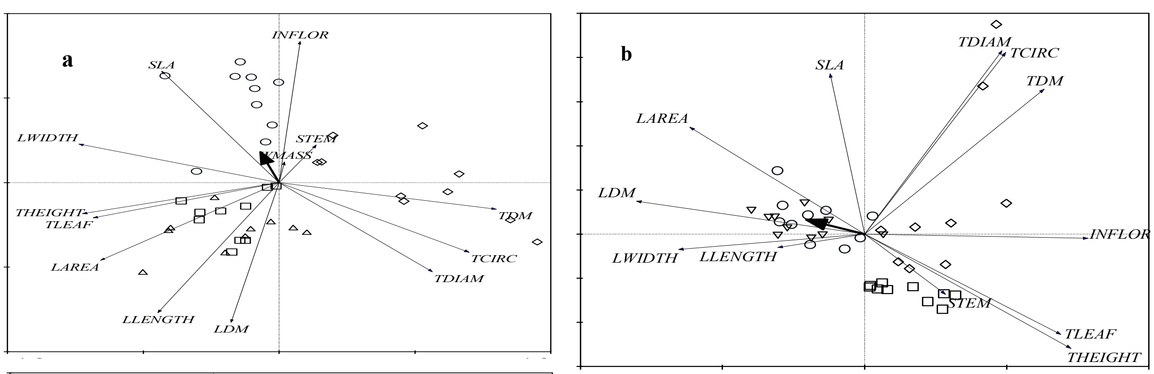


Figure 1. Redundancy analysis for *Aristida junciformis* and *Themeda triandra* (representing a. 26.16%, 12.5% and b. 47.35%, 13.07% of the total variance respectively) showing how physical traits vary along an altitudinal gradient [Coast (1), Midlands (2) and Drakensberg (3)].



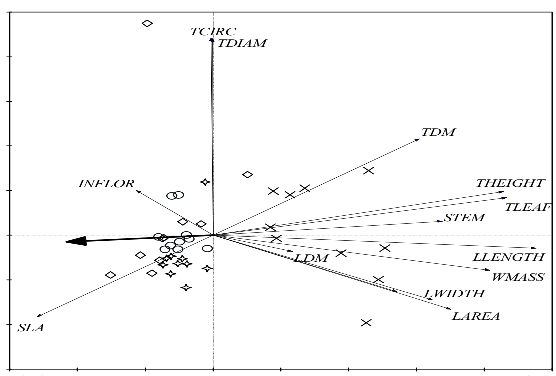


Fig [c] 2. **Principal Components Analysis of grass physical traits and flammability(s/g)** of **a. (Coast)** *Themeda triandra* (circle), *Aristida junciformis* (diamond), *Digitaria eriantha* (upright triangle) and *Sporobolus africanus* (square) (Axes 1 and 2 represent 29.7% and 25.3% of total variance), **b. (Midlands)** *Themeda triandra* (circle), *Aristida junciformis* (diamond), *Diheteropogon amplectens* (downward diamond) and *Sporobolus africanus* (square) (Axes 1 and 2 represent 34.5% and 26.2% of total variance), **c. (Berg)** *Themeda triandra* (circle), *Aristida junciformis* (diamond), *Alloteropsis semialata* (star), and *Festuca costata* (cross) represent 39.1% and 16.3% of total variance, rate of combustion (s/g) (thick black arrow).

Conclusions and Implications

For all species, SLA influenced rate of combustion. Knowledge of species composition and abundance of species is required to predict how fire will burn together with climatic and environmental variables. Physical traits vary among species. However, SLA was an important predictor variable for flammability for all grass species across all sites.

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Seasonal Effects of Fire and Defoliation on Purple Threeawn (*Aristida purpurea*) Forage Quality

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Key words: Purple threeawn, fire, forage quality, defoliation

Introduction

About three-quarters of all domestic livestock depend upon grazing lands for their production (DiTomaso 2000). Beef production on grasslands is limited by several factors including weather and invasion of undesirable species. One of these non-desirable species, due to its low forage quality, is purple threeawn (*Aristida purpurea*). Threeawn is a warm season, native perennial bunchgrass that tends to increase under overgrazing conditions (Evans and Tisdale 1972). Management techniques such as fire and grazing have been used to increase forage quality of grass species (Bennett et al. 2003) but there is little information about seasonal disturbance effects on threeawn forage quality. The objective of this study was to determine if seasonal defoliation events such as clipping and fire can be used to increase threeawn forage quality.

Materials and Methods

This study was conducted during the summer of 2010 on the Texas Tech University Native Rangeland, located in Lubbock, TX. The climate is considered dry steppe with annual precipitation of 475 mm. Vegetation is characterized as short grass plains. To evaluate the effect of fire and clipping on purple threeawn forage quality, plants were exposed to a combination of three defoliation treatments; burning (B), clipping (CL) and control (CT) at three phenological stages; vegetative (V), Reproductive (R) and post-reproductive (PR) with 45 replications. Burning was applied using a portable burner. Clipping consisted of removing 90% of the total forage, by volume. One set of plants were untreated and used as a control. Samples to determine forage quality were collected 2, 4 and 6 months after treatment application for posterior crude protein (CP) content and *in vitro* dry matter digestibility (IVDMD) determinations.

Results and Discussion

Vegetative stage

Crude protein content and digestibility values of threeawn plants treated during vegetative stage followed almost the same pattern across the collection times; this pattern was characterized by slow but constant decrease on forage quality since treatment applications (Figure 1 [A and B]).

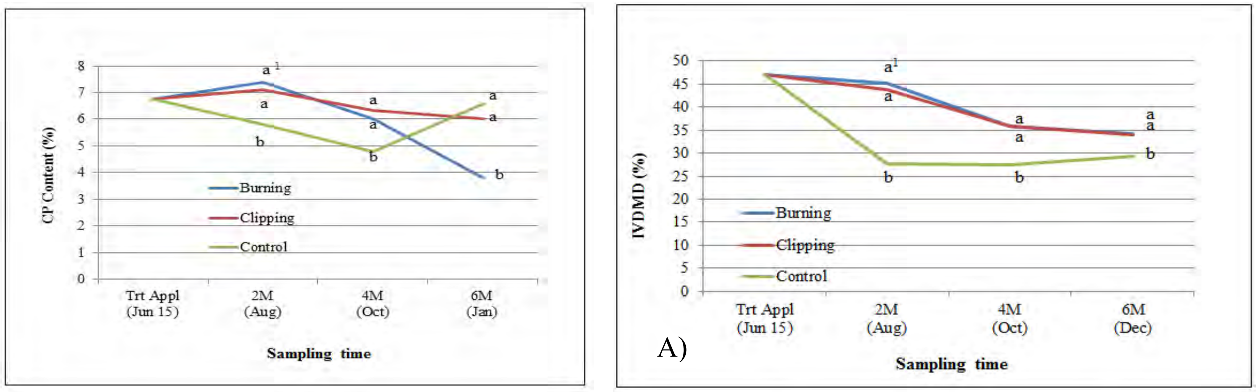

Figure 1. CP A) and IVDMD B) in purple threeawn treated during V stage with three defoliation types, during three sampling times. [1]CP means within each sampling time followed by the same letter are not significantly different (*P<0.05*, LSD). [1] IVDMD means within each sampling time followed by the same letter are not significantly different (*P<0.05*, LSD).

Reproductive stage
Crude protein and digestibility of burned and clipped plants was higher than on control plants during the first two forage collections, however, by the last sampling collection there was no, or very little difference among treatments (Figure 2, A and B).

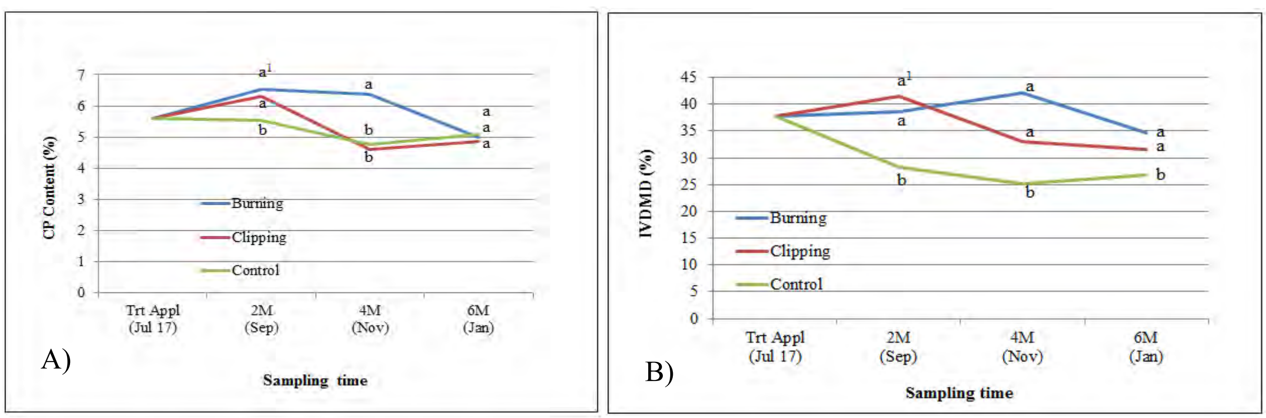

Figure 2. CP A) and IVDMD B) in purple threeawn treated during R stage with three defoliations types, during three sampling times. [1]CP means within each sampling time followed by the same letter are not significant different (*P<0.05*, LSD). [1] IVDMD means within each sampling time followed by the same letter are not significant different (*P<0.05*, LSD).

Post-reproductive
Plants treated during this stage did not produce forage during the first two sampling collections. We were able to collect samples until 6 months after treatment applications and by this time we found the highest forage quality values in burned plants that showed slightly higher forage values than clipped plants (Figure 3, A and B).

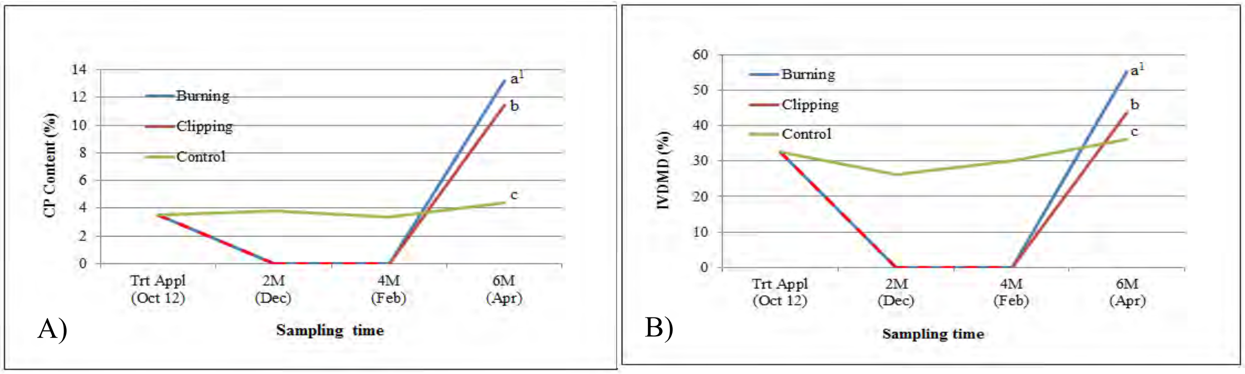

Figure 3. CP A) and IVDMD B) in purple threeawn treated during PR stage with three defoliation types, during three sampling times. [1]CP means within each sampling time followed by the same letter are not significant different (*P<0.05*, LSD). [1] IVDMD means within each sampling time followed by the same letter are not significant different (*P<0.05*, LSD).

Management Implications

Burning and clipping proved to be useful tools to increase and extend threeawn forage quality across phenological stages compared to control plants. Both treatments had basically the same effect in improving threeawn forage quality with burning slightly better. In general burning improved threeawn forage quality lasting from 2 to 4 months depending weather conditions and burning time. Burning during the post reproductive stage produces the highest increase in forage quality.

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Seasonal Effects of Fire and Defoliation on Purple Threeawn (*Aristida purpurea*) Total Non-Structural Carbohydrates Concentration and Mortality

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Key words: Purple threeawn, fire, TNC, survival rates

Introduction

About three-quarters of all domestic livestock production depends upon grazing lands for their sustenance (DiTomaso 2000). Beef production on grasslands is limited by several factors including weather and invasion of undesirable species. One of these non-desirable species due to its low forage quality is purple threeawn (*Aristida purpurea*) which is a warm season, native perennial bunchgrass. In nondisturbed communities, threeawn is a minor component, but under overgrazing conditions tends to increase reducing productivity (Evans and Tisdale 1972). An alternative to control threeawn is the use of natural disturbances such as fire (Wright and Bailey 1982) and grazing. There are some studies dealing with fire and threeawn but there is no information about its response to seasonal burning and total nonstructural carbohydrates (TNC) dynamics across the growing season. The objective of this study was to evaluate the effects of burning and clipping at different phenological stages on purple threeawn survival rates and TNC concentrations in the Southern Great Plains.

Materials and Methods

This study was conducted from 2010 to 2012 on the Texas Tech University Native Rangeland, located in Lubbock, TX. Climate is considered dry steppe with precipitation of 475 mm. Vegetation is characterized by the short grass plains. To evaluate the effect of fire and clipping on purple threeawn mortality and basal cover, plants were exposed to a combination of three defoliation treatments; burning (B), clipping (CL) and control (CT) at three phenological stages; vegetative (V), Reproductive (R) and post-reproductive (PR) with 150 replications per treatment. Burning was applied using a portable burner (Stinson and Wright 1968). Clipping consisted of removing 90% of the total forage, by volume. One set of plants were untreated and used as a control. Mortality was evaluated during the spring of 2011. Finally, basal crown samples were collected 30 and 45 days after treatment applications. These samples were used to determine TNC reserves in the laboratory. Samples were prepared using the acid hydrolysis process then TNC concentration was measured spectrophotometrically at 612 nm.

Results and Discussion

Mortality and change in basal area

There were significant differences among survival rates of defoliation treatments at every phenological stage. Burned plants showed the lower survival rates among defoliation types. In the same way, plants during reproductive stage presented the lower tolerance to our defoliation treatments; the combination of burning at reproductive stage was the most detrimental treatment combination (Table 1).

Table 1. Survival rates (%) and standard error of the mean of threeawn plants defoliated during 2010 growing season, evaluated in 2011, on the Texas Tech University, Native Rangeland, Lubbock, TX.

Treatment	Phenological Stage			Mean
	Vegetative	Reproductive	Post-repro	
Control	90 b[1] (0.75)	100 a (1.521 exp-4)	100 a (9.22E-5)	96.66
Clipping	77.5 c (1.044)	92 b (0.070)	100 a (9.22E-5)	89.83
Burning	95 a (0.544)	75 b (1.083)	90 b (0.779)	86.66
Mean	87.50	85.33	96.6	

[1] Percentages within a column followed by the same lower case letter are not significantly different ($P > 0.05$ LSD).

TNC concentrations

There were significant differences among TNC concentrations of treated plants at each sampling day and across defoliation treatments. In general terms, control plants presented the highest TNC concentration values, while the lower values were found on burned plants (Table 2).

Table 2. TNC concentrations of basal crown of purple threeawn plants sampled 30 days after treatment applications at the Texas Tech University, Native Rangeland, Lubbock, TX.

Treatment	Phenological Stage			Mean
	Vegetative	Reproductive	Post-repro	
		30 Days		
Control	1.28 A[1] a[2]	1.49 A b	1.58 A b	1.45
Clipping	1.58 B a	1.50 A a	1.04 B b	1.37
Burning	1.78 C a	1.33 B b	1.31 C b	1.47
Mean	1.54	1.44	1.31	
		45 Days		
Control	1.53 A a	1.96 A b	2.25 A c	1.91
Clipping	1.28 B a	0.82 B b	1.82 B c	1.31
Burning	1.48 A a	1.57 C a	2.00 C c	1.68
Mean	1.43	1.45	2.02	

[1] Defoliation type means within a phenological stage under the same collection day followed by the same upper case letter are not significantly different ($P > 0.05$ LSD). [2] Phenological stage means within a level of defoliation under the same collection day followed by the same lower case letter are not significantly different ($P > 0.05$ LSD).

Conclusion and Implications

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Based on this study we found that fire is the best option to decrease purple threeawn infestation especially when it is applied during reproductive stage which seems to be the most susceptible phenological stage to defoliation events for this grass species.

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Effect of Drought, Clipping and Fire on Purple Threeawn (*Aristida purpurea*) Survival

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Key words: drought, purple threeawn, fire, survival rates

Introduction

Most of the rangelands around the world evolved under drought, grazing and fire. Research was conducted to answer the question: what is the percent survivorship of Purple Threeawn in response to drought, fire and grazing disturbance during the vegetative, reproductive, and post-reproductive life stages? Purple Threeawn is not a desirable forage species because of its long awns that deter grazing and is typically classified as an early successional species. For these reasons, the answer to the above question can be used by range and ranch managers who wish to decrease the presence or density of Purple Threeawn on their property. If range managers are able to correctly identify during what life stage Purple Threeawn is most susceptible to disturbance and experiences the highest mortality, they can effectively decrease the occurrence of Purple Threeawn on their properties by implementing grazing or fire pressure during those sensitive times of the year.

Materials and Methods

Treatments were applied during the spring of 2010. Data collection was carried out over a four-year period between the spring of 2011 and the spring of 2015 on the Texas Tech Native Rangeland located in Lubbock, TX. The rangeland is 130 acres of native shortgrass prairie dominated by Honey Mesquite (*Prosopis gladulosa*) with additionally high presence of Blue Grama (*Bouteloua gracilis*) and moderate levels of Side-oats Grama (*Bouteloua curtipendula*), Purple Threeawn (*Aristida purpurea*), and Russian Thistle (*Salsola iberica*). Topography varies from 0-3% slope. Soil is composed of approximately 42% Acuff-Urban land complex, 39.3% Amarillo-Urban land complex, 11.3% Midessa fine sandy loam, 1.2% Olton-Urban land complex, and 6.3% Randall clay. This experiment was designed to follow a completely randomized design (CRD). As such, 450 Purple Threeawn individuals were randomly selected within the Native Rangeland area. From this group of 450 plants, individuals were selected in groups of 50 and randomly assigned 1 of the 9 testing groups. The testing groups were as follows: (1) Fire disturbance, vegetative stage; (2) Fire disturbance, reproductive stage; (3) Fire disturbance, post-reproductive stage; (4) Clipping disturbance, vegetative stage; (5) Clipping disturbance, reproductive stage; (6) Clipping disturbance, post-reproductive stage; (7) Control, no disturbance, vegetative stage; (8) Control, no disturbance, reproductive stage; (9) Control, no disturbance, post-reproductive stage. Fire disturbance was applied to individual plants using a portable propane burner. The specific style of burner used in this experiment was designed by Britton and Wright in 1971. The propane burner was calibrated to produce heat levels identical to those Purple Threeawn would experience in a natural wildfire or controlled burn.

Mortality evaluations were performed at the beginning of the growing season each evaluation year. Plants with no live tillers were classified as dead plants.

Results and Discussion

It was determined that Purple Threeawn experiences the highest levels of mortality via clipping when these disturbances occur during the reproductive stage. Measurements taken in 2015 showed that specimens burned in both the reproductive and post-reproductive life stages had the same rate of survival; however, because in 2011 and 2012 plants burned during the reproductive stage showed lower levels of survival than those burned in the post-reproductive stage, it can be assumed that the similar survival rate in 2015 between these two stages occurred as a misnomer due to the influence of some unmeasured factor. It is hypothesized that this factor could be the variation in precipitation seen between each study year. Most significantly, an intense and prolonged drought occurred throughout the study area during 2011-2013. It is hypothesized that this drought contributed to the overall decrease seen in Purple Threeawn survival rates during this study, and negatively affected the survival rate of the control group that received no direct disturbance but showed significant mortality levels in year 1 and each subsequent study year. It is also hypothesized that because Purple Threeawn is an early successional species, it occurred at lower densities each year of the study as time passed and the study area shifted towards higher prevalence of mid successional species.

Table 1. Average survival and statistical data for 2015. Data was analyzed holding phenological stage constant. Within each stage, different letters symbolize significantly different average survivorship ($p>0.05$, LSD); same letters signify no statistical difference.

Treatment/ Phenological Stage	Vegetative	Reproductive	Post-reproductive
Control	47.37 a	69.23 a	53.85 a
Clipping	31.58 bc	18.92 b	86.84 b
Burning	39.47 ac	27.5 c	27.5 c

Conclusion and Implications

This study shows that Purple Threeawn experiences highest levels of mortality when disturbed during the reproductive life stage regardless of the management method. Disturbance in the form of a prescribed burn or wildfire displays higher levels of mortality than disturbance via clipping/grazing during the post-reproductive life stage, but clipping shows higher levels of Purple Threeawn mortality when applied during the vegetative or reproductive life stage. Clipping displays the highest levels of mortality when executed during the reproductive life stage. Therefore, in order to achieve optimum levels of Purple Threeawn mortality, prescribed burns should be implemented during the post-reproductive life stage, and/or grazing during the reproductive life stage.

Managers may wish to burn or clip Purple Threeawn in this manner when they desire a decrease in Purple Threeawn abundance or presence because of its lack of palatability for most ungulate wildlife and livestock. Some managers in the Colorado region or the Southern Great Plains may wish to maintain Purple Threeawn abundance for use by white-tailed jackrabbits (*Lepus townsendii*) or as a winter grazing source for livestock. Such managers who wish to maintain this species may deter disturbance during the reproductive life stage that shows the highest levels of mortality, and conduct any necessary disturbance during the vegetative life stage which displays the highest level of survivorship from both clipping and burning.

It is generally thought that because of fire's ability to remove all aboveground mass, it is the superior method of control for Purple Threeawn; however, this study shows that burning is actually only as effective as grazing when done during the spring vegetative stage, but indeed is more effective than grazing when applied during the post-reproductive stage.

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Restoration of Steppes in Algeria: Case of the *Stipa tenacissima L.* Steppe

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Key words: desertification, arid, pastoral management, soil fertility, Algeria.

Introduction

Steppes of arid Mediterranean zones are deeply threatened by desertification. To stop or alleviate ecological and economic problems associated with this desertification, management actions have been implemented since the last three decades. The struggle against desertification has become a national priority in many countries. In Algeria, several management techniques have been used to cope with desertification.

Two important restoration programs have been led to fight against the desertification and to improve the pastoral and the rural life: fodder plantations of 1.7 million ha and exclosure of 3 million ha rangelands moderately degraded. This last measure constitutes the basis for this study with the purpose to characterize the effects of exclosure on (i) floristic diversity, (ii) pastoral value, (iii) soil fertility, and (iv) soil surface element.

Materials and Methods

One hundred and sixty-seven (167) phyto-ecological samples were studied; 122 inside the exclosure and 45 outside. Systematic sampling was done along a transect of 500 m for the grazed area and 1500 m for the ungrazed area in order to show floristic and ecological changes**.** A minimum area of 64 m^2 was determined using the Braun-Blanquet and De Boulos (1957) method. Vegetation cover was described with pin-point technique, met by a pin descending to the ground on 100 points separated by 10 cm along a 10 m long line within the 64 m^2 plot. Description of the soil surface (with the following typology: litter, bare silt crust, sand, bare ground, coarse) and that of vegetation cover were carried out by the pin-point sampling technique. To identify possible changes in the soil mineral contents, in each of the 167 plots, a sample of soil, from the surface horizon, has undergone chemical (Conductivity,pH,Total calcium carbonate, Organic matter (OM) and total nitrogen).

To estimate biodiversity the species richness (R), Shannon index (H') were computed for each plot using the software R version 2.13.1(package Vegan). The differences between the indices computed (diversity index and pastoral value), the measured surface elements and chemical descriptors determined inside and outside the exclosure were tested by the nonparametric Kruskal-Wallis test due to unbalanced model. Post hoc comparisons between the two treatments were made using the Wilcoxon rank sum test. Both tests were conducted using R version 2.13.1 software.

Results and Discussion

Table 1 shows that the species richness (R) is two times greater in exclosure areas than on grazed areas ($P < 0.001$). Shannon index (H') indicates that the exclosure areas are more diversified and covered than the grazed areas ($P < 0.001$). The pastoral value follows the same trend as that of the diversity indices, with values significantly higher in the exclosure areas ($P < 0.001$). For the surface characterization, we find that vegetation cover, litter, as well as bare silty crust are significantly higher in exclosure areas, while the rate of sand, bare soil and coarse elements increase with grazed areas. Chemical analyses show a significant difference between grazed and ungrazed plots (P< 0.05). The greatest species richness recorded in exclosure is the result of the lack of use by livestock. This allowed plants to complete their phenological cycles and to produce seed, thus increasing their stock in the soil as well. By contrast, in grazed areas, species with high specific quality index were grazed at different phenological stages, resulting in the reduction of seed stock in the soil. Additionally, trampling bound to overgrazing caused soil compaction, preventing water infiltration and therefore seed germination. Overgrazing changes the structure of plant communities and their floristic composition. The analysis of the soil surface has highlighted a significant improvement of vegetation cover inside the exclosures. This indicates that the restoration of vegetation increases the rate of litter into the soil and improves its physical properties. Total soil porosity promotes good water infiltration by reducing runoff and thereby increasing the species richness of these areas. The low levels of these two elements in the grazed areas are the consequence of the biomass reduction and the degraded floristic composition that are reducing the rate of litter in the soil (Hai et al., 2007).

Table 1. Exclosure effect on floristic, pastoral value, soil surface and soil chemical analysis.

	EX	GR	**P-Value**
Floristic diversity index			
Floristic Richness R	32.3 [a] ± 2.3	14.4 [b] ± 2.8	< 0.001***
Shannon index H'	3.3 [a] ± 0.1	2.5 [b] ± 0.2	< 0.001***
Pastoral value Vp	28.3 [a] ± 5.2	10.7 [b] ± 3.18	< 0.001***
Soil surface elements (%)			
Plant cover	67.7 [a] ± 7.4	29.2 [b] ± 6.2	< 0.001***
Litter	8.0 [a] ± 2.3	5.0 [b] ± 2.4	< 0.001***
Bare silty crust	10.1 [a] ± 3.9	3.2 [b] ± 2.6	< 0.001***
Sand	8.8 [a] ± 4.2	9.9 [a] ± 3.4	> 0.05 ns
Bare ground	3.3 [b] ± 2.6	44.3 [a] ± 10.3	< 0.001***
Coarse elements	2.2 [a] ± 3.0	8.4 [a] ± 6.0	> 0.05 ns
Soil chemical analysis			
pH	8.1 [a] ± 0.3	8.1 [a] ± 0. 2	> 0.05 ns
Conductivity	0.18 [a] ± 0.2	0.16 [a] ± 0.4	> 0.05 ns
% Organic matter	3.1 [a] ± 0.6	0.8 [b] ± 0.3	< 0.001***
% Total nitrogen	0.2 [a] ± 0.04	0.09 [b] ± 0.04	< 0.001***

Means ± SE are given. The differences between the treatments were tested by Kruskal-Wallis test (p-value). Asterisks indicate significance of tests (* = p < 0.05, ** = p < 0.01, *** = p < 0.001, ns: non-significant). Different letters indicate differences between inside and outside exclosure (Wilcoxon test, p <0.05). EX : Exclosure ; GR : Grazed areas.

Conclusion

The study has shown that after four years of protection the technique improves quantitatively and qualitatively the vegetation and the soil surface, with little change in soil chemical proprieties. The restoration period is too short to improve the quality of the soil, its nutrient capacity, although the plant recovery increases with result the total increase in the rate of organic matter and total nitrogen.

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Ecosystem Restoration on Interior British Columbia's Dry Forests Ecosystems

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Key words: Prescribed fire, ecosystem restoration, climate change, ecosystem resilience

Introduction

Decades of wildfire suppression combined with a prolonged absence of prescribed fire has had an effect on many of British Columbia ecosystems, most notably in the dry-forests where it has contributed to the in-growth of trees in previous open forest and the encroachment of trees onto the grasslands of British Columbia.

Historically, these areas were part of a mixed-severity fire regime that included low, moderate and high severity fires that created a landscape mosaic. These "fire-maintained ecosystems" represent approximately five percent of British Columbia's landbase and has been recognized as a provincial conservation concern (Austin et al., 2008).

Provincially, this has had a negative effect on ecosystem resilience, wildfire hazard, forage supply, habitat, timber values, non-timber forest resources and forest susceptibility to insects and disease. Additionally, at risk are loss of First Nations values such as medicinal and culturally important plants, habitat in traditional hunting and trapping areas, protection of archaeological sites from severe wildfire, traditional knowledge and cultural activities related to managed fire.

Results and Discussion

To mitigate these trends and respond to a changing climate, an Ecosystem Restoration initiative was an initiated in the fall of 2006 by the British Columbia government. Ecosystem restoration treatments involving applying varying combinations of harvesting, mechanical slashing and/or prescribed burning to key areas. The initial focus is the lower-elevation grasslands and the dry open forests in the province's Southern Interior which are rich in biodiversity. Adding to the management complexity, these same areas are highly favored for agriculture, settlements, community watersheds, cultural activities and recreation.

By coupling First Nations traditional knowledge of managed fire, with historic photography, tree ring analysis, stand reconstruction and climate change analysis we were able to gain some understanding of the historic conditions that existed under that fire regime. Although the historical information offers insight into a previous resilient forest condition, Ecosystem Restoration treatment activities are also guided by landscape-level considerations such as wildfire hazard, land conversion, fragmentation, species losses, invasive plants, cultural needs, and large scale phenomena such as climate change.

In 2008 the British Columbia Prescribed Fire Council was formed; composed of representatives from multiple provincial and federal agencies who are charged with leading a more coordinated approach to the application of prescribed fire in the province. The council's terms of reference includes:

- Developing standardized training and certification to aid in providing opportunities for practitioners to maintain and improve their skills;
- Educate the public about the objective and benefits of prescribed fire;
- Supporting coordinated prescribed fire planning and operations; and

- Supporting improved air shed management to help minimize the potential negative health impacts, primarily arising from smoke in populated areas.

Conclusions and Implications

In a changing climate, reducing forest vulnerability to future disturbances will be an important aspect of maintaining ecosystem resilience. "The judicious use of prescribed fire is increasingly regarded as an effective tool in helping to mitigate the catastrophic wildfire risk and for creating greater resiliency in the province's forests in light of climate change" (Okrainetz and Neal, 2013).

To quote the well-known forest ecologist Dr. Harold Biswell, "fire is a natural part of the environment, about as important as rain and sunshine…. Fire has always been here and everything good has evolved with it" (Biswell, 1989).

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4.3 Cropland Abandonment, Revegetation with Perennial Forages and re-used as Rangeland

Seedling Growth of Three Forage Shrubs under Four Radiation Environments for Revegetation Purposes

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Key words: Rangelands revegetation, climate, restoration, root and shoot length.

Introduction

Plantations of native srhubs represent an alternative for the restorations of deteriorated rangelands. Restoration brings several benefits to the ecosystem such as the increase of diversity and abundance of plants and animals (El-Keblawy et al., 2015). Properties such as the physical and chemical soil characteristics can be improved, as well as the increase of organic matter content and the water retention capacity. However, the restoration of deteriorated rangelands through plantations is a lengthy and costly process (Snyman, 1999). Therefore, effective methods which either shorten the production period or lower the costs of the process are required to make this practice more reliable and attractive to implement.

The environmental factors greatly influence plant growth and development. From them, radiation plays a key role (Taiz y Zeiger, 2002). The colors from the visible range of the electromagnetic spectrum have differentiated effects on the photosynthetic activity and the growth rate of plants (Chung-Liang y Kuan-Pi, 2014). Plants respond to the quality of the incident light, which is not only an energy source for photosynthesis but also a regulator of physiological processes (Ganguly et al., 2014). Therefore, the aim of this study was to evaluate if different radiation environments can shorten the seedling production process of two shrub species under greenhouse conditions.

Materials and Methods

The experiment took place in an experimental greenhouse covered with transparent polyethylene located at the University of Chihuahua, Chihuahua, Mexico. Dimensions of the greenhouse were 12 m x 6 m x 3.5 m (LxWxH). To produce the radiation environments, three scaled-down greenhouses (1 m x 0.5 m x 0.75 m) were built and placed inside the experimental greenhouse. The scaled greenhouses were covered with red, blue and green polyethylene plastics.

Seeds of *Dalea bicolor* and *Eysenhardtia texana* were used. They were collected during November of 2013 from natural communities of the State of Chihuahua, Mexico. Inside each scaled greenhouse, five petri dishes, containing 100 seeds each, were placed. Water was applied to the germination substrate to keep high moisture contents during the period of the experiment, which took place during 23-30 of October, 2015.

The treatments consisted of four radiation environments, which were red, blue, green and a control (the experimental greenhouse environment). Repetitions were five. The variables measured were root and shoot lengths and were measured from the 10 biggest seedlings from each repetition, separated by species. The measurements were performed seven days after the seeds were sown. Data was processed with an analysis of variance and the Tukey procedure (α=0.05) was applied when significance differences were found.

Results and Discusion

Results from the Analysis of Variance shown significant effects (P<0.05) of the radiation environments on the shoot length of *Eysenhardtia texana*. For the case of root length, differences were not significant (P>0.05). For *Dalea bicolor* significant effects (P<0.05) were detected for both the root and the shoot lengths (Table 1). The red and the green radiation environments produced the same effects on the shoot length of *Eysenhardtia texana*. The seedling size under these two environments was bigger than under the blue environment and the control. In the case of *Dalea bicolor,* the red radiation produced the biggest seedling size, followed by the green, blue and finally the control. For the shoot length, all the effects were significant for the three environments and the control, with a significant positive effect under the red environment (P<0.05). The effect of the radiation environments on the root length was not as notorious as in the case of the shoot length of this species. For this variable, only the red and green radiation environments were significantly superior then the control (P<0.05).

Table 1. Means ± standard error of shoot anf root lengths (cm) of two forage shrubs under four radiation environments.

Radiation environment	*Eysenhardtia texana*		*Dalea bicolor*	
	Root length	**Shoot length**	**Root length**	**Shoot length**
Red	1.8 ± 0.05 a	3.3 ± 0.06 a	1.7 ± 0.06 a	4.6 ± 0.09 a
Green	1.8 ± 0.05 a	3.2 ± 0.06 a	1.6 ± 0.06 a	4.2 ± 0.09 b
Blue	1.8 ± 0.05 a	2.8 ± 0.06 b	1.5 ± 0.06 a b	3.9 ± 0.09 c
Control	1.3 ± 0.05 a	2.2 ± 0.06 c	1.3 ± 0.06 b	3.2 ± 0.09 d

For each variable measured, different literals mean significant differences (Tukey P < 0.05).

Conclusions and Implications

The quality of radiation produced by the red, green and blue environments have a significant effect on the growth of seedlings of *Eysenhardtia texana* and *Dalea bicolor*. The red radiation environment may contribute to a greater extent to the growth of *Eysenhardtia texana* and *Dalea bicolor*., compared to the green and blue environments.

Future experiments could consider testing the effect of these redietion environments on the growth of the species studied under commercial greenhouse conditions. The final aim is to reduce the time and costs of production of seedlings for revegetation programs.

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Planting Time and Grass Mixtures Affect Forage Kochia Establishment

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Key words: Forage kochia, establishment, seed mixture, planting time, reclamation

Introduction

In the United States, especially in the western arid and semiarid areas, rangelands are disturbed or degraded due to coal and gas extraction, overgrazing, wildfire, drought, or exotic weed invasion (Waldron et al., 2010). Successful seeding of adapted and desirable perennial plant species can be one of the effective ways to reclaim or restore these disturbed and degraded areas. Attempts have been made to restore these areas by using native and nonnative perennial grasses, although native grasses show poor establishment success in areas degraded by exotic weeds (Roundy et al., 1997).

Forage kochia (*Bassia prostrata* [L.] previously *Kochia prostrata* A.J. Scott), an introduced long-lived perennial semi-shrub, may have potential for use in restoring these disturbed and degraded rangelands. It has drought and heat tolerance, can grow in saline and alkaline soils, possesses the capability of extracting soil moisture and competing with exotic invasive weeds, and can suppress wildfires on rangeland (Harrison et al., 2002: Waldron et al., 2010). Forage kochia, when grown with perennial grasses, can increase forage production and improve forage quality during fall and winter (Waldron et al., 2010). Despite these advantages, a major concern associated with forage kochia is its unpredictable establishment due mainly to poor seed viability and germination, improper planting time and methods, excessive weed competition, and environmental stresses during early germination (Creech et al., 2013). The objective of this study was to evaluate the establishment of forage kochia under different planting dates and in mixtures with grasses in weed dominated areas.

Materials and Methods

The study was conducted at the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) near Lingle, Wyoming (42°7'50'' N latitude; 104°23'34" W longitude; elevation 1,272 m). Forage kochia ('Immigrant') and six perennial cool-season grass species (four natives and two nonnatives) were used in the study. Native species included 'Critana' thickspike wheatgrass (*Elymus lanceolatus*), 'Rosana' western wheatgrass (*Pascopyrum smithii*), 'Anatone' bluebunch wheatgrass (*Pseudoroegneria spicata*), and 'Magnar' basin wildrye (*Leymus cinereus*). Nonnative perennial grasses included 'Hycrest' crested wheatgrass (*Agropyron cristatum* × *A. desertorum*) and 'Texoma MaxQ II' tall fescue (*Schedonorus arundinaceus*). Species in each seed mixture were mixed in equal proportion based on their seeding rate on pure live seed (PLS) basis. Recommended seeding rate for forage kochia was 2.2 kg PLS ha^{-1} and for grasses was 4.5-11.2 kg PLS ha^{-1}. The experiment was conducted in a split-plot in space set in a randomized complete block design with four blocks. Each block contained two planting dates as the main-plots and six seeding mixture treatments as subplots. Winter dormant planting (March 3, 2014) and spring planting (April 8, 2014) were done in respective main-plots within each block. Winter planting was conducted by hand broadcasting on the top of snow while drill seeding was done in spring with 19 cm spacing. Forage density count was done three times in 2014 (June, August, and October) and two times in 2015 (June and July) using a quadrat. The GLM procedures of the SAS software 9.4 were used for statistical analysis.

Results and Discussion

There was an interaction effect (P<0.05) of planting dates and seed mixture treatments on average forage kochia density in both years (2014 and 2015). Overall forage kochia density was higher in April planting than March planting regardless of monoculture or mixture with grasses (Table 1). This suggests that the April planting (early spring planting) may be suitable for higher emergence or seeding success of forage kochia than the March planting (late winter planting). Forage kochia seeds might have obtained enough soil moisture for germination and emergence soon after early April planting from precipitation that occurred in April. Monsen and Turnipseed (1989) suggested that spring seeding would be successful, if spring precipitation occurs to provide enough moisture for germination of forage kochia seeds. They also reported about successful forage kochia establishment when planted in early spring in Idaho, a similar environment to Wyoming. This all suggests that time of planting and moisture play a major role in establishment of forage kochia.

Table 1. Density (plant/0.25 m^2) of forage kochia in 2014 and 2015 for different seed mixtures within each planting dates at SAREC, Lingle, Wyoming.

Seed mixture	2014		2015	
	March planting	April planting	March planting	April planting
FK	11.1 aB	46.7 aA	4.3 aB	25.8 aA
FK+Na	3.5 bB	11.4 cA	0.7 bA	6.0 bA
FK+CWG	6.4 abB	21.5 bA	2.2 bB	6.0 bA
FK+TF	8.0 abB	18.7 bA	1.8 bA	5.8 bA
FK+NN	4.9 bB	11.5 cA	1.5 bB	3.5 bA
FK+Na+NN	3.6 bA	8.0 cA	1.3 bA	2.5 bA

Lower case letters indicate significant differences among different seed mixtures within each planting date and capital letters indicate difference within a seed mixture between different planting dates (P<0.05). **FK**, forage kochia; **Na**, four native grasses (basin wildrye, bluebunch wheatgrass, thickspike wheatgrass, and western wheatgrass); **CWG**, crested wheatgrass; **TF**, tall fescue; **NN**, nonnative grasses (**CWG+TF**).

Conclusions and Implications

Early spring (April) planting provided higher density of forage kochia than late winter planting (March) irrespective of monoculture and mixture with grasses. Forage kochia is a highly nutritious forage species which can be utilized for reclamation of degraded areas in the western United States and perhaps in Canada and other similar areas, provided that successful stand establishment is achieved. Compatibility between forage kochia and native or nonnative grasses and their persistence can be better understood by monitoring the study sites for long-term. This warrants future studies especially on compatibility and persistence of forage kochia with rangeland species.

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Effect of Particle Size of Para Grass (*Brachiariamutica*) and Maize Grain on Intake, Digestibility and Growth Performance of Crossbred Heifers under Zero Grazing Condition in Bangladesh

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Keywords: Maize grain, para grass, particle size, weight gain and digestibility

Introduction

The main problem of rearing dairy cattle in Bangladesh is the shortage of livestock feeds and fodder both in terms of quality and quantity. In past, most of the research work on livestock feeds done in Bangladesh was emphasized on the improvement of poor quality roughage and little effort was given on efficient utilization of good quality green roughage and concentrates. Therefore, the objectives of the present research were to study the effects and interactions between maize grain particle size (MPS) and para grass particle size (PPS) on DMI and growth performance of crossbred heifers.

Material and Methods

The experiment was conducted at Bangladesh Agricultural University Dairy Farm, Mymensingh for a period of 90 days.Treatments were arranged in a 2 x 2 factorial design; two levels of PPS (full length and chopped into 4-5 cm) were combined with concentrates based on either ground powdered maize grain or crushed maize grain. Twelve crossbred heifers (Holstein Friesian × Indigenous) were grouped into three blocks according to their body weights (99 to 104 kg/cow) having four animals in each block and these animals were assigned into four treatment combination randomly.

Table 1. Effects of PPS and MPS on DMI and interaction effect on crossbred heifers.

Para Grass	DMI (kg/d)						
	A	B	C	D	E	F	G
Full length	2.825	2.900	2.967	3.122	3.249	3.410	3.078
Chopped into 4-5cm	3.355	3.470	3.547	3.667	3.771	3.860	3.612
SEM	0.142	0.134	0.116	0.137	0.144	0.156	0.137
Significance level	*	*	*	*	*	NS	*
Maize Grain							
Coarse particle	3.088	3.205	3.267	3.420	3.499	3.667	3.357
Powdered form	3.092	3.165	3.247	3.368	3.521	3.603	3.333
SEM	0.142	0.134	0.116	0.137	0.144	0.156	0.137
Significance level	NS	NS	NS	NS	NS	NS	NS
Particle size of Para grass × Maize Grain							
L_f M_c	2.883	2.971	3.017	3.177	3.249	3.490	3.131
L_f M_p	2.767	2.828	2.917	3.067	3.250	3.330	3.026
L_{ch} M_c	3.293	3.438	3.517	3.663	3.750	3.843	3.584
$L_{ch}M_p$	3.417	3.502	3.577	3.670	3.793	3.877	3.639
SEM	0.201	0.189	0.164	0.193	0.204	0.220	0.194
Significance level	NS	NS	NS	NS	NS	NS	NS

A=1st 15 days, B=2nd 15 days, C=3rd 15 days, D=4th 15 days, E=5th 15 days, F= 6th 15 days of experimental period respectively and G=whole period of experiment (90 days); L_f=full length para grass, L_{ch}=chopped para grass, M_c=crushed maize grain, M_p=powdered maize grain; *Significant at 5% ($P<0.05$); NS=not significant

Table 2. Effects of PPS, MPS and interaction on daily weight gain (kg/d) of crossbred heifers.

Para Grass	Daily weight gain (kg/d)						
	A	B	C	D	E	F	G
Full length	0.229	0.236	0.246	0.227	0.231	0.242	0.235
Chopped into 4-5cm	0.288	0.260	0.279	0.266	0.278	0.283	0.275
SEM	0.004	0.010	0.012	0.008	0.008	0.005	0.002
Significance level	**	NS	NS	*	**	**	**
Maize Grain							
Coarse particle	0.259	0.259	0.262	0.260	0.265	0.264	0.261
Powdered form	0.258	0.238	0.263	0.233	0.244	0.261	0.249
SEM	0.004	0.010	0.012	0.008	0.008	0.005	0.002
Significance level	NS	NS	NS	NS	NS	NS	**
Particle size of Para grass × Maize Grain							
$L_f M_c$	0.236[b]	0.246	0.263	0.242	0.236	0.237	0.243
$L_f M_p$	0.222[b]	0.226	0.228	0.212	0.226	0.246	0.227
$L_{ch} M_c$	0.281[a]	0.271	0.260	0.277	0.295	0.291	0.279
$L_{ch}M_p$	0.294[a]	0.249	0.298	0.255	0.262	0.275	0.272
SEM	0.005	0.014	0.017	0.012	0.011	0.007	0.003
Significance level	*	NS	NS	NS	NS	NS	NS

**Significant at 1% (P<0.01); *Significant at 5% (P<0.05); NS=not significant

Results and Discussion

DMI and daily weight gain (kg/d) increased when heifers were fed chopped para (4-5 cm) grass than heifers fed full length para grass. On the other hand, maize grain and any combination of the interactions (particle size of Para grass × maize grain) can be followed in feeding technique to crossbred heifers as they were statistically similar (P>0.05). Cao *et al*. (2008) showed that DMI of cows fed short Lucerne hay was higher than long Lucerne hay, and also found that cows fed short Lucerne hay showed better performance.MPS did not affect DMI and body weight gain except that of overall 90 days period. Bengochea *et al.* (2005) reported that DMI decreased linearly with finer degree of processing of grains. No interaction of MPS main effects were found for DMI. Interaction for weight gain of heifers occurred only for the1st15 days of experimental period.

Conclusion and Implications

Based on the above findings, it may be concluded that chopped para grass can be the best option for feeding to obtain better performances in terms of dry matter intake and body weight gain of crossbred heifers.

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Support for Survival and Sustenance to the Marginalised People from the Semi Arid Lands of Southern Districts of Tamilnadu, India

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Key words: Wild vegetables, unpalatable grass, medicinal products

Introduction

Wild plants are an important lifeline support to many rural folks in India. At various periods of the year, different plant species provide supplemental earnings that augment incomes and sustain families. In some regions wild areas are used primarily for fodder but plant communities on fallow lands are also used for food, folk medicine, building materials, bund preservation, weaving, fire wood, religious ceremonies, organic fertilizers etc. To improve our understanding of the importance of plant species among rural folks, a few villages in the Virudhunagar, Tirunelveli and Thuthookudi districts of Tamilnadu, India were selected for evaluation. The study assesses how semi-arid land dwellers obtain additional income and sustenance by utilizing specific annual and perennial plant species.

Materials and Methods

A general survey was implemented in 2013 and 2014 among the rural and tribal communities of Virudhunagar, Tirunelveli and Thuthookudi districts of Tamilnadu. Most residents of these communities earn their living by herding livestock, harvesting plants, and developing and selling plant products. Questionnaires were used to obtain information about specific lifestyles within community. Lifestyles varied widely from unskilled nomadic shepherds and fire wood gatherers to skilled craftsmen. Each of these groups utilized plants for different purposes. Based on the data of interviews, the plant species of economic importance were identified and categorized according to their availability at various months during study period.

Results and Discussion

The results showed that many plant species provide sustenance to marginalized people with meager income. Collection time depends on precipitation patterns which in turn influences where and how they grow. The study area receives patchy rains from June to September and sparse rains from October to December. Collection also depends on the part of the plant that is being harvested and its growth stage at the time of harvest. The vast array of wild plant utilization by the various dwellers within the communities is described below.

Fodder is among the main uses of wild plants in the area. Native women utilize species of grasses for their live stock and earn additional income by selling the surplus. Grasses represented by *Dactyloctenium aegyptium, Panicum javanicum, Eleusine indica, Paspalidium flavidum, Digitaria species, Eriochloa polystachya, Chloris barbata, Iseilema anthephoroides* are harvested and sold to the housed cattle keepers in towns during the months between November and March. *Cenchrus ciliaris* is a drought tolerant grass species available among the fallows from August and till the end of February.

Wild culinary fruits are available at various periods of the year and have multiple uses. *Physalis minima* and *Ziziphus jujuba* fruits are collected and sold from March to June; medicinal fruits of *Solanum torvum* and *Solanum virginianum* are collected and used from June to October. Green fruits of *Momordica cymbalaria* and *Solanum nigrum* are harvested and marketed during November to March. Perennial

Cassia auriculata leaves and flowers are collected throughout the season for medicinal use; as are the seeds of *Strychnos potatorum* which are used for clearing water turbidity by flocculation.

Young tender stems of *Cissus quadrangularis* and *Cardiospermum halicacabum* are gathered as medicinal vegetables for small trade from August to December. *Azadirachta indica* seeds are collected and sold to oil extractors during the months of August to October. The oil is used in organic pesticide combinations and ethno medicine. *Gloriosa superba* rhizome is collected during November and December and sold to the plant product exporters.

Some wild plant species are used for food. *Agaricus campestris,* an edible mushroom, is picked and sold a few days after every rain. Edible plant products such as tender jelly seeds and sweet sap are obtained from the Palm tree (*Borassus flabellifer*) for public marketing from April to July of every year.

The *Eragrostis cynosuroides* grass species is considered as sacred and used in traditional Hindu rituals (Williams, 2006). *Eragrostis cynosuroides* and *Cynodon dactylon* is collected and marketed by the rural people from September to December.

Unpalatable grasses like *Phragmites karka, Saccharum spontaneum, Ophiuros exaltatus* and Borasses tree fronds are used for thatching huts and cattle sheds. Other grass species like *Sporobolus tremulus*, *Phragmites karka, Chrysopogon zizanioides* etc., are used as sand binders to avoid erosion in the community ponds and the mud wall slopes of irrigation reservoirs.

Prosopis juliflora is an exotic woody species that exists throughout the semiarid plains and fallow lands and is considered a species of economic importance for many because it is used for fire wood and charcoal production throughout the year.

Beautiful artistic sleeping mats made of *Cyperus pangorei* grass are produced by skilled people. These products receive a geographical indication tag which helps in marketing and exporting them.

The species like *Cymbopogon citratus* and *Chrysopogon zizanioides* used in aromatic oil production available throughout the year in the foot hills of Western Ghats. Lemon grass oil an ethno medicine is produced by the hill tribes from the fresh cut leaves of *Cymbopogon citrates*, and the essential oil is a valuable forest product (Burdock, 1997).

In addition to all of the above, *Calotropis gigantea* biomass is collected for green manure purposes.

Conclusion

The tribal and rural communities of the study area utilize wild plant species in fallow semi-arid lands within their region to supply fodder, fire wood, wild vegetables and medicinal products. The multiple uses of plants other than fodder contribute greatly to the sustenance of people with marginal income by providing additional sources of income.

Because many of the dependant people in the study area are migrating towards cities seeking a better life, a better understanding of the ecosystem upon which these people depend could improve their ability to use plant resources more sustainably and help to solve day to day challenges for survival that they face.

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Can Legumes 'Stem the Tide' of Pasture Rundown?

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Key Words: Pasture rundown, legumes, nitrogen, GRASP, modelling

Introduction

Sown grass pastures in northern Australia are initially highly productive because land renovation during pasture establishment (e.g. land clearing and/or cultivation) generally leads to breakdown of organic matter and thus mineralisation of nitrogen. However, sown pastures generally lose vigour and quality over time. The characteristics of this rundown are variable but can reduce productivity by half and can occur over just a few years to more than 30 years in some cases. Rundown of existing sown pastures is estimated to cost the beef industry in northern Australia some $2B per annum (Peck et al. 2011). This paper examines the potential of legumes to offset the effects of pasture rundown by providing additional N for pasture growth. Results from field data and outputs from a sown pastures version of the GRASP (pasture growth) model (Day et al. 1997, McKeon et al. 2000, and Clewett 2015) are reported. Further details about GRASP are given below.

Materials and Methods

Sown grass and grass legume pastures were established at two sites in south-east Queensland, Australia on undulating basalt derived vertosols previously used for grain/forage crop farming. The first site at Colliery Park (-27.977S, 151.927E) had two treatment paddocks (one planted in 2007 and the other in 2012) with both paddocks under-sown to forage oats using several tropical grasses at 10 kg/ha of coated seed and 1kg/ha of Flaredale lucerne (*Medicago sativa*). The grasses were *Chloris gayana* Cv Fine Cut, *Bothriochloa insculpta* cv Bissett, *Panicum maximum var trichoglume* cv Gatton, *P. coloratum* (Bambatsi panic) and *Digitaria eriantha* cv Premier. The second site at Cattle Camp (-26.788S, 151.468E) had three treatments applied during the 2012-13 summer to an established pasture sown in 2007 with the above grasses and *Dichanthium aristatum* cv Floren. The treatments for Cattle Camp were: (a) control (no treatment), (b) lucerne 'sod seeded' at 3 kg/ha after applying a light rate of glyphosate (0.5 L/ha) to 'freeze' growth of grass pastures, and (c) poultry manure (3.5% N) broadcast at 6 t/ha. Paddocks at both sites were grazed in rotation with other property paddocks for periods of 3 to 14 days. Further site details are given in Clewett (2015). Pasture observations under grazing were recorded in May each year for the period 2013-15 on all paddocks using the Botanal technique (Tothill et al. 1992) to record 50 observations of: pasture total yield, species present and their proportion of total yield, ground cover and percent green. Net primary production and pasture nitrogen uptake were recorded in 10 m x 10m exclosures using the SWIFTSYND methodology (Day et al. 1997).

The above treatments were simulated using a sown pastures version of the GRASP model to estimate impacts of weather conditions, pasture rundown, grazing pressure and management on daily changes in the soil water balance, pasture growth and cattle performance, and annual changes in pasture condition, soil carbon and economic returns. Model parameters were derived from literature and field data e.g. pasture rundown for the experimental sites were estimated to occur over a 10 year period. Lucerne was estimated to persist for 10 years and to contribute 1.5 kg/ha to overall pasture N uptake per 100 kg of lucerne growth. The simulation experiments were 11 periods of 10 years using long-term historical climate data (1894 to 2013) for both field sites with a sown pasture being established at the start of each

10 year period. Grazing pressure was annually adjusted to 25% utilization of pasture growth. This is a sustainable grazing pressure and provided near optimum economic returns.

Results and Discussion

Mean annual pasture growth for all treatments was 3779 kg/ha at Colliery Park and 4017 kg/ha at Cattle Camp. Lucerne was successfully established when under-sown with oats at Colliery Park and by sod seeding into existing sown pasture at Cattle Camp. In both cases the lucerne initially provided 15-20% of pasture yield. Sown pasture production was maximised in the second year of growth and this averaged 5552 kg/ha compared with 3098 kg/ha for native pasture. Corresponding levels of nitrogen uptake were 31 and 17 kg/ha respectively for the sown and native pasture. Compared with native pasture, the initial lift in sown pasture productivity was 79 %. The presence of lucerne was estimated to significantly slow the rate of pasture rundown (see Figure 1) and to also increase cattle production and economic returns. Lucerne was estimated to increase mean annual pasture growth by 710 kg/ha/yr with increases in annual nitrogen uptake ranging from 0 to 9 kg/ha/yr by the pasture. Broadcasting manure had little impact on pastures.

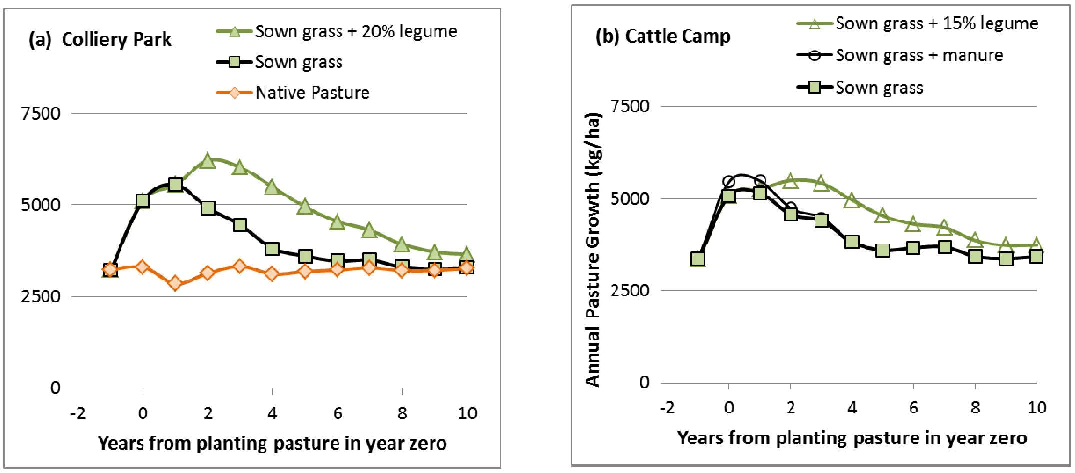

Figure 1. Estimated effects of pasture rundown on mean annual growth (kg/ha) of sown grass and grass/legume pastures compared with existing aged grass only native pasture for: (a) Colliery Park and (b) Cattle Camp. Data shown are the means of eleven simulations of 10 years with GRASP.

Conclusions and Implications

The addition of a legume to grass pastures boosted their productivity above levels achieved by grass only pastures. A more persistent and productive legume, such as the tropically adapted *Stylosanthes* and *Desmanthus* species, might maintain higher production levels than grass only pastures and equilibrate at higher production levels than grass only pastures. Despite the addition of legumes, the rundown process still occurs but legumes may stem that process to maintain higher production levels.

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Possible Rehabilitation Methods of Abandoned Croplands in the Cederberg Mountains, South Africa

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Key words: Indigenous perennial species, soil disturbance, species diversity.

Introduction

Large parts of the Succulent Karoo and Fynbos biome along the west coast of South Africa, including areas in the Cederberg Mountains, were used by farmers for cropping in the previous century in order to be self-sufficient and it provided an income. Taljaard (2008) found that after the government stopped subsidies to the farmers, cropping was no longer a viable option. Farmers therefore stopped planting crops, especially on the marginal lands. This caused large areas of land to lie fallow. Most of these lands are now dominated by mono-stands of the unpalatable, sometimes toxic, pioneer perennial shrub *Galenia africana* (Kraalbos; Allsopp 1999) with seed of desirable perennial species absent in the soil seed bank. These abandoned lands don't contribute to the fodder supply for livestock or wildlife and when rehabilitated they can form corridors between natural areas which are important for the conservation of fragmented landscapes.

The objective of this study was to determine what rehabilitation methods and which indigenous perennial species are the most successful and economically feasible to rehabilitate old lands to a more productive state with a richer diversity.

Material and Methods

Study area

The study was conducted in the Agterpakhuys region of the Cederberg Mountains on an old cropping land that was abandoned in 1992 and is now dominated by *Galenia africana*. It is situated in the Cederberg Sandstone Fynbos on the border with Doringrivier Quartzite Karoo (Mucina and Rutherford 2006). The area has an average annual rainfall of 196 mm, falling mostly in winter. The soils are sandy with a pH of 5.4 and an organic carbon content of 0.23%

Treatments

A complete randomised block design was followed with eight (8) treatments and four (4) replicates. Each plot size was 10x10 m. The treatments were applied in May 2012 at the start of the rain season. The treatments were: seeding only (S), spade and seeding (SS), ripping and seeding (RpS), ploughing and seeding (PS), brush-cutting and seeding (BS), rolling and seeding (RS) and herbicide and seeding (HS). Species for re-seeding was: Grasses *Chaetobromus involucratus* subsp. *dregeanus* and *Ehrharta calycina* and dwarf shrubs *Manochlamys albicans*, *Tetragonia fruticosa* and *Tripteris sinuata*. The density of the re-seeded species and other perennial species were determined each year during October at the end of the rain season. The cost of each treatment was also determined. Analysis of variance (ANOVA) was performed on the data using PROC GLM procedure of SAS software Version 9.3 of the SAS System for Windows (SAS Institute, 2015).

Results and Discussion

In 2012 the perennial species increased due to good germination by the re-seeded species, especially *T. sinuata* but these died back due to the dry summer of 2012/13. By 2014 less than 1% of the seeds that were sown in 2012 survived. Of the species sown, the grasses *C. involucratus* subsp. *dregeanus* and *E. calycina* did significantly better than the shrubs species (F = 4.74; p = 0.0016), with *T. sinuata* having the highest rate of establishment. It is necessary to supply seed of desirable perennial species as they are absent in the soil seed bank and dispersal from the adjacent natural areas is very slow. The species richness increased from four (4) perennial species encountered before the treatments were applied to 12 different perennial species found in 2014. The numbers of *G. africana* increased in 2013 after good winter rains in the undisturbed plots and their numbers remained high because of good summer rainfall. The plant density of the re-seeded species was significantly better in the ploughing and seeding (PS) and rolling and seeding (RS) treatments (F = 2.99; p = 0.0242) by 2014 and they had the highest species diversity. Ploughing is however a very drastic soil disturbance and we will not recommend it. These two treatments are also the most cost effective treatments with the cost of PS = R1.55/plant established and RS = R1.82/plant established. The costs were calculated with the assumption that the implements are available on the farm.

Conclusion and Implications

Data for this study was severely limited by poor seedling establishment but we may deduce that soil disturbance is necessary for re-seeded species to establish and rolling with a knife roller may be the most practical method. However, additional work may be required to verify this finding. Re-seeding is necessary to supply seed to the soil seed bank and *C. involucratus* subsp. *dregeanus, E. calycina* and *T. sinuata* are recommended. Due to these actions the species diversity of the study area increased with more palatable perennial species present making more fodder available for animals. Rainfall is however the limiting factor. Because this may be a common scenario in this region it may be necessary to assess site conditions and seedling establishment after the initial seeding to determine if reseeding should be considered at the onset of the next rainy season.

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Stratification Needs of *Hierchloe odorata*

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Key words: Stratification, *Hierchloe odorata*, emergence

Introduction

Re-establishment of indigenous plants requires knowledge of the needs of the individual species. Species dependent germination requirements are common among non-commercialized species (Wagner et al. 2011) and may be implicated in the failure to establish of indigenous plant species used in experiments (e.g. Picasso et al. 2008). *Hierchloe odorata* (sweetgrass) is of interest due to its importance in both cultural (Boe and Bortnem 1998) and reclamation aspects of rangelands (Shebitz and Kimmerer 2005). Low viability, germination and emergence values have been reported for this species (van Leeuwen et al. 2014) resulting in vegetative propagation techniques being employed for establishment (Boe and Bortnem 1998; Shebitz and Kimmerer 2005). Germination requirements have not been reported for *H. odorata*, however anecdotal evidence suggests a vernalization requirement (John Morgan, personal communication). The object of this study was to examine the need for a pre-germination treatment for enhanced seedling emergence.

Methods and Materials

Seed was collected near Winnipeg, Manitoba (N49:85523, W97.32325) in 2011. Seed was hand threshed and stored at room temperature (20-22°C). In December of 2102, 2013, 2014, 2015 and 2016, 12 or 16 (2015) groups of 25 seeds were counted. One half were assigned to a control group, maintained at room temperature, the second half assigned to a vernalization treatment. The vernalization treatment consisted of 6 to 8 replicates of 25 seeds each, soaked in distilled water on filter paper in 90 cm plastic petri dishes and placed into a dark, 4°C chamber for two weeks. After the two weeks (in January), all seeds were planted at 0.5 cm in 20 cm pots filled with a soiless commercial potting mix (Metromix). Pots were placed in the greenhouse with 20/15°C day/night temperatures and a 16 hour daylength. Emergence counts were made over the following 18 days after seeding (DAS). Data was analyzed with SAS proc glimmix for treatment comparisons and mean treatment data was used in SigmaPlot 10 for emergence curve development and through proc nlin in SAS.

Results and Discussion

Emergence in January 2012 was negligible for both treatments with a total of seven seedlings of the 300 seeds planted emerging, all in the vernalized treatment. In January 2014, seeds in the vernalization treatment had visible fungal growth and resulted in reduced emergence (<8%) and the data is not presented herein. Emergence for the 2014 non-stratified materials was 9% at 18 DAS.

For 2013, 2015 and 2016, vernalized seed emerged four days before the control (data not shown). Significant treatment differences were not seen until 10, 9 and 8 DAS for 2013, 2015 and 2016, respectively (data not shown). Days to 50% emergence decreased with increasing years from harvest, with the stratified treatment reaching 50% emergence at least two days earlier in each year (Table 1). Stratification resulted in a 30-44% emergence at 18 DAS for the three years reported, and the control ranged from 2.7 to 10.7 % emergence (Table 1) similar to reported values (van Leeuwen et al. 2014).

Table 1. Within year mean comparisons for days to 50% emergence and total emergence at 18 days after seeding in sweetgrass for the control and stratified treatments for 2013, 2014 and 2015.

	days to 50% emergence		total emergence (18 das)	
Year	control	stratified	control	stratified
2013	17.4 a*	14.8 b	2.7 b*	31.3 a
2015	15.7 a*	12.9 b	11.0 b*	41.5 a
2016	13.0 a*	10.8 b	11.3 b*	44.0 a

*Means between rows and within Emergence category are significantly different at P=0.05.

A sigmoidal curve was found to fit all of the data except the control treatment for 2013. This may be due to emergence occurring only at the end of the observation period with the 50% emergence time being at 17.4 days (Table 1). Emergence curve equations can be found in Table 2. The 2013 equation for stratified treatment may be due to a prolonged, continued small increase in emergence on the upper portion of the curve, giving different slopes to either ends of the sigmoidal curve. While the asymptote values were similar between years for both the control and stratified treatments, the slope values were approximately 50% lower in 2016 compared to 2015 for both the control and stratified treatments, indicating a shift, or a shorter duration of emergence. All equations had high adjusted R^2, indicating a good fit to the data.

Table 2. Regression equations (sigmoidal) for 2013, 2015 and 2016 year x treatment emergence curves, where; f = emergence and x = days after seeding.

Year x treatment	Equation	a	b	xø	yø	Adj R^2
2013 stratified	f=y0+a*exp(-exp(-(x-x0)/b))	-30.868**	-1.615	11.383**	30.711**	.997
2015 control	f= a/(1+exp(-(x-x0)/b))	11.455**	2.033**	12.906**	-	.987
2015 stratified	f= a/(1+exp(-(x-x0)/b))	40.700**	1.803**	8.554**	-	.994
2016 control	f= a/(1+exp(-(x-x0)/b))	10.944**	1.172**	9.753**	-	.953
2016 stratified	f= a/(1+exp(-(x-x0)/b))	43.346**	0.822**	8.400**	-	.984

** indicates a p value < 0.01.

Seed was harvested in 2011 and seedling emergence experiments began approximately six months after seed harvest. Through four years of testing, stratification treatment resulted in significantly higher and more rapid emergence in all years, except where seed was impacted by fungal growth on the seed in 2014. Seed stored at room temperature appears to have retained its emergence potential for four and a half years after harvest. However, as total viability of the seed source was not measured, overall retention or loss of seed viability over time cannot be commented upon. Stratification enhances emergence in sweetgrass. Aging of seed did not appear to increase emergence percentage, however it appeared to reduce the period to full emergence. A seed treatment may be used to limit seed decay under stratification conditions.

Conclusions and Implications

Current establishment of *H. odorata* relies on vegetative propagation. Establishment potential from seed was enhanced 3-4x by a cold stratification treatment. Care is advised as emergence may be hampered by disease under the stratification conditions (results for 2014). If using seed propagation in the field, seed will either require pre-treatment prior to seeding or will need to be dormant seeded in the fall to enhance the emergence potential the following growing season. These considerations will be of greater importance if seeded in mixtures as individual species requirements may vary.

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The Effect of Film Coating on Sideoats Grama (*Bouteloua curtipendula)*

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Key words: Film coating, seed treatment, germination, sideoats grama

Introduction

Sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] is a warm-season, perennial grass. Ease of establishment, good seedling vigor, and drought tolerance are recognized attributes. Sideoats grama is considered a good quality winter and summer forage for livestock and wildlife and their seeds are eaten by upland birds (Larson and Johnson, 1999). Sideoats grama grows under a wide variety of climatic conditions and their seedlings are more drought tolerant than many other warm-season grasses, although if seedlings are not well established they can be killed by a short drought period (Bridges, 1942). Some stem and leaf rust occurs in wet years and Mankin (1969) detailed several leaf tar spot, root rot fungi and rust disease occurred on Sideoats and blue grama. Pests and diseases, especially soil and seed borne diseases, are limiting factors of Sideoats grama production and utilization. Seedling diseases could be controlled and pasture establishment could be improved effectively by seed coating with fungicide. With seed coating technology, insecticides and fungicides can be incorporated with the seed (Wynia, 2007). Seed treatment pesticides can be applied to the seed using film coating that is applied around the seed to completely seal in the pesticide and reduced dust for worker and farmer safety, which is a major impetus of using film coating (Taylor *et al.*, 1998). The objectives of this research were to determine the effect of a slurry and film coating on germination percentage and uniformity, germination rate (T_{50}) and seedling growth of Sideoats grama.

Materials and Methods

A seed lot of Sideoats grama 'Butte' was provided by ERNST Seeds in PA, USA. Disco (Incotec, Salinas, CA) and Red-dye (Bayer CropSciences, Research Triangle Park, NC) were used mixed with distilled water in an aqueous suspension. The coating procedure employs a rotary seed treater wherein the seed is tumbled while the coating material is added thereon (Fig. 1). Germination tests were conducted in alternating temperatures of 20-30 °C. A completely randomized design with four replicates was used and replicates (50-seed samples/on top of two layers of blue blotter paper moistened by adding 5 ml of 0.2% KNO_3 solution) were placed into a germinator. Germination counts were made twice a day for 10 days. Seeds with a radicle greater than 2 mm were considered germinated (Cole *et al.*, 1973).

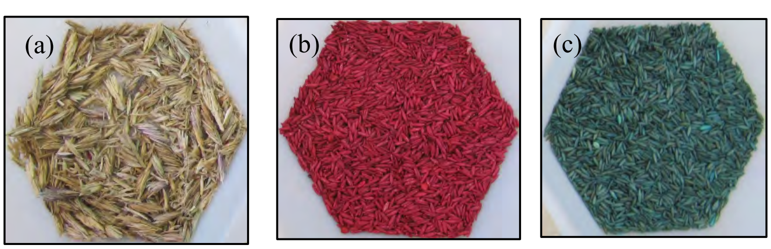

Figure 1. Representation of Sideoats seeds (a) non-treated, (b) slurry of Red-dye and (c) film coating with Disco, respectively.

Results and Discussion

The mean values of the different treatments were separated by LSD test for all germination characteristics and seedling measurement. Data on germination percentages were subjected to arcsine transformation for statistical analysis and no significant differences were measured. Germination percentages were 98%, 97% & 96% for non-treated, treated with Disco and Red-dye, respectively. Coated seeds of Sideoats grama had higher germination rate and germinated more uniformly than non-treated seeds. Both coatings significantly reduced T_{50} (16.5 hours), as compared with the control (19 hours) (Fig. 2a). Treatments were not statistically different on the shoot and root length according to ANOVA analysis (P. Value > 0.05) (Fig. 2b & Fig. 3).

Conclusion and Implication

This study demonstrated that seed coating of Sideoats grama grass had no negative effect on total germination percentage but had faster and more uniform germination compared with non-treated seeds. Burns *et al.* (2002) reported that coated seeds of Bermuda grass because of improved seed-soil contact showed better and faster germination and growth. Nutrients and fungicides may be coated onto seeds with this precise method that will helps manage seedling disease, and enhances seedling health.

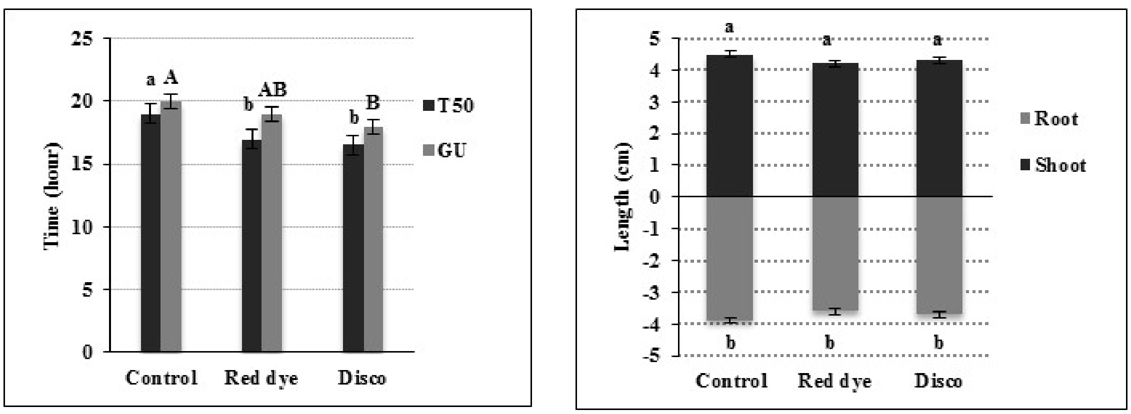

Figure 2. Effect of film coating on (a) T_{50}, germination uniformity (GU) and (b) shoot and root length of Sideoats grama.

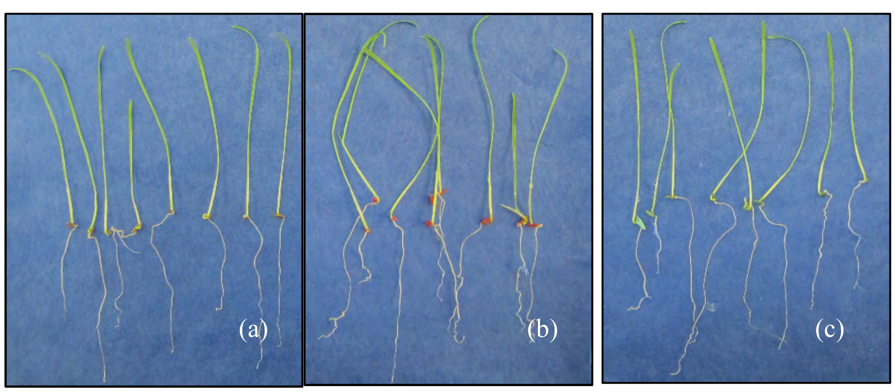

Figure 3. Representation of Sideoats seedlings (a) non-treated, (b) & (c) Film coated with Red-dye and Disco, respectively.

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Dry Matter Production and Water Use of Winter Wheat/Forage Catch Crop Rotation Systems in the Loess Plateau, China

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Key words: catch crop, rotation, dry matter production, water use efficiency

Introduction

Continuous cropping of winter wheat is the conventional crop planting pattern in the Loess Plateau, China, which results in soil erosion and low precipitation use efficiency (Liao *et al*., 2002). Using catch crop with rotation system has been proven to be an efficient way to improve precipitation use efficiency and dry matter (DM) production. In the Eastern part of Gansu, China, grain production of catch crop is usually limited by weaker solar radiation in autumn; however, forage crops have better adoption to local climatic condition. Forage rapeseed (*Brassica campestris*) and common vetch (*Vicia sativa*) have been introduced into winter wheat/catch crop rotation systems recently (Liu *et al*., 2015). However, only few studies investigate dry matter production and water use efficiency (WUE) of these systems. The objective of this study was to compare WUE and dry matter production among different cropping systems to determine an optimal cropping system.

Materials & Methods

Location and experimental design

The experiment was conducted at Qingyang Loess Plateau Experimental Research Station of Lanzhou University (107°51′E, 35°39′N). We designed four treatments: fallow-winter wheat-vetch-winter wheat (FWVW), fallow-winter wheat-forage rapeseed-winter wheat (FWRW), forage rapeseed-winter wheat-vetch-winter wheat (RWVW) and forage rapeseed-winter wheat-forage rapeseed-winter wheat (RWRW). The experiment was established after winter wheat was harvested in July 2011. The plots for FWVW and FWRW were planted with winter wheat in late September 2011 after about three months fallowing, and those for RWVW and RWRW were planted with forage rapeseed and followed by winter wheat. After winter wheat was harvested in July 2012, plots for FWVW and RWVW were planted with vetch and those for FWRW and RWRW were planted with forage rapeseed. All plots were planted with winter wheat again in late September 2012.

Sampling

Forage rapeseed and vetch were cut at ground level at flowering stage in September 2011 and 2012 and dried at 65°C for 48 h to determine aboveground dry matter. Winter wheat was cut at ground level at maturation stage in 2011 and 2012 to determine aboveground dry matter accumulation and grain yield. Soil samples at 0-10, 10-20, 20-30, 30-60, 60-90, 90-120, 120-150 and 150-200 cm depths were taken in each plot and then dried at 105°C for 10 h to determine water content. Seasonal crop evapotranspiration (ET) was determined for each growing season using the soil water balance method and water use efficiency (WUE) was expressed as yield per unit of ET.

Results & Discussion

Dry matter production under different rotation

Forage rapeseed produced 4.78 t ha^{-1} DM, the grain yield of winter wheat after forage rapeseed in 2012 was a bit higher than that after fallow. A significant difference of DM production was found in two catch crops; consequently, the yield of winter wheat was affected by the catch crop. The total dry matter under RWRW rotation system was the highest among the four rotation patterns and catch crop increased DM production by 28% compared with summer fallow rotation systems.

Table 1: Dry matter production from different winter wheat-forage catch cropping rotation systems (t ha^{-1}).

Cropping system	2011	2012	2012	2012	2013	2013	Total DM
	Forage	Winter wheat grain	Winter wheat stubble	Forage	Winter wheat grain	Winter wheat stubble	
FWVW	—	5.5±0.7	8. 3±0.3	0.99±0.03	2. 6±0.9	4.39±1.52	21.66±2.79
FWRW	—	5.45±0.72	8.27±0.33	5.53±0.46	1.81±0.15	3.11±0.36	24.17±1.17
RWVW	4.78±1.53	5.67±0.52	9.47±1.53	1.27±0.30	2.40±0.38	4.24±0.81	27.83±1.88
RWRW	4.78±1.53	5.67±0.52	9.47±1.53	5.7±0.85	1.84±0.16	3.21±0.44	30.68±1.42
LSD (P=0.05)	—	1.09	1.92	0.78	0.75	1.40	2.96

Water use efficiency under different rotation

Table 2 shows that the water use efficiency of winter wheat grain and stubble had no difference among cropping rotations in 2012. However, the water use efficiency of forage rapeseed was significantly higher than that of the vetch. Overall, the water use efficiency under RWRW rotation system is the highest, indicating that forage rapeseed increased the water use efficiency.

Table 2: Water use efficiency of winter wheat/forage catch crop rotation systems (kg mm^{-1} ha^{-1}).

Cropping system	2011	2012	2012	2012	2013	2013	Total WUE_{DM}
	Forage	Winter wheat grain	Winter wheat stubble	Forage	Winter wheat grain	Winter wheat stubble	
FWVW	—	6.06±0.80	9.20±0.37	3.54±0.12	4.73±1.59	8.12±2.81	6.72±0.88
FWRW	—	6.06±0.80	9.20±0.37	18.57±1.56	3.41±0.29	5.87±0.68	6.81±0.35
RWVW	28.04±8.98	6.10±0.56	10.20±1.65	4.61±1.09	4.29±0.67	7.56±1.44	7.80±0.56
RWRW	28.04±8.98	6.10±0.56	10.20±1.65	20.65±3.05	3.32±0.29	5.80±0.79	7.80±0.43
LSD (P=0.05)	—	1.20	2.07	2.77	1.37	2.56	0.91

Conclusion

We concluded that catch crop may increase DM production by 28% compared with summer fallow rotation systems. Forage rapeseed may exhaust soil water content, which could significantly affect the winter wheat yield when low rainfall occurs in fall. However, incorporating it as a forage crop could enhance the yield of rotation system by producing higher forage yield. The RWRW rotation system had the greatest dry matter production and water use efficiency.

Acknowledgement

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Forage Production and Quality of Summer Sown Forage Crop after Spring Wheat in the Loess Plateau, China

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Key words: forage, dry matter, crude protein, Loess Plateau

Introduction

Crop rotation is strongly recommended in arid and semi-arid regions to avoid the risk of crop failure and increase production per unit area and land available for crop production (Wei *et al*., 2014). Meanwhile, the historical crop monoculture and over-cultivation of farmland resources have resulted in severe environmental deterioration and soil fertility degradation in the Loess Plateau (Wang *et al*., 2015; Rezig *et al*., 2013). The aim of this research was to assess the forage production and nutrients content of eight summer sown pastures after spring wheat.

Material and Methods

Location and experimental design

A field experiment was conducted at Qingyang Loess Plateau Experimental Station of Lanzhou University (107°51′E, 35°39′N). Eight annual forage crops: sudan grass (*Sorghum sudanens* L.), millet (*Panicum miliaceum* L.), small millet (*Setaria italic* L.), soybean (*Glycine max* L.), pea (*Pisum sativum* L.), vetch (*Vicia sativa* L.), spring wheat (T*riticum aestivum* L.), and oat (*Avena sativa* L.) were established in 5 m × 6 m plots in a randomized complete block design with 4 replications, crops were sown on July 21, 2014. Sudan grass was sown with 40 cm spacing while all other species were sown on 20 cm row spacing. All species were sown at 30 mm depth, except for millet which was sown at 20 mm depth. All species were fertilized with 450 kg P_2O_5 (200 kg P), grass species were applied with 225 kg urea ha^{-1} (104 kg N ha^{-1}) and legumes with 75 kg urea ha^{-1} (35 kg N ha^{-1}) at sowing. The preceding crop of spring wheat was sown on April 8, 2014 and harvested on July 9, 2014.

Field and Laboratory

After emergence, three 0.5 m lengths of adjacent crop rows were cut at ground level at 2 random locations within each plot and bulked at three weeks interval. Samples were partitioned into leaf, stem and reproductive components and dried at 80°C for 48 h, the dry weight was measured. Leaf area index (LAI) was measured by LAI-2000 in each plot. Plant total nitrogen content is determined by Kjeldahl determination, converted into crude protein (CP) content. Data were subjected to analysis of variance (ANOVA) using the GenStat 17th statistical software. Means values of different treatments were separated by the least significant difference (LSD) test at the 0.05 probability level ($P = 0.05$).

Results

The dry matter yield of forage increased substantially from jointing to flowering, and then decreased slightly until maturity except for millet, pea and vetch (Fig.1). Sudan grass, millet, small millet, spring wheat and oats produced the greatest ($P < 0.05$) dry matter yields (Fig. 1) and protein at the flowering stage but peas yielded the most ($P < 0.05$) protein at maturity (Table 1). Spring wheat, sudan grass, oat and soybeans had relatively greater production and better nutritional quality, and thus these crops can be used as the alternative feed crop after spring wheat in the Loess Plateau, China.

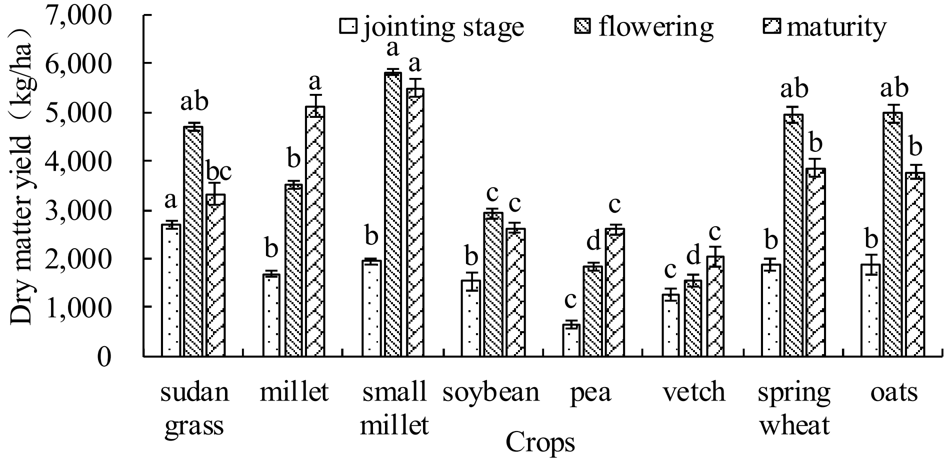

Figure 1. Dry matter yield of forage crops under different rotation.

Table 1. The TNC (mg/g) and yield of protein content of studied forage crops.

Crops	Flowering		Milk-maturity	
	TN (mg/g)	yield of protein (kg/ha)	TN (mg/g)	yield of protein (kg/ha)
sudan grass	43.55 ab	1279.02 a	33.94 c	487.46 bc
millet	37.56 c	966.16 bc	21.32 e f	616.02 b
small millet	35.44 cd	1181.54 ab	23.01 e	503.50 bc
soybean	37.95 c	694.10 cd	28.44 d	588.77 bc
pea	47.55 a	523.2b c	45.42 a	892.36 a
vetch	39.18 cd	360.84 e	36.90 b	594.24 bc
spring wheat	31.66 d	978.22 bc	14.94 g	362.98 bc
oats	39.11 bc	1218.88 ab	18.13 g	345.81 c

Note: Means followed by the same letter are not significantly different using LSD at P=0.05

Acknowledgement

This work was supported by the Special Program of Key Research in Science and Technology of Gansu Province, China (1203FKDAO35), and Key Grant Project of the Chinese Ministry of Education (313028).

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Vegetation Patterns of Different Managements in Natural Grasslands of Pampa Biome

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Key words: disturbance, grazing, Southern Campos

Introduction

The Pampa vegetation, in Rio Grande do Sul state has approximately 450 grasses and 150 legumes BOLDRINI, 2002) and is an important habitat for biodiversity. It also provides free forages to livestock. In this context, for sustainable grazing management to be effective, it is necessary to establish an *equilibrium* between preservation of diversity and forage production (OVERBECK, 2007). Thus, further studies are needed concerning the grazing effects on Pampa's plant communities and how plants response to it. These interactions are essential to understand the patterns of vegetation according to grazing regime adopted.

Thus, this research aimed to identify the vegetation patterns of natural grasslands of Pampa biome under different grazing managements.

Material and Methods

The experiment was conducted in a natural grassland of Pampa biome located at Bagé city (31° 18' S, 53° 57' W) in Rio Grande do Sul state. The area is situated in a transition zone between the Southern Campaign and Southeast Hills and the climate is Cfb, temperate humid, according to Köpen classification with the historical average rainfall, of last 30 years, of 1446.2 mm and average temperatures of 18.7 ºC (INMET, 2015). The area has no history of agricultural mechanization and, during the last 40 years, it was managed extensively with cattle and sheep herds at low stocking rates (< 0.5 animal unit ha^{-1}).

In June 2012, the experimental area was completely excluded from grazing of large herbivores and it was subdivided in two management regimes: grazed (GRAZ) and ungrazed (UNGRAZ). The Brangus heifers' entrance in GRAZ occurred in February 2013.

The vegetation was preferentially sampled, comprising of variations in sunlight exposure, relief, soil and drainage. Fifty transects with 1.25 m² of area were demarcated (40 in GRAZ and 10 in UNGRAZ). It was used the Londo-scale (LONDO, 1976) modified to estimate the cover class of each vascular plant species. The vegetation survey was carried out from December 2014 to February 2015.

The relative cover data of species *per* transect was submitted to ordination by principal coordinates analysis (PCoA), based on chord distance between transects, in 'vegan' package of R software (Oksanen et al., 2016; R Development Core Team 2015).

Results and Discussion

The first and second axes of PCoA analysis explained 22.90 % and 17.82 % of the total variation respectively. It was possible to observe a defined vegetation pattern only in UNGRAZ management that was positioned along the positive portion of second axis. In GRAZ management, it was not possible to distinguish a pattern.

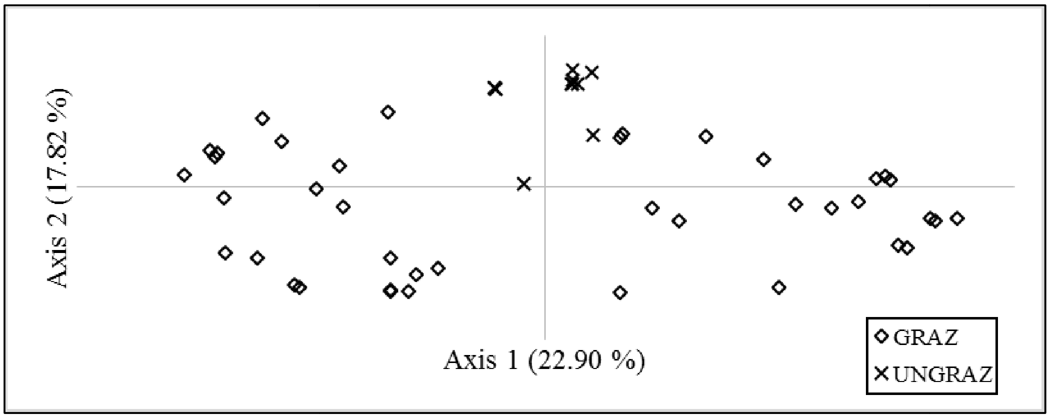

Figure 1. Plant communities' ordination diagram of grazed (GRAZ) and ungrazed (UNGRAZ) managements.

In UNGRAZ management, determinant factor to dominance is light capture followed by plants that have taller vertical size. Great efficacy in light capture became dominant while short-plants size are subdued to shading. The latter disfavors the full maintenance of the vital activities of these, causing disappearance of some plant species. Therefore, in our UNGRAZ management, spatial occupation is done by few species (e.g. *Acanthostyles buniifolius*, *Anthaenantia lanata* and *Saccharum angustifolium*) and it decreases communities' heterogeneity revealing a distribution pattern in them.

Grazing effects (e.g. defoliation, trampling) reduces the mean height of vegetation's canopy allowing capture of light for higher number of plant species than in UNGRAZ management. Concomitantly, there is the effect of grazers' preference for some plant species that influence in spatial distribution of species. Both factors play an important role in vegetation, changing the dominance of species along the GRAZ area and increasing the heterogeneity of it. As consequence, plant communities of GRAZ management do not have a defined pattern of distribution.

Conclusions and Implications

Plant communities of Pampa biome responds rapidly to grazing disturbances. The comprehension of interaction between plant and grazer is the core for development of managements that aim the sustainable use of natural ecosystems.

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4.4 Invasive Species Impacts and Management in Rangelands

When Tame Species Go Wild: Plant Biodiversity Loss Associated with *Bromus inermis* Encroachment in Unseeded Grasslands

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Key words: Plant invasion, biodiversity, agronomic species, multi-site comparison, off-ranch effects

Introduction

Globally, planted pasture species represent a source of potentially invasive plant species, able to disperse and colonize surrounding unplanted areas (Driscoll et al 2014). Throughout much of Canada's rangelands, smooth brome, *Bromus inermis*, is both a planted forage species and an aggressive invader of unseeded rangelands, natural areas, and disturbed sites (Otfinowski et al. 2007). Though brome is well known to have spread into unseeded rangelands in Alberta, and its local dominance is associated with decreased plant diversity (Bennet et al 2014), lacking has been a broad synthetic survey integrating brome invasion, diversity impacts, and abiotic drivers. Due to the delicate balance between ecological risk and economic value of this species, it is essential that there is a clear understanding of the ecological mechanisms driving invasion and its impacts. Such an approach is critical to allowing stakeholders to develop science-based risk-mitigation strategies.

To facilitate this understanding, study investigators have developed a general conceptual model (Fig. 1) that identifies putative causal factors that can influence both the rate of growth of smooth brome within an unplanted grassland, as well as its impacts on the resident plant species. This paper presents findings from a broad survey across diverse rangelands in Alberta, using these data to test aspects of the model.

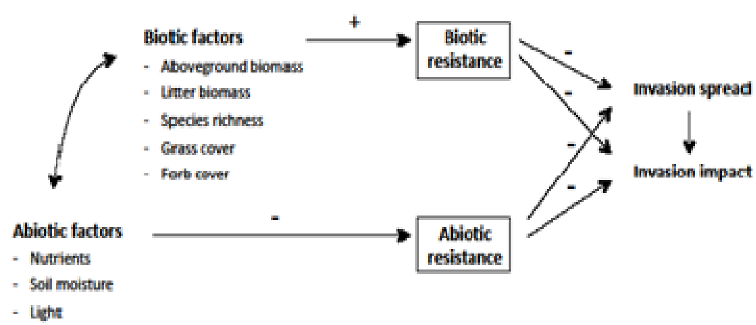

Figure 1. Conceptual Model

Materials and Methods

In 2012, investigators established up to 20 4m transects in each of eight research sites distributed across the shortgrass prairie and Aspen parkland ecoregions of Alberta. Each transect was oriented perpendicular to the edge of a local brome patch, such that 2m from the center point in one direction was a brome-dominated patch and 2m in the other direction was a "native" grassland (though may still contain low densities of brome). By comparing plant and abiotic factors at opposite ends of the gradient, investigators were able to infer differences associated with brome invasion, while minimizing spatial confounds. Longitudinal data indicates the edges of brome patches were not due to preexisting differences in the native community, and instead represent the growing front of a brome patch. Grazing did not occur on our transects during this study (2012-2014).

Along each transect, the abundance and diversity of vascular plant species, soil fertility (using PRS probes in three sites), and plant biomass (living and litter) was measured over three years. Though here only the initial year's data is presented, the longitudinal survey information data allows us to measure the rate of invasion spread of already established brome patches. For each site, precipitation data and growing degree days information from available databases was gathered. The diverse data were used to test specific predictions regarding the causal links among variables, as shown in Fig. 1.

Results and Discussion

The eight sites varied greatly in annual precipitation (range 246-423 mm/yr) and all other measured characteristics (productivity, brome density within brome-dominated' patches, growing degree days, species richness, etc.), supporting the use of these data to test aspects of our model.

The sites with the highest species richness in the native grassland areas were also the sites in which brome exhibited the lowest local dominance (brome biomass/total biomass in a brome-dominated patch) within brome-dominated patches. This finding is consistent with aspects of biotic resistance, where local diversity appears to reduce invasive plant performance.

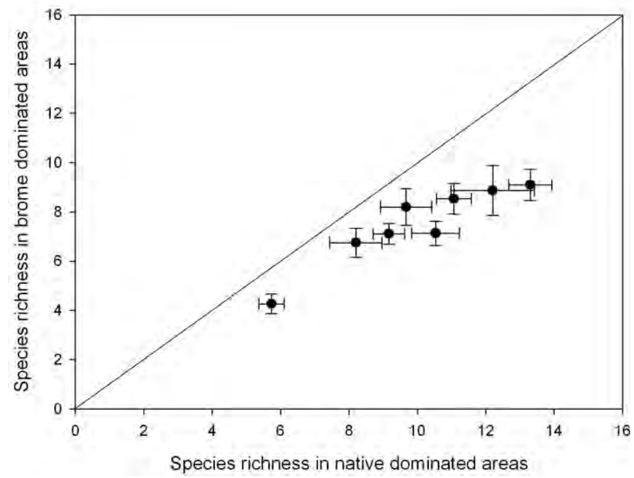

Figure 2.

However, high-diversity sites were also those where plant species richness was most severely suppressed in brome-dominated patches relative to the nearby native grasslands. Investigators found that the suppressive effects of brome on resident plant diversity increased non-linearly with site-level diversity (Fig. 2). Thus, though brome suppresses plant diversity in all locations where it is established, its effect on local diversity is greatest in the more diverse sites. Neither precipitation nor growing degree days were associated with either the suppressive effect of brome on resident plant diversity or brome densities within a brome-dominated patch.

Brome's suppressive effects appear to apply equally to both native and non-native resident species, as indicated by a lack of shift in native fraction of species in brome dominated patches relative to nearby native communities. This suggests that brome acts as a generalist competitor, likely through a combination of both resource consumption and litter production. This finding is consistent with prior work showing brome disproportionately impacts common species within a community, regardless of the phylogenetic origin of the resident species (Bennett et al 2013).

The use of PRS probes in three sites resulted in an unexpected finding: available lead levels in the soil were higher in brome-dominated patches relative to nearby native grasslands. Study investigators have not identified the mechanisms or ramifications of this effect, but suggest it warrants further study.

Conclusions and Implications

Across a broad geographic extent, brome invasion was consistently negatively associated with resident plant diversity. This finding highlights a need to take off-ranch impacts of this planted pasture species into consideration when assessing the biodiversity consequences of on-ranch management activities. Further, that more diverse grasslands appear to most strongly limit local brome dominance while are also most severely impacted by brome invasion is surprising, and indicates the need for a better mechanistic understanding of how species interact in rangelands.

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Spray it, Wipe it, Eat it — Demonstration of Different Noxious Weed Control Options on Saskatchewan Rangelands

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Key words: Noxious weeds, wiping, goat browsing, common tansy, absinth

Introduction

Noxious weeds decrease quality forage and land market value while impacting the ecological functions of rangelands and pastures. Absinth wormwood (*Artemisia absinthium*) is a long-lived perennial herbaceous plant with a woody base. Individual plants grow 40 to 100 cm tall. Common tansy (*Tanacetum vulgare*) is a perennial herbaceous plant with an extensive root system. Individual plants grow 40 to 100 cm tall. The Saskatchewan Weed Control Act (The Weed Control Act, 2010) lists both absinth and common tansy as noxious weeds. In Saskatchewan, noxious weed infestations must be prevented from expansion if the infestation is greater than 5 hectare (12.5 acre) or eradicated if the infestation is less than 5 hectares in size. Once established, absinth and tansy are very difficult to eradicate and will take over forage stands, reducing both forage quality and quantity. Cattle do no graze either plant by choice. Both weeds contain alkaloids with varying degrees of toxicity to both humans and livestock. Dairy cattle consuming absinth on pasture or in hay produce tainted milk. Wildlife habitat of the range is degraded as species diversity decreases and weed thickets increase. Registered herbicides that control either species also remove any desirable broadleaf species. Despite ongoing research, no biological controls for use on absinth or common tansy have been released in Canada.

Three demonstration projects were undertaken in the period of 2011 to 2015 to increase awareness of noxious weed control options on Saskatchewan rangelands: 1) Broadcast spraying of six herbicides to control absinth in mixed tame forage stands, 2) Wiping of absinth and common tansy with a concentrated solution of glyphosate herbicide, and 3) Goat browsing of common tansy.

Materials and Methods

The broadcast spraying involved four separate Saskatchewan sites with tame pastures or hay fields containing a proportion of a legume such as alfalfa, sainfoin or cicer milkvetch. Herbicide treatments included: (1) an unsprayed control, (2) 2,4-D LV Ester (700 g/L) as a chemical of lower cost but less long-term effectiveness; (3) Banvell II as an option which may provide only limited long-term effectiveness; (4) Restore II, (5) Reclaim, and (6) Grazon as higher priced rangeland products with differing residual effects; and (7) Rejuvra XL as a new product comparison. The plot sizes for each herbicide treatment at each site varied from 0.006 to 0.5 ha (0.015 to 1.3 acre). A single herbicide application during the period of active plant growth (late June to early July 2012) was used to allow for comparison of residual effects and longer-term effectiveness of each product. Canopy cover estimates were taken at one, three, and twelve months following spraying. Observations were compared against pre-treatment measurements and the untreated (unsprayed) control.

The wiping trial tested two types of wiper equipment at three separate Saskatchewan sites. The first weed wiper consisted of a large PVC pipe which is filled with herbicide mix. Wick ropes threaded in and out of the PVC pipe are saturated with herbicide solution and wipe the herbicide onto the target plants. The second applicator was a Rotowiper® which uses a steel rotating drum covered with a specialized synthetic carpet-like material. The carpet is wetted through spray nozzles inside the drum. The synthetic carpet holds the chemical until it comes in contact with the weeds. Glyphosate herbicide, currently the only herbicide registered for wiping application on common tansy and absinth, was used in both equipment types and applied at the recommended wiping rate. Plot size varied based on weed distribution patterns. Where possible, pastures were grazed immediately prior to wiping to create a sword height separation between target weeds and desirable forage. Wiping was completed in early July 2015 and coincided with peak vegetative growth or bolting of the target weeds.

The goat browsing trial was implemented in eight paddocks approximately 900m^2 each, on a pasture near Pathlow, Saskatchewan. A goat herd of 125 goats were browsing on site for an average of 8 days each during the summer of 2014 and 2015. The animals were herded daily to and from the paddocks to a night corral. A herder, one herding dog, and one guard dog always accompanied the group. Tansy samples were sent for forage analysis during the growing season of 2014. A pre- and post-treatment vegetation inventory based on percent plant cover was completed during both years of the trial.

Results and Discussion

Broadcast herbicide application may control absinth but comes at the expense of losing desirable legumes (Table 1). Based on their increasing effectiveness in controlling absinth, herbicides were ranked as follows: 2,4-D < Banvel II < Rejuvra XL < Grazon < Restore II < Reclaim. However, economical considerations related to herbicide cost, herbicide rate, and number of required applications are all important considerations. Based on cost per acre at the time of the trial period, the herbicides (excluding Rejuvra XL as the product had not been released for sale) can be ranked as follows: 2,4-D ($9.04/acre) < Restore II ($33.60/acre) < Reclaim ($42.50/acre) < Grazon ($48.16/acre) < Banvel II ($65.00). Note that currently only 2,4-D, Banvel II and Restore II are registered for suppressing or controlling absinth. Effective herbicide treatments will also kill or injure the desired legume component.

The Rotowiper® achieved an average of 80% effectiveness of weed kill while the wick applicator only produced an average of 20% effectiveness. Plant height reduction of the desirable vegetation prior to wiping was critical in isolating herbicide application to target plants. Where no measures to reduce sward height were taken, desirable vegetation was affected equaly to target weeds killed. Glyphosate only provides season long top-growth control. Herbicides with long-term effectiveness need yet to be registered for wicking or wiping application.

The goats used in the browsing trial adapted surprisingly fast to the new feed source. Some animals were seen seeking out dried out common tansy seed heads from previous year’s growth. It is unclear how well tansy seeds survive the process of digestion. Goat browsing should occur when common tansy is at vegetative or bolting growth stages to avoid potential seed spread (Davison et al., 2005). Forage quality of common tansy also declines through the growing season and earlier browsing provides greater forage quality to the animals. The preferred method of consumption was gripping a tansy stem at the bottom before stripping the leaves off the stem with a sweeping head motion, leaving but the stems behind (Picture 1). The goats used in this trial did not exhibit any health issues although prolonged or continued browsing of common tansy may cause subclinical damage to liver and kidney tissue (Dr. Chris Clark, pers. commun.). The reduction in common tansy volume immediately following browsing was visually striking. However, plants grew back with lush, dense vegetative growth late in the growing season. A second round of browsing or a fall rangeland herbicide application would be suggested for future demonstrations or applications of this control method. Common tansy tended to leaf-out close to the ground following browsing which resulted in an increase in canopy cover of the weed although the vertical plant height and abundance of mature plants was significantly reduced (Fig. 1). Goat browsing requires a multi-year approach to weed containment and control.

Table 1. Average pre-treatment and after herbicide treatment (1 month, 3 months, 12 months) canopy cover percentage of perennial pasture averaged across four Saskatchewan treatment sites.

Item	Control[1]	2,4-D	Banvel II	Restore II	Reclaim	Grazon	Rejuvra XL
Grasses							
Pre-treatment	48.8	55.3	38.8	47.5	32.4	34.6	50.7
1 month	35.6	64.4	63.1	69.6	74.0	79.0	62.9
3 month	37.1	77.3	80.9	90.9	85.1	93.4	87.0
12 month	36.6	65.3	70.1	83.6	84.8	81.8	85.5
Legumes							
Pre-treatment	18.8	18.8	18.8	16.9	18.6	17.9	18.4
1 month	49.8	17.7	10.2	7.5	12.7	7.5	12.2
3 month	46.8	3.7	3.2	0.7	0.7	0.0	1.0
12 month	33.7	7.6	3.3	0.1	0.0	0.1	0.3
Other weeds[2]							
Pre-treatment	16.0	8.1	19.9	15.1	23.8	25.3	14.4
1 month	5.5	1.2	2.0	0.8	0.3	1.8	0.7
3 month	2.7	2.3	1.5	1.0	1.2	1.2	1.0
12 month	6.1	2.6	5.1	2.3	0.8	6.3	0.0
Absinth							
Pre-treatment	8.2	8.3	10.7	7.8	13.3	11.2	4.3
1 month	10.5	9.3	16.0	7.8	6.7	5.3	12.3
3 month	13.1	11.3	10.5	0.0	0.3	0.0	3.0
12 month	15.1	10.6	4.8	0.1	0.1	0.6	1.1
Bareground							
Pre-treatment	8.2	9.4	11.8	12.6	11.9	11.1	12.2
1 month	8.9	11.9	14.3	17.4	11.0	12.4	15.4
3 month	8.7	8.0	6.8	7.4	13.9	4.8	11.0
12 month	7.6	14.6	15.9	13.3	14.1	15.1	13.0

[1]Herbicide was not applied.
[2]Other weeds included dandelion, perennial sow thistle, field chickweed, Canada goldenrood, shepherd's purse, pennycress blueburr, and flixweed.

Picture 1. The grip and strip goat browsing method.

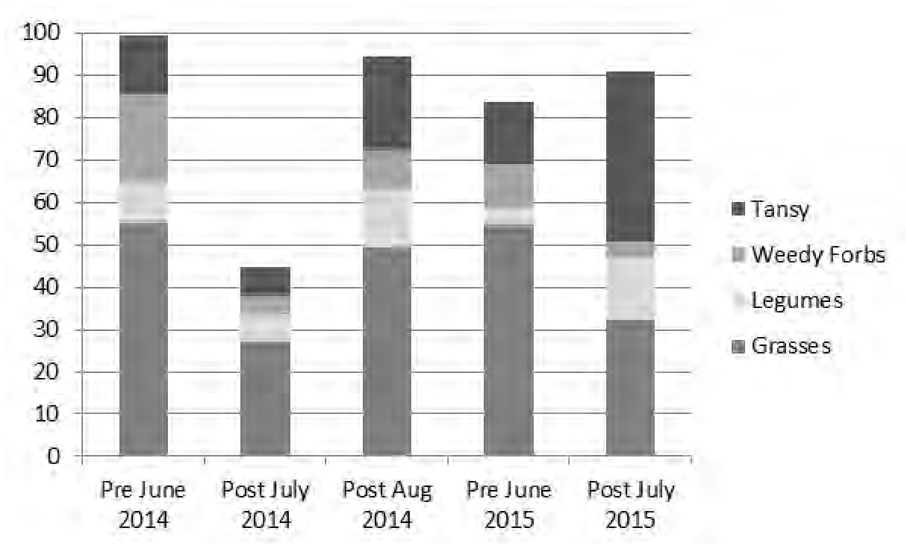

Figure 1. Canopy cover data summary across paddocks browsed for an average of eight days each in early July 2014 and 2015 on a perennial tame forage pasture near Pathlow, SK.

Containing and eradicating absinth and common tansy remains an on-going challenge on Saskatchewan rangelands and pastures. The choice of control method will depend on a range of factors. Where the loss of desirable legume species is of limited concern, a broadcast rangeland herbicide application such as Restore II may be the desired method of control. Where the loss of the desirable legume component is of economical concern, a wiping application using equipment such as the Rotowiper® may be explored. Finally, in areas where noxious weeds grow in environmentally sensitive areas, such as close to water, or in areas with limited accessibility, such as on steep slopes, the use of goat browsing can be a viable, yet multi-year control option.

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Ecology and Management of Saltcedar

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Key words: *Tamarix ramosissima*, imazapyr, imazapic, triclopyr

Introduction

Saltcedar [*Tamarix ramosissima Ledeb.*] also known as tamarisk, is an invasive, woody phreatophyte found throughout most of the western U.S. along rivers, reservoirs, wetlands, and streams. Several other species and hybrids exist. *Tamarix* spp. were introduced into the U.S. from southern Europe and eastern Mediterranean in the 1820s and planted as ornamental trees or shrubs, create windbreaks, provide shade, and stabilize eroding stream banks (DiTomaso, 1998). Saltcedar can tolerate high concentrations of salt (36,000 ppm) in the soil and cycles salt through glands on the needle-like leaves. Flowering occurs from April through October. Mature trees produce in excess of 500,000 seeds per plant. Seeds can germinate on bare moist soil. Over 20,000 ha of saltcedar exists in Kansas primarily along the Arkansas and Cimarron rivers. Once established, saltcedar decreases forage production, reduces species richness, and affects water quality and quantity**.** Saltcedar is a prolific resprouter following fire, cutting, or grazing (Fig. 1)

Figure 1. Saltcedar resprouts following shredding.

O'Meara et al. 2010 reviewed biological, mechanical, and herbicidal control methods and the impacts of grazing, fire, and flooding on saltcedar. Duncan and McDaniel (1998) reported on the use of glyphosate and imazapyr applied as foliar treatments for saltcedar control. Fick and Geyer (2007) summarized 3 years of cut-stump treatments for saltcedar control concluding that imazapyr and triclopyr were effective treatments. The objective of the current study was to compare the efficacy of imazapyr, imazapic, and triclopyr for saltcedar control in southwest Kansas.

Materials and Methods

The study site was located on the Cimarron National Grasslands in Morton County, Kansas. Soils are classified as Happyditch loamy fine sand, occasionally flooded. Saltcedar is the major woody species on site. Herbaceous vegetation includes alkali sacaton (*Sporobolus airoides*), composite dropseed (*Sporobolus compositus*), saltgrass (*Distichlis stricta*), and burningbush (*Bassia scoparia*). Herbicides included foliar applications of 1% imazapyr + 1% methylated seed oil and 1% imazapic + 1% methylated seed oil. The treatments were compared to a basal application of 10% triclopyr in diesel. All treatments were applied on August 29, 2014 with 33 C air temperature, 31% relative humidity, and 0.9 m sec^{-1} wind speed. All treatments, including an untreated check, were applied in a completely randomized design with four replications. Each plot was about 7.6 x 7.6 m in size, with foliar treatments applied at 432 L ha^{-1}. Mortality was determined for all treatments on September 16, 2015 with data analyzed using chi square analysis ($P<0.05$).

Results and Discussion

Imazapyr and imazapic, each applied as high-volume treatments in 1% solutions provided 92 and 85% control of saltcedar, respectively. Duncan and McDaniel (1998) had recommended imazapyr at 1% v/v in water for individual plant treatments. A basal treatment of 10% triclopyr in diesel provided only 44% control in the current study. All untreated saltcedar was alive with 5% defoliation. Fick and Geyer (2008) had reported greater than 85% control of saltcedar with a similar rate of triclopyr applied as a basal treatment. Variation in control using basal treatments can occur if all stems are not sprayed completely. There was a tendency for perennial grasses to decrease and forbs to increase on all treatments, including the untreated checks. Above normal precipitation in 2015 likely stimulated broadleaf plant populations. The greatest changes in herbaceous vegetation occurred in the imazapyr treated plots as perennial grasses decreased 91% and forbs increased 57%. Alkali sacaton, composite dropseed, and western wheatgrass (*Pascopyrum smithii)* were not present in imazapyr treated plots 1 year after treatment. Burningbush increased dramatically as the grasses and canopy cover of saltcedar decreased. Alkali sacaton was still present in all plots treated with imazpic 1 year after treatment.

Conclusions and Implications

Previous studies have recommended imazapyr for saltcedar control. The negative aspect of imazapyr is the off-target damage to associated vegetation. Imazapic provides an alternative herbicide for control of saltcedar with much less damage to herbaceous vegetation.

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Indian Couch (*Bothriochloa pertusa*) Invasion in Queensland, Australia: Development of an R&D Project to Address Loss of Productivity in Pastures

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Key words: Indian bluegrass, landscape degradation, exotic grasses, grazing management.

Introduction

Indian couch (*Bothriochloa pertusa*), an exotic grass naturalised in many parts of Queensland (Qld), Australia, is spreading and potentially threatens the feedbase that underpins many beef grazing businesses. Initial introductions in the 1930s and 1950s (Bisset, 1980) were typically for amenity purposes but aided by drought and overstocking, the *Bowen* ecotype spread rapidly into native (*Heteropogon contortus*) pastures in the seasonally-arid regions of NE Qld (McKeon *et al*., 2004). Extensive monocultures now exist in this region, particularly on granodiorite landscapes, of which span 700,000 ha. Notwithstanding any negative productivity impacts, these monocultures are grazed by cattle and give good ground cover on otherwise bare soil. More recent invasions into fertile basaltic soils, are however being reported (Stacey, 2014) and are a source of serious concern. The encroachment of *B. pertusa* into planted *Cenchrus ciliaris* pastures is also occurring in central Qld severely reducing productivity (Buck, pers. commun.).

The limited available research (Howden, 1988) indicates that overgrazing alone does not necessarily drive invasion. Adding to this lack of understanding of the drivers of invasion is the relatively limited available data on guidelines for managing *B. pertusa* monocultures. In this paper we report on a consultation process with graziers, researchers and extension officers to develop a Research and Development (R&D) project to address this problem.

Materials and Methods

The consultation occurred in two steps. In step 1 a workshop was held in NE Qld with government research and extension officers as well as a small number of local producers to discuss the issue of *B. pertusa*. Step 2 included four separate producer workshops in north and central Qld, covering native and sown pastures across different landtypes.

The workshops captured the different view-points, knowledge and experiences of participants. Producers discussed multiple aspects of *B. pertusa*, including extent of invasion, changes over time, the virtues and shortcomings of *B. pertusa*, and possible management options. Agency staff presented findings from their own research or from the literature. Each workshop utilised small group activities as well as open discussions, and ended with participants identifying and nominating key R&D questions regarding *B. pertusa* ecology and management.

The information collected at the workshops was synthesised and used to develop an R&D project proposal.

Results and Discussion

The consultation in step 1 identified that the key areas requiring further investigation were that the criteria for, and drivers of, *B. pertusa* invasion be identified, and that the impacts of this invasion on landscape function and productivity be ascertained. The latter aspect was investigated by Jones (1997) who reported that *B. pertusa* did not reduce steer performance when compared to native pasture at moderate and high stocking rates. However, in this study, native pasture was oversown with *B. pertusa* and thus was not analogous to a native pasture invaded by *B. pertusa*. The workshops in step 1 also highlighted the facts that *B. pertusa* dominance may be symptomatic of a range of issues, such as overgrazing, drought and soil fertility decline.

The producer workshops in step 2 identified a range of shortcomings of *B. pertusa*, including lowered carrying capacity and liveweight gain, reduced drought resilience and heavier reliance on supplementary feeding. The invasive nature of *B. pertusa* was also a major concern for all producers, as was its effects on soil health and the potential difficulties in restoring invaded pastures to a more productive state. In contrast to producers where *B. pertusa* is already dominant, those in more recently invaded landtypes or those with planted pastures were in favour of management options to control or eliminate *B. pertusa*. Of key interest was determining how to suppress *B. pertusa* growth in native pastures and reduce the *B. pertusa* soil seedbank in cultivated land. The role that intensive grazing systems with multi-paddocks, new pasture species, pasture renovation or soil fertility improvements through legumes, as well as the role of prescribed burning might play in suppressing *B. pertusa* invasion were also deliberated.

A final synthesis of the information collected identified a number of research gaps, including the need to improve understanding of the biology of *B. pertusa*, documenting the extent of *B. pertusa* invasion in Qld and quantifying its long-term economic impacts. Furthermore, any management options tested would need to be very case or context specific: these could include managing for *B. pertusa* dominance in degraded native pastures, reversing *B. pertusa* invasion in healthy native and sown pastures or eradicating it completely in sown pastures or on arable land.

Conclusions and Implications

The producer consultation outlined here has been used to develop an R&D project that aligns with the needs of the beef industry. This project aims to map the spatial extent of *B. pertusa* in Qld pastures and model the impacts of *B. pertusa* invasion on pasture production and carry capacity across a range of landtypes. Work is also planned on identifying the drivers of *B. pertusa* invasion and determining ways to reduce or halt, eliminate, or live with the impact of *B. pertusa* dominance. Information from this research will assist in the development of grazing management guidelines to improve pasture production and resilience, restore rangeland health and improve the quality of water flowing into the Great Barrier Reef lagoon.

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Maasai Pastoralists' Livelihoods Threatened: The Case of Pastoralist Field Schools in Controlling *Ipomoea spp* in Kajiado County, Kenya

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Key words: *Ipomoea*, Maasai, Pastoralist Field Schools, rangelands

Introduction

Ipomoea spp. is a creeping annual herb, widespread in the semi-arid districts of Southern Kenya, which colonizes and spreads rapidly immediately after the onset of the rainy season (Mganga et al., 2010). The species is mainly found in disturbed or degraded sites. Invasive plant species are hazards that have shown negative environmental and socio-economic impacts in East African drylands (Obiri, 2011). *Oltiameleteti* and *Olbeneyio* are the local Maasai names for this invasive weed. According to the Maasai pastoralists in Kajiado County, Kenya, this weed was first identified after the El Nino rains in 1997. Since then, the weed has invaded and colonised over one million acres of rangeland and is expanding year after year. In addition to this while the sheep and goats graze and browse with their young most of them get lost in the *ipomoea* bushes during the rain season and this is a big loss to the pastoralists. Apart from the bees that feed on the *ipomoea* flowers no animals have been seen eating the weed, however honey from areas invaded with the weed when consumed causes dizzines. Recently, a black caterpillar has been seen feeding on the leaves but is yet to be identified and classified.

Table 1: Percent invasion of *Ipomoea spp* in Kajiado County.

Sub-County	Total Area (Acres)	% Invasion	Area Invaded (Acres)
Kajiado Central	1,040,956.13	60 %	624,574
Kajiado East	645,019.18	40%	258,008
Kajiado North	36,571.60	Negligible	0
Kajiado South	1,584,192.60	10%	158,419
Kajiado West	2,075,067.44	20%	415,013
	5,381,806.95	**27%**	**1,456,014.10**

The Pastoralist Field School (PFS) approach is an adaptation of the participatory and interactive learning approach; Farmer Field Schools (FFS). The FFS approach was developed by the Food and Agriculture Organization of the United Nations (FAO) in South East Asia in 1989. PFS are schools without walls that introduce new technological innovations while building on indigenous knowledge. Through experiential learning techniques applied in a group setting, with regular meetings over a longer time period, pastoralists learn how to analyse their situation and make informed decisions about their livelihood practices and resource use strategies. The approach empowers pastoralists through the use of experiential and participatory learning techniques rather than advising them on what to do. The purpose of the PFS is to improve the decision-making capacity of participants and their wider communities and to stimulate local innovation. A PFS usually comprises a group of between 25 and 30 pastoralists (including elders, men, women and youth) who meet regularly over a defined period of time to make observations that relate livestock production to the rangeland ecosystem (FAO 2013).

Kajiado County is semi arid and forms the southern rangelands in Kenya where pastoralism is the main source of livelihood to most rural households in the county. The main livestock species are sheep, goats, beef and dairy cattle (CIDP, 2014).

Materials & Methods

Project sites

There are six Pastoralist Field Schools in the heavily infested areas of Kajiado County. The predominant land use and management system in the region is free range grazing with the main livestock species kept being cattle and small stock.

Methodology

Training of PFS Facilitators was carried out for three weeks. The trained facilitators mapped the heavily infested areas and mobilized the communities creating awareness on the threat posed by the *Ipomoea spp* weed using campaign posters, role plays and poems during public barazas. In addition, pastoralists were engaged in exposure tours, live talk shows and radio advertisements using the local language (Maasai) radio FM station. A documentary was aired in one national TV station to create awareness to the wider stakeholders and provoke action to eradicate this invasive weed threatening pastoralist livelihood. The documentary can be viewed at: https://m.youtube.com/watch?v=exBmND6k1_Q.

Weekly demonstrations are carried out on various range rehabilitation and pasture management practices that are appropriate. More information is transmitted to all members using a bulk short message service (sms) by mobile phones.

Results and Discussion

Pastoralists have embraced the field school concept and have registered the groups formally. The experimental sites have perfomed well results being achieved in one rainy season. Individually they are manually uprooting the weed and fencing off the areas for pasture regrowth. There is emergence of pasture species that had disappeared due to land degradation and increased pasture production per unit area.

Figure 1. Control plot (left) and experimental plot (right).

Conclusions and Implications

Ipomoea spp is a threat to pastoralist livelihood but can be eradicated through fencing off grazing land, uprooting and other range rehabilitation practices. This has proven to work best using the PFS approach if institutionalized in the County extension system and joint effort by all stakeholders

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Who Fenced the Dogs Out? Collaborative Area Management in South West Queensland

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Key words: Predation, total grazing pressure, cluster fencing, land management, invasive species.

Introduction

Predation on livestock and uncontrolled total grazing pressure (TGP) combined with climate change consequences are having negative effects on the management of pastoral enterprises across the Australian rangelands. Land managers in south west Queensland, Australia, are using an innovative collaborative approach to manage the growing list of factors that are impacting on their livelihoods. While exclusion fencing to reduce predation and TGP is not a new concept, Collaborative Area Management (CAM) or 'Cluster fencing' is a novel approach. Land managers are working in groups to construct and maintain exclusion fences around their cluster of properties. Once the fence is complete, land managers can work together to mitigate shared problems. These landscape scale problems need landscape scale solutions and economies of scale dictate that fencing collaboratively is far more beneficial than fencing individually.

Total grazing pressure is applied by domestic livestock and unmanaged herbivores. These unmanaged animals are able to maintain large populations across pastoral lands where artificial water points are readily available (Fisher *et al.,* 2004a). Unmanaged TGP may also be impacting on the biodiversity in the area as small native mammals use ground cover as refuge from predation and exposure (Fisher *et al.,* 2004b).

Throughout south west Queensland, sheep and wool production have historically been the primary agricultural industries. In more recent times sheep numbers are declining and cattle are on the rise, a change that may be partly blamed on high levels of predation by invasive animals. Predation on livestock by wild dogs is a major concern for sheep and cattle graziers in Queensland. In 2009 the major economic costs associated with wild dogs for the grazing industry totalled over $67 million (Hewitt, 2009). Recently industry sources revised this figure and estimate that costs are likely to be much greater, running into hundreds of millions of dollars annually (National Project Steering Committee, 2014).
Expected outcomes from the CAM project include a decrease in predation, allowing land managers the option to return to the sheep industry if desired, and a decrease in TGP, enabling land managers to conduct rotational grazing and paddock spelling resulting in improved pasture health, a reduction in erosion and reduced weed spread.

Materials and Methods

The Collaborative Area Management project started in 2013 with two 'proof of concept' trial clusters established. Following from the trial sites, phase 1 of the project was funded by the Queensland Government to establish a further 5 clusters. Phase 2 is currently underway with funding for a further 8 cluster groups.

The existing clusters were formed by land managers from adjoining properties coming together to submit applications to South West Natural Resource Management (SWNRM) for funding of 50% of fencing material costs. This 50% input equated to approximately $2500 (AUD) per km with the average fence length totalling 300km per cluster. Successful applications demonstrated a strong cost benefit; appropriate production type; potential for positive environmental outcomes and a history of collaboration through activities such as coordinated wild dog baiting.

As part of the process, clusters were required to form an incorporated association, a recognised legal entity separate from the individual members. The incorporated cluster then signed a contract making them responsible for the timely erection and continued maintenance of the exclusion fence. Clusters were then able to use their collective buying power to purchase fencing materials at a reduced cost.
A range of monitoring techniques are in place both inside and outside of the clusters to assess the impact of the project on businesses, land condition, wild dogs, feral herbivores and native macropod numbers. These include: passive tracking index using sand plots to monitor wild dogs and other wildlife, spotlight counts to assess macropod numbers, collection of economic data from grazing enterprises, and collation of pest animal records from local councils.

Monitoring will be expanded into phase 2 of the project with training packages to be developed and delivered to land managers with an expectation on them to undertake their own monitoring. This raises awareness of the importance of assessing indicators of success and continued monitoring will ensure the longevity of the learnings.

Results and Discussion

There are currently seven clusters implemented across south west Queensland with funding secured to establish a further eight. The existing clusters cover an area of approximately 1,645,339 hectares with approximately 1855 km of fencing. Phase 2 of the project has received significant interest from land managers in the region indicating a sound understanding of the value of the project.

Monitoring has been carried out on existing clusters since their establishment however due to severe drought conditions and the short timeframe (3 years) only a relatively small data set has been collated to date. Anecdotal evidence from land managers indicates lambing rates increasing from 7% to 70% following the closure of the fence in one cluster. From 8000 ewes this is an extra 5040 lambs which, at a value of approximately $100 (AUD) each, translates to $504,000 as a return on investment. Sightings of native wildlife have increased in one cluster where land managers report seeing a return in small mammals and a recent survey found koalas in one cluster where they haven't been seen for many years.
Positive social outcomes have been unexpected but are also being reported. Distances between properties in the Australian Rangelands can be great and interactions between neighbours are often rare. Land managers in one cluster are reporting social changes with cluster meetings often being held at the local pub while having a neighbour over for dinner is becoming more common.

Conclusion and Implications

A number of significant learnings have come about from the Collaborative Area Management project. The importance of having a standard fence design will ensure the longevity of the infrastructure while written agreements with neighbouring properties will ensure positive relationships across the landscape. Questions have arisen regarding how to encourage pest animal management once the fence is complete and questions continue to emerge as the project progresses regarding how people plan to restock their properties.

While this cluster group concept is still in its infancy, the positive feedback has been immense. Increased lambing rates translate as decreased predation on sheep populations and a reduction in TGP may be one reason for increased sighting of small mammals who use ground cover for refuge.

The expected outcomes of this project include a reduction in TGP allowing for improved pasture management resulting in improved pasture health, reduced erosion and weed spread and a reduction in predation allowing land managers to return to the sheep industry if desired. Anecdotal evidence is indicating that the project is beginning to achieve these outcomes while the breakdown of some of the social barriers in rural areas has been an unexpected benefit.

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Assessment of Rangeland Rehabilitation Using Ground Based Photo Monitoring (GBPM) Tool: The Case of Didahara, in Southern Ethiopia

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Key words: Degradation, monitoring, photopoint, rangeland, rehabilitation

Introduction

The Borana lowland of southern Ethiopia experienced multiple interrelated stressors that include frequent drought and human and livestock population pressure induced rangeland degradation. Bush encroachment, gulley formation and reduced pasture productivity are major threats to the rangeland (Ayal et al., 2015; Desta and Coppock, 2004). Climate change related challenges, coupled with the demographic stressors erode the adaptive capacity and compromise food and nutrition security of herders living in these areas (Ayal and Muluneh, 2014).

Materials and Methods

This study uses the **Ground Based Photo Monitoring** (GBPM) tool to monitor the rangeland rehabilitation efforts in Denbi-Dikale communal grazing land and Doyo Duba enclosure locally called *Kallo*. GBPM provides a visual depiction of spatiotemporal rangeland rehabilitation changes through generating multiple qualitative data by repeatedly taking photos in the same location, and thus, allows easy communication of rangeland rehabilitation effects to various stakeholders (government agencies, donors, NGOs, Community) (Lassoie et al., 2014; Liniger et al., 2011). To use the GBPM tool, a representative GBPM team was established comprising of Managing Risk for Improved Livelihood (MARIL), Pastoral Development Office, Developments Agents and local community rangeland managers. The rangeland rehabilitation interventions included bush control, reseeding, check dam and normal trench constructions. The team designed the GBPM framework using visual indicators to provide standardized meaning for interpretation of each photos series (e.g. T0, T1, T2. etc.) over time. Random sampling method was used to select 14 photopoints (pps) in Denbi-Dikale communal grazing and 10 pps in Doyo Duba enclosure.

Results

Photos taken during T00 and T01 were archived using Microsoft excel for a baseline data. Data collected from two seasons T 00 and T01 were thematically analyzed. Rangeland improvement and threats were explained using GBPM set key words. The preliminary results show that soil and water conservation and bush controlling efforts have tangible results in reclaiming the lost ecological services of the Denbi-Dikale communal grazing land and Doyo Duba enclosur*e* sites. The application of low cost biophysical structures and management greatly improved the rangeland conditions and increased the biomass (see PP 1 T00 and T01). These results are consistent with and complement findings from the quantitative assessment of changes in herbaceous cover in the two sites and changes in woody vegetation in Doyo Duba enclosure (see Fig. 1). The quantitative assessment shows that bare ground has declined by 29.97% and about 13 more herbaceous species emerged.

Conclusion

The GBPM is cost-effective and valuable tool to document effects of rangeland interventions. By linking visual images to a framework of rangeland rehabilitation activities and practices that are promoted through the intervention program, photographs taken over time from the same points and locations can be used to examine, discuss and understand changes in patterns of land use and land cover that are attributable to the efforts of the rangeland intervention. The visually-oriented approach i.e., GBPM to assess and monitor changes is especially useful in engaging participants and stakeholders in range rehabilitation activity and to appreciate the effects of their efforts and can be highly motivational as well as educational. Thus, we recommend the application of GBPM in range studies.

Figure 1. Denbi Dikale communal degraded rangeland PP2 T00.

Figure 2. Denbi Dikale communal rehabilitated rangeland PP2 T01.

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Grasses and Shrubs Species Composition and Abundance in *Opuntia humifusa* Invaded Karoo Rangeland Grazed by Sheep and Cattle Herds

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Key words: Cactus pear, forage, palatable, ruminant, vegetation

Introduction

Productivity of the Karoo rangelands of western Free State region of South Africa has diminished due to droughts associated with the El Nino weather pattern over the southern zone. Recurring droughts reduce biomass yield from dwarf shrubs and grasses and there is loss of plant species, which affect carrying capacity of the veld. Opportunistic weeds such as creeping wild cactus are rapidly colonizing bare patches and displacing indigenous grasses further exacerbating nutritional deficiencies of ruminants grazing on Karoo rangelands. *Opuntia humifusa* is the most common creeping invader in the Karoo, which, is rarely foraged by ruminants. Hence, the rapid spread of *O humifusa* endangers red meat production from rangelands (Van Wilgen *et al*., 2001) as herbivory and colonization increases pressure on palatable species. There are currently no studies assessing changes in species composition and abundance in affected areas.

The study aimed to assess the effects of *O. humifusa* density on composition and abundance of most common grasses and palatable species occurring in the western Free State rangelands grazed by sheep and beef cattle herds.

Materials and Methods

The study was conducted in Koffiefontein, western Free State region, South Africa, latitude 29.4^0 S and longitude 25.0^0 E.

The assessment of forage species composition and abundance was done on a 300 ha grazing area divided into two adjacent camps. The animals were on continuous grazing system with regular mineral lick supplementation. Visual observations showed that there is a defined West/East gradient in *O. humifisa* density. *O. humifusa* densities in camps was quantified using quadrat surveys and three clusters were defined as 1) < 2 cacti/quadrat: zero zone ZZ; -;2) transitional zone TZ and 3) > 20 cacti/quadrat: heavily invaded zone HZ. The sheep and cattle plots were each divided into three zones based on *O. humifusa* density. Nine subplots of 25 m x 25 m were randomly selected in each zones of the sheep and cattle camps. All the subplots were assessed for composition and abundance of most common species using transects and point survey method (du Toit, 2010). Species abundance was determined using a 1 m x 1 m quadrat after every 5 m along the transect.

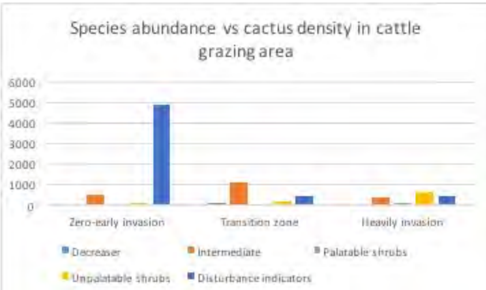
Statistics

Data on species composition and abundance were assessed separately for the sheep and cattle zones. Qualitative data was coded before analysis. The general linear model procedures of SAS (2013) were used to test effects of level of *O. humifusa* invasion on species abundance and composition. Mean differences were determined using Tukey's test and significance declared at P<0.05.

Results and Discussion

Sheep and cattle grazing area

The anomalous distribution of plants and *O. humifusa* in ZZ, TZ and HZ are shown in Figure 1. The palatable grass species were depleted in HZ relative to ZZ and TI. There was an inverse relationship between palatable grasses and unpalatable shrubs in HZ. The declines in palatable grasses may be linked to poor grazing management, which created large bare areas prone to *O. humifusa* invasion. In the cattle grazing area the presence of dominant disturbance indicator grasses in the ZZ (Figure 1) suggests that other factors mainly edaphic properties, climate change and poor grazing management were influencing the changes in range condition in addition to the competition for resources caused by the explosive cactus growth.



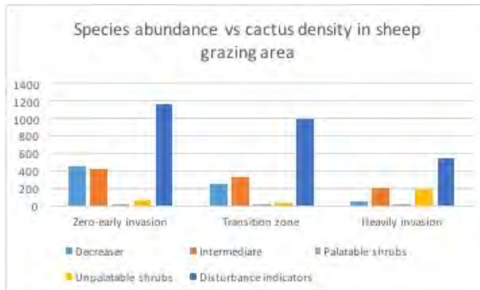


Figure 1. Grass and shrub species abundance distribution in the cattle and sheep grazing areas.

Comparisons of plant abundance in heavily invaded sheep and cattle grazing areas

Disturbance indicator, intermediate and palatable grasses were high in the sheep HZ although the differences were not significant (P>0.05). Difference were noted in counts of palatable and unpalatable shrubs (P = 0.001 and P = 0.002, respectively). There were 10 times more palatable shrubs in the cattle HZ (Table 1); and double the count of unpalatable shrubs compared to the sheep HZ. The reduced abundance of other grasses and heavy presence of *O. humifusa* in the cattle area is worrisome and requires a shift in utilization patterns of the rangeland.

Table 1: Variations in grass and shrub species abundance in sheep and cattle grazing areas with heavy *O. humifusa* invasion.

Class	Sheep area	Cattle area	
	LS Means	LS Means	P
O. humifusa	80±44	112±40	0.324
Disturbance indicator grass	229±102	125±114	0.225
Intermediate grasses	85±46	66±47	0.582
Palatable grasses	12±11	0	0.356
Palatable shrubs	4^b±3	30.0±8^a	0.001
Unpalatable shrubs	52^b±26	112±34^a	0.002

Conclusion

The rangeland has deteriorated significantly with complete loss of palatable grasses and existence of dense stands of creeping cactus in the areas grazed by cattle. There is need for surveillance to determine the rate of colonization of new areas by the invader species and rapid response in formulation of rehabilitation strategies and approaches to manage existing invasions effectively.

Acknowledgements

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Effect of Silvicultural Thinning and Prescribed Burning on Bush Invasion in South Ethiopia

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Key words: Encroachment, prescribed fire, rangeland, silvicultural practices

Introduction

In Borana pastoral and agro-pastoral areas of Ethiopia the level of woody species encroachment on the rangelands has reached 40% to 53% and this has suppressed the growth of desirable grasses, which means reduced productivity of livestock (Coppock 1994; and Gemedo, 2006). This study is designed to 1) evaluate the effects of prescribed fire and silvicultural thinning on tree/shrub mortality and regeneration in a rangeland, 2) to investigate how the treatments impacted rangeland condition; and 3) to establish criteria that can assist manipulation of tree densities to achieve specific agro-pastoral objectives.

Materials and Methods

The site, located at the base of a mountain on black clay soil, is heavily encroached by woody vegetation, and dominated by *Acacia* species and *Acacia drepanolobium* trees. An area (108 hectares) containing relatively uniform stands of woody vegetation was selected for the study site. A ten meter wide firebreak was prepared, and some shrubs/trees were thinned and the others remained un-thinned. Thinning was done at 60% intensity. Four treatments were applied during the dry season: control; thin; burn; and thin and burn.

Data Collection and Analysis

The parameter estimates mean (± SE) Number of stems per hectare (N ha^{-1}), n = 32 quadrants of 100 m^2 of total encroaching shrub/tree species mortality, coppices and seedling/sapling emergence, trees un-thinned and total tree/shrub density following treatments in the study sites.
Tree/shrub mortality and regeneration was recorded annually for three years starting five months after treatment application and means were analyzed using SPSS 16 version. Differences between species and treatments were tested using Duncan Multiple Range Test (DMRT) at a significance level of $P < 0.05$. Herbaceous vegetation was also assessed.

Results and Discussion

Woody vegetation

The study revealed that there is a significant variation in coppicing ability/sapling ($P < 0.0001$), seedling ($P < 0.0005$) and mortality ($P < 0.045$) of tree species due to the treatments. Both *Acacia drepanolobium* and *Acacia melliferea* were affected by treatment. *A.seyal* had the greatest coppicing ability (800 saplings ha^{-1}) due to treatment at the study site. *A. seyal* (300 ± 00), *A. nilotica* (168 ± 48) and *Maerua triphylla* (300 ± 00) N ha^{-1} all had high sapling populations. Furthermore, *A. seyal* (500 trees ha^{-1}) followed by *A. nilotica* (168 ± 47 trees ha^{-1}) had high seedling density.

The result of this study shows that ‘thin’ (87 ± 30 N ha^{-1}) and ‘thin + burn’ (125 ± 42 N ha^{-1}) decreased the tree/shrub density relative to the control (322 ± 125 N ha^{-1}).

There is a significant variation among the treatments regarding mortality (P<0.04), sapling (P<0.0001), seedling (P<0.003) and total woody plants density ha^{-1} ($P < 0.04$). The mortality is four fold greater in ‘thin+burn’ (22 ± 9 stems ha^{-1}) than in ‘thin’ (5 ± 3 stems ha^{-1}) treatment. Coppicing ability was also greater in ‘thin + burn’ (162 ± 64 stems ha^{-1}) than in ‘thin’ (124 ± 46 stems ha^{-1}) treatment. Both mortality and coppicing did not occur in the control. Sapling and seedling density was higher in control than treated plots.

Herbaceous vegetation

Chrysopogon plumolosus (43.8%) and *Themeda triandra* (27%) were the most dominant herbaceous components in the ‘thin’ plot. The ‘thin +burn’ plot was also dominated by *Ch. plumolosus* (60%) as was the control (*Ch. plumolosus* 48.55%) Both treatments had a greater relative species abundance of *Ch. plumolosus* compared to ‘thin’ plot. Proportion of bare ground in ‘thin’, ‘burn’ and ‘thin + burn’ plots was reduced to less that 10% compared to the control (31%).

Conclusion and Implications

This study indicates that thinning in combination with prescribed burning have influenced tree density and range condition. Silvicultural treatments reduced the number of seed producing acacia trees by approximately one-half, and thinning and/or prescribed burning enhanced the growth of desirable herb species. Post-fire mortality varied with species of woody plant with significant mortality in *A. drepanolobium*.

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Elaeagnus angustifolia Colonization and Herbaceous Succession in Mid Valley Riparian Areas

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Key words: *Elaeagnus angustifolia*, invaders, understory vegetation, forage resources, biomass.

Introduction

In 1893 Darwin described the Río Negro as a wide river surrounded by plains with rich grasses and willow-trees. The only native tree is *Salix humboldtiana* Willd, but many invasive *Salicaceae* have colonized the river banks as well as *Tamarix* species. From circa 1970 the principal invader has been *Elaeagnus angustifolia* (silverberry, Russian olive) (Klich, 2013). A tree invasion implies changes in the floristic composition and influences the understory microclimate, soil and plant community. In this study, the effects of different *E. angustifolia* colonization stages on herbaceous forage resources were evaluated.

Materials and Methods

The study site is the Mid Valley of Río Negro, Argentina (39º 30´ S, 65º 30´ W); a temperate semiarid region with annual precipitation of 303 mm and evapotranspiration over 800 mm. Long droughts are common. The river is characterized by meandering and branching. The natural flow regime depends on snowmelt in the Andes Mountains and hydroelectric dam regulation.

Regional climatic data were provided by INTA (2000) and site data were recorded (Klich, 2000). Soil fertility and salinity were determined in 1998 and 2012. Between 1994 and 2009 the understory vegetation was observed and described but not quantified. In 2010 and 2011 the flora underneath and outside the *E. angustifolia* canopy was described and compared using the Sorensen similarity index (Andrada et al 2011). Plant species, biomass and cover were monitored in the understory zone from 2012 to 2015. At the end of 2015 the revegetation success after mechanical tree suppression at silverberry sites was studied in a 3 ha area.

Results and Discussion

Before the arrival of *E. angustifolia* the herbaceous layer was composed of highly palatable grasses and legumes. Once established it developed into dense populations, and it began to reduce available light to the understory, which decreased in density and volume (Klich, 2013).

During the rainy years of 2000 to 2006 the vegetation underneath the silverberry trees included their own seedlings, plus patches of *Cynodon dactylon* and caltrops (*Xanthium sp.*). In 2002 and 2006 water release from dams caused coastal floods and temporary reactivation of old channels leading to *E. angustifolia* colonization of wet lands.

The floristic inventory (2010-2011) showed 47 species in the understory belonging to 20 families. Poaceae and Asteraceae were the most represented families. The Sorensen index was 0.28, showing differences in floristic composition underneath and outside the canopy. Presence of *E. angustifolia* facilitated an increase in plant diversity. These years were also extremely dry and some edge plants lost their leaves. Leaf abscission decreased by 10 to 30% the rate of light attenuation previously quantified (90%) due to the effect of a dense canopy (Klich, 2000). From 1998 to 2012 a significant increase in the amount of organic matter (from 3 to 6.5-

%) was found, and hence more total nitrogen, was detected in the upper soil layer under the actinorhizal shrub canopy.
Since 2012, the Russian olive sites had been used to feed breeding cows using a schedule of high density grazing (3 to 5 CE/ha) during one month in each plot. As *E. angustifolia* is consumed by bovines, the grazing, trampling and dunging under trees may have affected the understory communities. With some exceptions (e.g. *Cynodon dactylon* and *Sonchus oleraceus*) the herbs are not grazed. According to the literature, there are many species among those that cattle do not eat that are nitrophilous.

After the winter removal of plants near fences, *E. angustifolia* resprouted fast. Herbaceous plant germination and growth was notable in the disturbed areas, especially Poaceae and Fabaceae. By the end of spring (December, 2015) the herbaceous biomass production was 7240 kg DM/ha and exceeded 1.5 m in height at many places.

Table 1. Herbaceous strata under *Elaeagnus angustifolia* (E.a.) shrub canopy: Families, dominant species, % cover, biomass (DM/ha) and the most grazed species in different periods of shrub colonization and under diverse climatic conditions.

Period	Stage/ clima /condition	Main understory Families	Dominant Spp.	Total % herbaceous cover	DM ton/ha	Most grazed spp.
Since 1970	Introduction of the shrub	Poaceae Fabaceae Asteraceae	*Erodium cicutarium Melilotus sp, Lolium sp. Hordeum sp. Bromus sp.*	> 90 %	¿?	*Erodium cicutarium Melilotus sp, Lolium sp. Hordeum sp. Bromus sp.*
2000-2006	Colonization Rain/flood	Poaceae Fabaceae Asteraceae	*Cynodon dactylon* *Xanthium sp* E.a. plantlets	< 20 %	¿?	*Cynodon dactylon*
2010-2011	drought	Poaceae Fabaceae Asteraceae Brassicaceae	*Bromus sp., Lolium sp., Xanthium sp., Melilotus albus, Medicago lupulina*	20-40 %	1.2	*Bromus catharticus, Melilotus albus*
2012-2015	rain	Poaceae Fabaceae Asteraceae Brassicaceae	*Carduus sp., Taraxacum officinalis, Sonchus oleraceus, Hirschfeldia incana, Boopis anthemoides, Geranium sp., Mentha sp., Rumex crispus, Urtica sp.*	20-30 %	0.7	*Cynodon dactylon* *Sonchus oleraceus*
2015-2016	Shrub removed	Poaceae Fabaceae	*Melilotus albus, Xantium sp., Carduus sp., Bromus sp., Hordeum sp.*	100 %	7.2	*Bromus catharticus* *Hordeum sp.* *Melilotus albus*

Conclusions and Implications

Rainy years and wet soils hastened *E. angustifolia* colonization. Once established, the amelioration of soil quality and the attenuation of incident sunlight enhanced herbaceous plant diversity under the shrub canopy during drought years. Subsequent grazing affected understory communities and with non-palatable species benefiting from enhanced soil nitrogen. When silverberry trees were removed, the herbaceous strata provided important forage biomass, although the reinvasion of *E. angustifolia* was rapid and difficult to control. A comparison of the forage resource provided by the *E. angustifolia* trees (paper ID 10729 on this IRC-2016) and the potential herbaceous resource in the invaded area will be completed soon.

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Scheduling Cattle Grazing Considering the Offer and the Nutritive Value of the Invader Elaeagnus angustifolia

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Key words: *Elaeagnus angustifolia*, invader, grazing, forage resource.

Introduction

Now that the invasive *Elaeagnus angustifolia* (silverberry, Russian olive), naturalized in the Mid Valley, Rio Negro, Argentina, has been recognized as a forage resource, its presence and phenology must be considered in the yearly schedule of rangeland management.

Previous studies showed leaf heteromorphology (Klich, 2000). Field observations showed that cattle prefer the leaves of *E. angustifolia* that are included on the reproductive branches which develop as an inflorescence called a proliferating thyrse.

The aims of this field/laboratory trial were to find out the incidence of *E. angustifolia* in the breeding cow's diet as determined by microhistological analysis of cow faeces; to map the distribution patterns and quantify the abundance of *E. angustifolia* in different parcels; to estimate the volume of forage produced by this species and to determine the nutritive value of the edible parts of the plants. The results are used to schedule grazing periods in a valley farm divided into plots with different abundances of *E. angustifolia* and a known floristic composition.

Material and Methods

Study site

A 560 hectare farm at the northern margin of Río Negro province, Argentina (39º 30′ S, 65º 30′ W) where *E. angustifolia* has become naturalized. Temperate semiarid, annual precipitation is 303 mm.

The farm is divided into 12 parcels of different sizes, distributed from the river coast to the plateau/valley ecotone (Figure 1). The area, the percentage occupied by *E.angustifolia* and the distribution of the populations were defined for each plot using maps and satellite images (Table 1, Figure 1, detail).

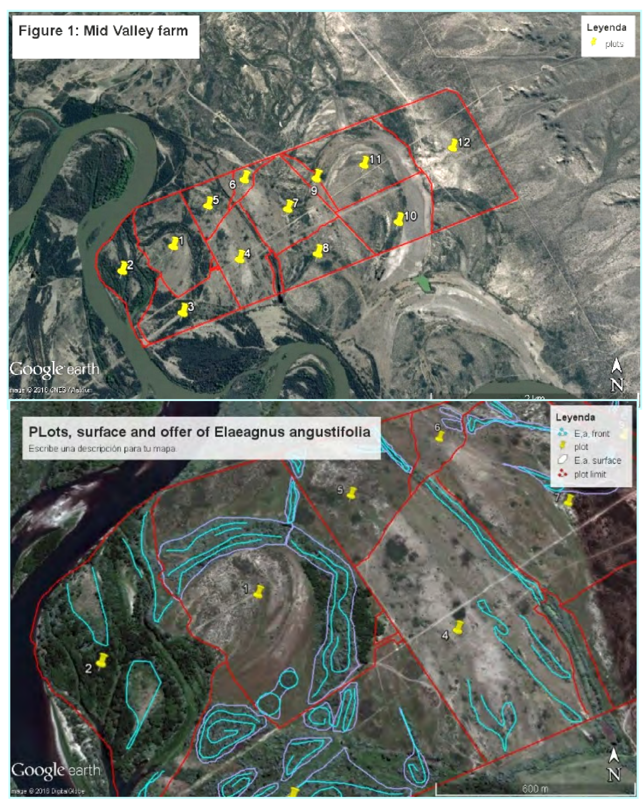

Figure 1.

Biomass

To estimate the amount of forage that cows may eat from the *E. angustifolia* trees, samples were collected, dried and weighed in the middle of the growth cycle, i.e. in January, when the fruits have formed on the thyrses but they are not mature and the seeds are soft and digestible by cows (from

February onwards the entire seeds are eliminated in the faeces).

Cows may eat the thyrses up to 2.50 m in height. Average weight of thyrse 11.03 gr DM, 20 per branch, there are 92 reproductive branches in 1 linear meter per 2.5 m height, and the dry matter production was estimated as 20.29 kg/m /2.5m). Where the population of *E. angustifolia* follows the course of old river channels we considered the dry matter produced on both sides and ignored the production of reproductive branches on the interior of the channels because they were small and of difficult access for the bovines (Figure 1, detail).

Diet microhistological studies and Feed Analysis. Detailed method explanation in Klich, 2014.

Statistical analysis. Data were analyzed with ANOVA, and Tukey Test (p-level 0.05).

Results and Discussion

It was planned to use the padlocks with silverberry for grazing during the spring/summer and the data confirmed that cattle find the thyrse leaves palatable and eat them first when moved into a plot (table 1). Table 2 shows that this plant offers a nutritive and digestible forage resource.

Table 1. Plot surface (P ha), Surface occupied by *E. angustifolia* (E.a. ha), % of the plot area (% E.A. inv), Edible E.a. Biomass offer per plot (t/plot) and E.a. biomass available per bovine consumption per ha of invaded area. (t/ha inv.) or per plot (t/plot) , month of grazing by plot (Month. Gz), Consumption at the beginning of the grazing period as determined by microhistology, % of the total diet. (% E.a. diet). Different letters in the same column mean significant differences at $p<0.05$ by Tukey Test.

Plot N°	P ha	E.a. ha	% E.a. inv	E.a. t/plot	t /ha inv.	t/ha plot	Month Gz	% E.a. diet / stage
1	57.0	16.07	28.14	135	8.40 b	2,37 f	November	37.26 (flowering)
2	42.0	5.78	13.60	59	10.14 d	1,38 e	December	45.69 (small fruit)
3	39.0	11.97	30.72	133	11.10 e	3,44 h	January	70.59 (smooth seeds)
4	44.7	6.40	14.31	13	20.03 h	2,91 g	February	29.54 (hard seeds)
5	23.2	2.10	9.05	24	11.23 f	1,02 d	End October	
6	8.0	0.63	7.80	5	7.90 a	0,62 b	gathering paddock	
7	60.1	5.62	9.35	54	9.70 c	0,91 c	March	29.00 (hard seeds)
8	40.0	----	----	----	----		April, May	
9	8.0	----	----	----	----		gathering paddock	
10	54.0	----	----	----	----		August	
11	79.0	0.87	0.87	10	11.50 g	0,13 a	October	1.80
12	110.0	----	----	----	----		June, July	----

Table 2: Feed (crude protein (CP), ashes (ash), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) in vitro dry matter digestibility (IVDMD) as %) and nutritional analysis (ppm, except chloro as mg/100g) of complete thyrse and separated leaves and fruits in October 2013, January and March 2014.

Month and material	CP	ash	NDF	ADF	ADL	IVDMD	K	Ca	Mg	Na	P	S	Cl^-
Oct 2013	33,74	7,00	49,43	20,74	4,97	63,84	10896	4387	1615	408	5022	3662	229
Jan14 complete thyrse	15,35	5,11	35,37	22,23	8,53	66,30	2944	7817	2035	951	1027	1938	226
Only leaves	22,02	7,41	39,38	22,09	7,27	62,11	3743	9904	2446	1201	1149	2053	300
Only fruits (inmature)	8,60	3,44	14,74	9,09	2,82	88,25	3138	676	436	369	664	590	67
Mar14 complete thyrse	15,27	8,06	37,36	24,67	8,80	62,17	3851	9449	1952	1371	1332	2146	304
Only leaves	20,16	6,94	37,99	21,41	7,08	57,05	8702	9040	1859	1517	1418	2811	341
fruits (without seeds)	7,02	3,67	19,83	12,05	3,81	84,85	6028	1369	433	507	582	470	69

Conclusions and Implications

The grazing schedule of the farms in the Mid Valle of Río Negro may serve to improve the quality of feed considering the forage offer of the naturalized invader *E. angustifolia*. We are completing the study with an evaluation of the herbaceous strata biomass and quality, and also calculating brut protein/metabolized energy values to compare forage resources.

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Landscape Assessment of *Euryops floribundus* Invasion in the Communally Used Grasslands of South Africa and Impacts on Herbaceous and Soil Layer

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Key words: Biomass, organic carbon, topography, palatable grass, shrub density

Introduction

Euryops floribundus, a multi-stemmed indigenous shrub, has been observed to widely spread in several communal grazing lands of the Eastern Cape province of South Africa. Local community elders perceived that the invasion has started affecting livestock production and their livelihoods. Despite the perceived threat posed, scant information is available on the patterns of the invasion along topographic gradient and on the relationship of the invasion with soil and herbaceous vegetation. Development strategy to control or reduce new invasions requires a thorough ecological assessment of its landscape distribution and impacts. The aims of the study were to examine 1) the *E. floribundus* distribution along four elevation gradients and 2) the relationship between the abundance of the shrub, herbaceous vegetation and soil nutrients along topographic and density gradients.

Materials and Methods

The study was conducted in the Upper Mnxe communal grazing lands located in the Chris Hani municipality of the Eastern Cape Province, South Africa (altitude range:1286m–405m; coordinates: S 3151^{o}.585$^{'}$–31 52^{o}. 540$^{'}$ S; 2759^{0}.272$^{'}$–2759 ^{o}.933$^{'}$E). The vegetation is predominantly grasslands. The area has a temperate climate with an average annual rainfall of 500 mm, mean temperature 22 ºC and 12 ºC in January and July, respectively. To assess the *E. floribundus* distribution, herbaceous vegetation cover and soil along landscape gradients, four homogeneous grazing sites were selected. Each site was divided into four landscape positions: bottomlands (BL), middle-slope (MLS), upper-slope (UPS) and upland (Upl) plateau. In each landscape, 16 belt transects (50 m x 2 m) were established. To investigate the effect of *E. floribundus* invasion on grass cover and soil, a total of about 4 ha communal land was selected in a flat undulating terrain. Four invasion levels were distinguished, namely: no invasion, light, moderate and heavy invasions (Table 1). Twelve 50 m x 2m belt transects were marked at each invasion level. In both studies, soil, shrub and herbaceous vegetation data were recorded within each belt transect.

Statistical analysis

Vegetation and soil data were analysed using a General Linear Model (GLM) of SAS. Data were also subject to canonical correspondence analysis (CCA) of CANOCO version 4.5 software.

Results and Discussion

Along the landscape gradient, there was a significant increase in total density of *E. floribundus* in moving from the Upl (2301 plant ha^{-1}) down to the BL (4888 plant ha^{-1}). The observed differences may be attributed to anthropogenic and abiotic factors that influence seed dispersal, surface and sub-surface water and nutrient distributions. Grasses at the BL and slopping sites had greater (P<0.05) tuft diameter than grasses at the Upl sites (Fig. 1). Considering the density gradient, average tuft distance was highest (P<0.05) at heavily invaded site. Soil results showed an evidence of higher (P<0.05) OC, N and Ca in the

Upl sites. Great difference in the amount of soil C between the Upls and the other sites may be related primarily to elevation. On average, Upl sites were 113, 96 and 70 m higher than the BL, MLS and US sites, respectively. As for the density gradient, soil OC, Ca, P and N levels were greater ($P<0.05$) in soils from moderately or heavily invaded sites (Table 2).

Relationship between environmental and species variables

CCA analysis for landscape data showed that tuft diameter, basal cover and biodiversity had significant positive correlation with elevation and soil C level from 20 cm depth. Along the invasion density gradient, the abundance of *A. diffusa, E. muticus*, *E. chloromelas*, tuft distance, diversity and grass DM are strongly and positively correlated with total density and canopy cover of *E. floribundus*.

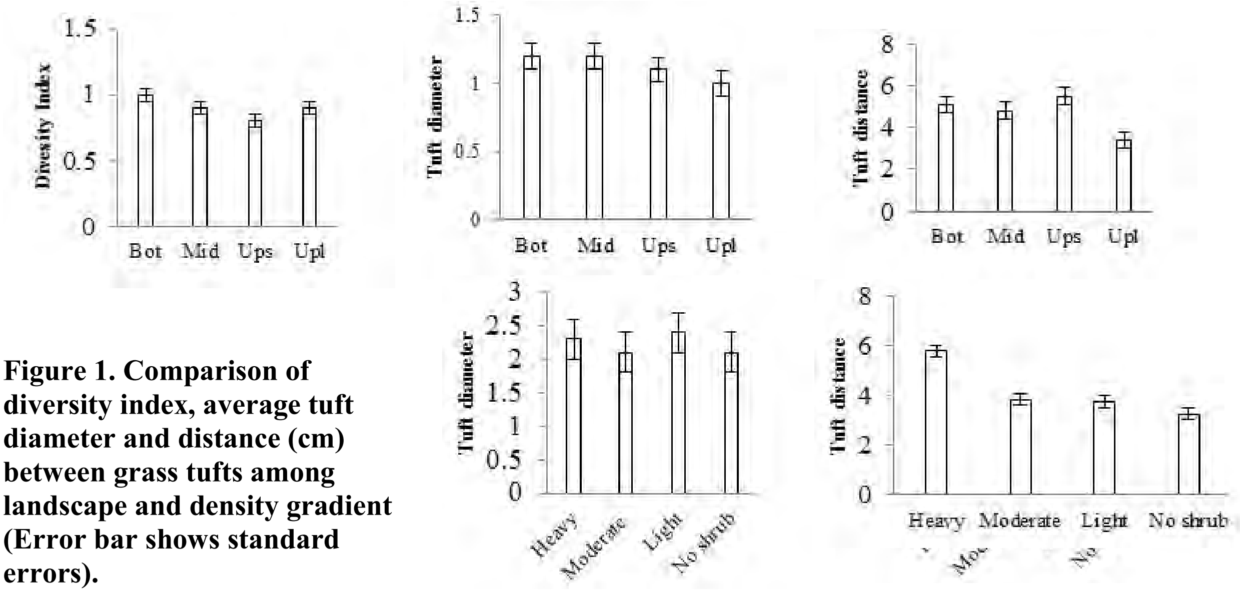

Figure 1. Comparison of diversity index, average tuft diameter and distance (cm) between grass tufts among landscape and density gradient (Error bar shows standard errors).

Table 2. Soil chemical properties along landscape gradient and invasion levels.

Landscape	Soil C	Ca	P	Resistance	pH	Total N
Bottom	2.3[c]	6.4 [b]	5.9[b]	781[ab]	5.3	0.11[c]
Middle	2.2[c]	5.8[c]	4.7[c]	747[b]	5.6	0.12[c]
Upper	2.4[b]	6.5[b]	5.9[b]	808[a]	5.2	0.16[b]
Upland plateau	3.3[a]	7.6[a]	6.2[a]	715[c]	5.2	0.24[a]
SEM	0.1	0.2	0.2	23.6	0.1	0.01
Density gradient						
Heavy	2.0[a]	5.5[a]	4.5[a]	1240[d]	5.3	0.13[a]
Moderate	2.1[a]	4.3[b]	4.3[a]	1397[c]	5.1	0.14[a]
Light	1.3[d]	3.4[d]	2.1[c]	1824[b]	5.0	0.10[b]
Non invaded	1.9[c]	3.8[c]	4.0[b]	2008[a]	5.1	0.11[b]
SEM	0.04	0.1	0.2	40.1	0.0	0.01

The vectors of the proportion of *T. triandra*, *M. caffra*, *H. contortus* and forbs abundance have opposite trajectories with *E. floribundus* density. A review made by Ratajczak et al. (2012) on 29 studies in North America vegetation communities concluded that herbaceous plant species diversity declined by 45% due to woody plant invasion. In the current study, however, the RDA analysis established a positive response of grass diversity to increased density *E. floribundus* suggesting that shrub invasion may create different niches of environments to support diverse grass species.

Conclusion

The dominance of low palatable species (e.g. *E. plana* and *S. afrcanus*) and the low occurrence of highly palatable species (e.g. *T. triandra*) in the BLs and in moderate to heavy invasion sites is more likely the result of the changes in ecological processes that arise from disturbance such as overgrazing and the invasion itself. Soil P, C, N and pH responded positively to the abundance of *E. floribundus*, although the increase in the concentration of these elements did not benefit the highly palatable grass species such as *T. triandra*. In density gradient, the substantial decreases in the abundance of palatable species suggest that the invasion may be concomitant with a decrease in rangeland productivity in terms of quality forage provision. Our results underscore the importance of considering landscape and density gradients to understand *E. floribundus* invasion and its impacts.

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Changes of Species Richness in Response to Seasonal Grazing Pressure

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Key words: Ecological adaptation, grazing resistant, domination, winter and summer pasture

Introduction

In Mongolia after 1990, loss of the previously formal regulatory institution led to decline in the number of seasonal movements (Fernandez-Gimenez and Allen-Diaz 2001). This has led to overgrazing, showing a classic example of the tragedy of the commons (Schmidt 2006). Due to overgrazing, the vegetation species composition, richness and productivity have changed, while some species have survived through adaptation. Effects of overgrazing may include the trampling and removal of plant structural material. These effects enhanced the growth of dominant plant species and usually lead to a decline in native flora abundance (Zhao, Li et al. 2007). The purpose of our study was: to describe long-term effect of season of grazing by livestock on plant species richness in forb-feather grass of forest steppe zone in Mongolia.

Materials and Methods

The study area, which is the winter and summer pastures of Javkhlant soum of Selenge province (107°30', 49°52'), is located on central part of Mongolia. The study area is in a typical example of the forb-feather grass. At each site, sampling plots of 1 m^2 were set up long distances (from each camp 2000 m) positions of the winter and summer camp. Within each sampling plot, each plant species and cover were recorded. Each plot was sampled once in the summer from 2006 to 2015. Plant cover was sampled using the Braun-Blanquet method; see the nomenclature according to Grubov (1982). The statistical analysis of the data was carried out with the SPSS for Windows package. Significantly different means ($p<0.05$) were identified by one-way ANOVA.

Results and Discussions

Table 4 shows that season of grazing influenced species richness. There were no differences in forb cover between season of grazing, but grass, sedge and legume coverage all had significant differences between seasons (Table 4). Species richness was lower on the summer than the winter pastures.

Table 4. One-way ANOVA table for species richness and functional group coverage.

		Mean	Std. Deviation	Std. Error	Mean Square	F	Sig.
Species richness, (e/m^2)	Winter	13.64	3.421	.484	992.250	127.824	.000
	Summer	7.34	1.955	.276			
Grass cover, (%)	Winter	14.24	7.214	1.020	1265.225	28.875	.000
	Summer	7.13	5.967	.844			
Sedge cover, (%)	Winter	2.50	3.182	.450	10243.464	142.313	.000
	Summer	22.74	11.568	1.636			
Forb cover, (%)	Winter	17.41	12.650	1.789	183.874	1.391	.241
	Summer	20.12	10.211	1.444			
Legume cover, (%)	Winter	10.50	15.550	2.199	2568.462	21.214	.000
	Summer	.36	.598	.085			

Agropyron cristatum, Cleistogenes squorrosa, Carex duriuscula and *Artemisia frigida* were the most abundant species. While forb cover was not significantly different with each season grazing pasture (p<0.241), but dominant species coverage were changed significantly.

Figure **14** shows cover of *Agropyron cristatum* and *Cleistogenes squorrosa* increased in winter pasture, while cover of *Carex duriuscula* and *Artemisia frigida* were highest in summer pasture.

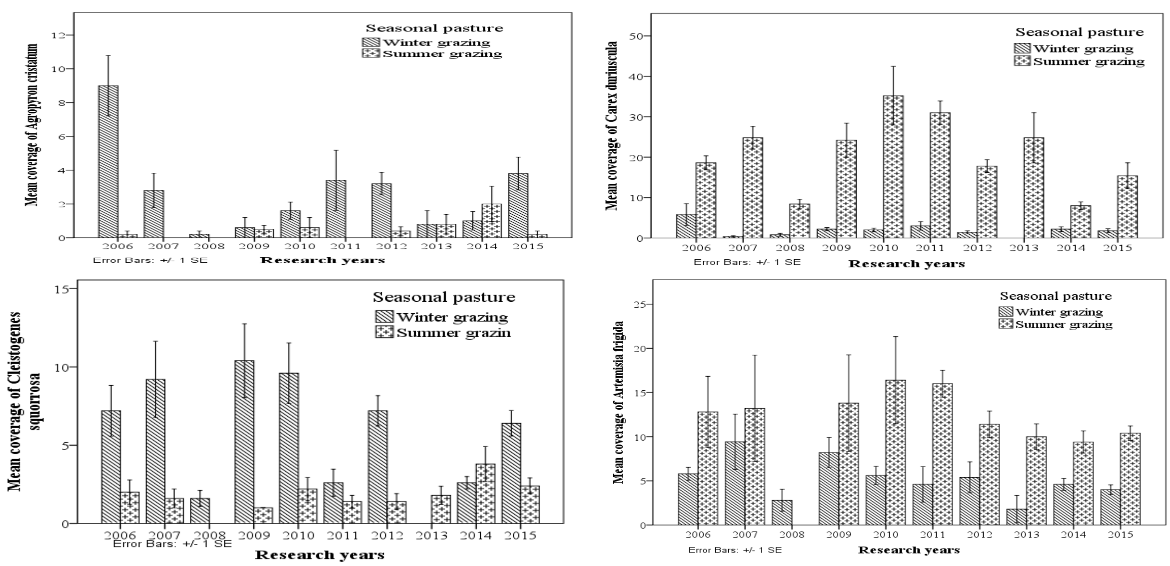

Figure 14. The coverage of dominant species during research years in winter and summer pasture.

However *Agropyron cristatum* is good livestock forage since it has a basal meristem and can continue to grow even even after grazing (Ishii and Fujita 2013). At the initial stage of degradation, some forbs and mesophytes disappear, and then later, only drought-tolerant and grazing-resistant grass species such as a for example, *Cleistogenes squorrosa* (Tuvshintogtokh and Ariungerel 2013) can readily spread,. *Carex duriuscula* was dominant with the highest abundance under light grazing (Chognii 2001).

Implications

Results from our study indicated that long term seasonal grazing by livestock leads to change of the dominant species by grazing-tolerant plants. *Artemisia frigida* and *Carex duriuscula* were more adaptive to light grazing than *Cleistogenes squorrosa*. However our alternative explanation was summer pasture was more overgrazed by livestock than winter pasture, it may affected winter pasture was dormant during the grazing period.

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Environmental Factors Affecting Decreaser, Increaser and Invading Species: Dominance and Distribution in the Semi-Steppe Grasslands in Northern Iran

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Key words: Invading species, intensity grazed, environmental factors, grasslands, dominated

Introduction

Most semi-steppic grasslands are distributed in north-east Iran, where they are intensively grazed and heavily utilized. Depending on the response to livestock grazing, vegetation species are categorized as decreasers, increasers or invaders. The most palatable plants are decreasing due to grazing pressure. Moderately palatable plants act as a secondary forage plants and under moderate grazing may increase slightly or remain stable. Species that increase under moderate to high grazing pressure and reduced range condition are defined as increaser species. Invasive species are usually unplatable plants that invade after the destruction of adjacent areas.

Methods and Materials

The study area was located in north-east Iran between the latitudes of 37°20'27"to 37°30'30"N and longitudes of 56°08'48" to 56°17'36"E. Elevation range was between 1000-2700 m. Mean annual precipitation is 400 mm and mean annual temperature is 9°C. Regional climate based on De Martone method (De Martone, 1942) is semi-arid cold. General slopes were 0-12% and major vegetation of the area includes perennial herbaceous with dominant grasses and forbs.

For sampling, digital maps including altitude, slope, aspect, vegetation and landuse were prepared. The maps were combined using GIS software version 9.3 and land units were identified. Sampling plot size was dependent on the type and distribution of plant species and determined using minimal area method (Kentand Coker,1992). The number of plots was determined by statistical methods considering the changes in vegetation cover. One hundred and twenty (12) plots 1 m^2 (random method) in size were selected and within each plot, the presence and absence of the species and cover percent were estimated by Braun-Blanquet method (Braun-Blanquet, 1972).

Results

The results of this study show that increaser plants have the greatest richness and number of species. This was greater than that of palatable and decreaser species (39.38%) established in the plain area of grasslands. The most species richness was on steep slopes. More plants (decreasers) were observed in low elevations (1300-1500 m). Invader plants were observed in all areas. The dominant palatable and decreaser species in dry grasslands were *Festuca ovina*, *Agropyron cristatum*, *Bromus tometellus* and *Taraxacum officinale*. The dominate increaser plants were *Artemisia sieberi, poa bulbosa, Serratula latifolia* Boiss. & Hausskn and *Stipa hohenacheriana* Trin & Rupr. The dominate invasive communities were covered vast areas and included, *Hypericum perferatum* L., *Cousinia nekarmanica* Rech.f., *Taeniatherum crinitum* (Schreb.) Nevski, *Rosa persica* Michx. ex Juss and *Phlomis cancellata* Bunge.

Conclusions

The results showed that all three plant associations were in semi-steppic grasslands but in almost all of them the invasive plants were dominant. Environmental factors effect vegetation communities, however, poor economic conditions of local ranches has led to over grazing which hampers decreaser and increaser species and helps invader species.

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Disturbance Effects in a Temperate Grassland of the Flooding Pampas, Argentina

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Key words: Fire, grazing, structure, diversity, cover.

Introduction

Natural and anthropogenic disturbances constitute determining factors in the structure and functioning of ecosystems (White & Pickett, 1985). It is difficult to predict the successional trajectories of a system when it is affected by combined disturbances.

The Flooding Pampas (Argentina) comprises a mosaic of plant communities with a great diversity of native and exotic plants. Grazing by domestic livestock is the most important influence on these communities, together with the water regime and their interaction (Burkart *et al*., 2005). Some grasslands dominated by *Paspalum quadrifarium* are managed with fire (Laterra *et al*., 1998). However, prescribed fire is not common practice in this region and there is limited information about the combined effect of grazing and fire in the humid mesophytic meadow. As fires occur spontaneously or by accident, the successional process after such events is of interest for those who work in developing management guidelines. The aim of this work was to evaluate the individual effects of fire and grazing, and the combined effect in a grassland of the Flooding Pampas.

Materials and Methods

We studied paddocks dominated by native grassland on a livestock farm in Buenos Aires, Argentina (35º 15′ 31.35″ S; 57º 38′ 09.95″ W), in a humid mesophytic meadow community (Burkart *et al*., 2005). Measurements were taken in two plots: with rotational grazing (G) (livestock density: 0.8 $AU.ha^{-1}.year^{-1}$) and with grazing exclusion for two years (NG). In the summer of 2000, an accidental fire occurred, affecting half of each plot. The treatments were: plot closed to grazing (NG), not affected by burning (F−); NG plot, but burned (F+); grazing plots (G), unburned (F−) and burned (F+). Braun-Blanquet floristic surveys were carried out in five fixed sites during winter in 2000 and 2015. Functional groups were determined: total cover (T), cool-season grasses (C3), warm-season grasses (C4), sedges and dicotyledonous herbs (Sd), and legumes (L). The Shannon–Wiener (H) and species richness (Ns) indices were calculated for each site. A nested plot design was considered. The data was analyzed by ANOVA and the differences between means, with Tukey's test ($p<0.05$).

Results and Discussion

Grazing and fire modified the structure of a mid-slope community in the Flooding Pampas, increasing the diversity and species richness, to include sedges, dicotyledonous herbs and legume cover (Table 1). However, Rusch & Oesterheld (1997) suggest that species diversity and/or richness alone are poor predictors of community functioning; the relative abundance and identity of species that are added or deleted by the specific disturbances that modify diversity should also be considered.

After 15 years, 69% of the cover species in G were Sd and 26% were grasses. In NG, 65% were Sd and 31% grasses C3 and C4. In the short term, T increase in NGF+ was due to a greater coverage of *Oxalis sp*. The cover in G comprised species without forage value: *Eryngium horridum* and *Cirsium vulgare*. In the NG treatment, shrubs like *Baccharis coridifolia* and *B. notosergila* increased significantly and, to a lesser extent, *E. horridum.*

Legume coverage increased in G plots after the fire in 2000, and this was maintained in 2015. This coincides with other works on *P. quadrifarium* grasslands, where fire and rest promoted the growth of *Lotus tenuis* (Laterra *et al.,* 1998).

C4 cover was significantly greater in NGF− in 2000 than in 2015. Both fire and grazing led to a significant cover decrease of the C4 functional group, particularly of *Paspalum dilatatum*. The consequent introduction of cool-season forb species has led to the displacement of warm-season grasses from dominant to subordinate positions in the community (Rusch & Oesterheld, 1997).

Table 1. Species diversity (H), number of species (Ns), and cover (%): total (T), C3, C4, sedge (Sd), legume (L). In the winters of 2000 and 2015, non-grazing burned (NGF+) and unburned (NGF−) plots; grazing burned (GF+) and unburned (GF−) plots.

	2000				2015			
	NGF+	**NGF−**	**GF+**	**GF−**	**NGF+**	**NGF−**	**GF+**	**GF−**
H	2.6bcd	1.9ab	2.8bcd	1.8a	2.1ab	2.3abc	3.3d	2.9cd
Ns	26d	15ab	22bcd	16.4abc	17abc	13.2a	27d	20.8cd
T (%)	54a	92.4d	69abc	67.6bc	67.8ab	80cd	80.5bcd	79.6bcd
C3 (%)	15.2a	34ab	32.5ab	49.4b	38.2ab	34ab	33.5ab	33.8ab
C4 (%)	10.2b	45.8a	9b	3.4b	1.4b	1.2b	15b	13.2b
L (%)	0.8c	0.2c	10.5a	0.8c	0c	0.2c	6.5ab	1bc
Sd (%)	27.8bc	12.4a	17ab	14ab	28.2bcd	44.6d	25.50abcd	31.6cd

Different letters between columns indicate significant differences between means ($p<0.05$) within years.

Conclusions and Implications

Excluding grazing tended to increase shrubs within the pastures, while grazing increased the exotic species with no forage value. Resting pastures for two years benefited C4 species; however, they too could not compete with a growing sedge population. The most promising treatment appears to be fire, as it increased legume cover.

If this result is considered in the context of sustainable management, it could be inferred that the grazing method on its own does not guarantee that grasslands will remain in good condition. Rather, livestock density must be adjusted and the rests must be planned.

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Environmental Management of a Military Training Area in North Eastern Australia

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Key words: Military land-use, land management, monitoring, semi-arid tropics.

Introduction

The Australian Defence Department (ADD) owns six military training areas for Australian Defence Force (ADF) training covering 2.3Mha of land across northern Australia. Although military training activities can have negative environmental impacts, the implementation of well-designed environmental management policies enables these impacts to be minimised and mitigated. Townsville Field Training Area (TFTA) is a 243,737ha military training area 45km west of the city of Townsville in the Burdekin River catchment of north eastern Australia. TFTA was previously three commercial pastoral leases that were severely overgrazed in places. The area is mainly semi-arid tropical savannah and includes a wide range of soils and topography.

Current Land Use

Although acquired in stages in 1967 and 1989, cattle grazing continued until 2001. However unauthorised cattle grazing still occurs on TFTA in most years; eg a December 2015 survey estimated 5000 cattle from neighbouring stations were present. In addition to the impacts of domestic livestock and feral animals, military activities such as built infrastructure, explosive ordnance, wheeled and tracked vehicles, vehicle servicing, access tracks and latrines also have environmental impacts. These impacts include vegetation clearance, soil disturbance, unplanned fires, alteration to flow paths for runoff, chemical contamination risk and increased nutrient loads. Following above average wet seasons, fires from TFTA also occasionally burn onto neighbouring cattle stations.

While cattle grazing has been suggested as a means of reducing fuel loads and fire intensities, McIvor (pers com 1999) concluded that it would add little value to the military use of TFTA due to the need for fences which would interfere with training activities and would make only a small contribution to fire management. Nevertheless, up to 10% of the property has been made available for grazing drought-affected cattle on two occasions. During the most recent drought in 2015/16, agistment was provided for 5000 head of cattle (over and above the unauthorised cattle numbers).

Environmental Management

Following the completion of land resource and vegetation surveys (Rogers *et al*., 1999) and the development of an environmental impact statement and an environmental management plan, plans were developed for the management of military training activities and their effect on soil erosion, fire, weeds, feral animals, water quality, riparian zones and aquatic and terrestrial biodiversity. The adoption of an extensive and comprehensive monitoring program (Dowe 2013 & Hawdon *et al*., 2012) has enabled the ADD to ascertain the effectiveness of, and adjust management plans across the 22 designated sectors. This guides the allocation of resources to address land degradation issues.

Management Practices

TFTA is managed as 22 sectors based on their suitability for different military uses. Environmental risks and management practices across TFTA are shown in Table 1. Annual meetings with the 20 neighbouring property owners help to maintain a good working relationship, particularly with regard to fire management, feral animals and weeds. Cattle agistment is raised only during severe drought.

Table 1. Management practices for environmental risks on TFTA (McIvor *et. al.,* 2000)

Risk	Management Practices
Soil erosion	• Development of recovery times for each military use eg areas with good land condition require a 2 to 3 year recovery period after tracked vehicle operations. • Control of erosion on access tracks eg appropriate siting, construction of earth diversion banks and sealing with bitumen in high use locations
Weeds	• Vehicle wash-down facilities • Weed surveillance (on-foot and remote) and targeted treatment of declared weeds • Weeds treated from top to bottom of catchments (McManus pers com)
Pasture degradation	• Early, cool patch burning based on fuel loads and planned military use • Satellite monitoring of ground cover and fire scars • Tailored recovery periods determined by military use, land type and land condition
Feral animals	• Annual aerial surveys for feral animals (pigs, deer, dogs, donkeys, horses & cattle) • Targeted control by mustering, trapping or aerial shooting
Riparian vegetation	• Minimal use for military training • Site selection for watercourse crossings • Erosion control at crossings
Water quality & aquatic biodiversity	• Control of feral animals, particularly pigs • Weed control • Agistment of cattle based on forage budgets • Erosion control on man-made features (eg roads & fire tracks)

Conclusions

The adoption and implementation of a comprehensive management plan based on a series of scientific studies has ensured that the TFTA is in good environmental condition which simultaneously allows the full range of military training activities for which it is intended. A detailed monitoring program has enabled the effectiveness of management practices to be evaluated and modified to allow for continuous improvement in land condition. This is shown by the fact that water quality and pasture cover on TFTA is superior to that on adjoining land used for commercial cattle grazing. This demonstrates that contrary to popular perception, military training can be conducted and land degradation controlled.

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Effect of Associated Pod Quality on Seed Recovery and Germination of *Dichrostachys cinerea* and *Acacia tortilis* Fed Ruminants

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Key words: Crude protein, germination percentage, seed dispersal, seed viability, tannins.

Introduction

Pods of different leguminous plant species form an important part of the diet of livestock during the dry season due to their high nutritional value compared to grasses (Janzen 1984). However, herbivores browsing pods of certain woody plants may disperse intact seeds that can potentially germinate and recruit into mature trees (Tews et al. 2004). The quality of associated diet such as pods chemistry (i.e. protein and tannin concentration) may be an important determinants of success of livestock faecal seed dispersal. We studied the effects of pods quality on seed recovery and germination of *Dichrostachys cinerea* and *Acacia tortilis* seeds.

Materials and Methods

A total of 12 female indigenous goats and 12 female Pedi sheep were used in this study, with the mean weights of 29.5 kg ± 1.6 (S.E) and 28.7 kg ± 1.6, respectively. Each animal was fed experimental diet and pods, individually placed in a 2 m^2 pens. Sheep and goats were fed *Eragrostis curvula* hay for 7 days prior to the experiment to allow them to acclimate to experimental conditions and clean any possible seeds from the digestive tract. Twelve goats were divided into two groups of six animals per group, one group was fed *D. cinerea* pods and the other group was fed *A. tortilis* pods. The same was also done for sheep. All animals were allowed to consume *D. cinerea* or *A. tortilis* pods within 24 hours, after which the remaining pods were collected and weighed. Faecal collection commenced immediately 24 h after pods feeding period and continued until no seeds were found in faeces. Seeds recovered were then germinated according to the International Seed Testing Association standards (1985).

Results and Discussion

Sheep consumed slightly more *D. cinerea* and *A. tortilis* pods (668 ± 10.70 658.3 ± 10.50) than goats (654 ± 10.44, 650 ±10.4), respectively. More *A. tortilis* (38.37 % ± 1.79) were recovered than *D. cinerea* (12.37 % ± 1.02, $P < 0.001$). The relatively high crude protein and low tannins in *A. tortilis* and *D. cinerea* may be used as the basis for justifying these results. Thus, associated high-quality diet tends to pass faster through the gut with less damage to the seed coat (Tjelele et al. 2014). However, no significant ($P > 0.19$) effect of animal species were found on seed recovery. *Acacia tortilis* and *D. cinerea* seeds that passed through the gut of goats and sheep had a significantly higher ($P < 0.01$) germination percentage than the control (i.e. no passage through the gut of goats and sheep). We noted that seeds may be sufficiently hard-coated that imperfect seed scarification and low germination percentages result (Schupp et al. 1997). However, a greater germination percentage of *D. cinerea* (34.56 % ± 1.99) and *A. tortilis* (26.02 % ± 2.10) seeds was observed in goats and sheep ($P > 0.02$).

Conclusion and Implications

The associated diet quality and passage through the gut of sheep and goats played a major role on seed recovery and germination, which may increase the dispersal of viable woody plant seeds. Thus, this suggests that mammalian herbivores foraging on pods of *A. tortilis* and *D. cinerea* are most likely to disperse intact seeds that can remain viable and potentially germinate. Moreover, this may be one of the plant's evolutionary strategies to disperse their seeds away from the parent plants. However, this mechanism may have both positive and negative effects on the abundance of plant species (i.e. it may increase the abundance of woody plant species in ways that may worsen woody plant encroachment in ecosystems and/or increase the biodiversity of plant species in these ecosystems).

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Supplementation with *Digitaria eriantha* Hay and Protein Licks Increases Bite Rate of *Acacia karroo* by Goats

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Key words: Palatable grass, nutritional quality, plant secondary metabolites, supplementation

Introduction

Globally, open savanna ecosystems have been transformed into closed savannas by the increase in woody plants and shrubs over the years, with the resultant loss of palatable grass species, which ultimately reduces the grazing capacity for livestock and grazing wild animals. Thus, an increase in abundance of woody plants also increase the costs associated with management of livestock (Ward 2005). There is a need for ecologists, farmers and rangeland managers to mitigate the problem of food shortages for livestock, and use available shrubs and trees for browsing material invading rangelands. Browse provides nutrients such as minerals, proteins and vitamins during the dry season. An appropriate type of livestock to feed browse are goats. Goats are mixed feeders that are flexible in their dietary choices, consuming both trees and shrubs as well as grasses whereas sheep and cattle are mainly grazers.

A major limitation of woody plant species as a source of nutrients for animals is the presence of plant secondary metabolites (PSMs), mainly tannins. Tannins are polyphenolic compounds found in many plants and are the most common secondary metabolites found in acacias and related trees. Tannins can be beneficial or detrimental to livestock, but this depends on the amount of tannin concentration ingested by the animal. However, there is evidence that supplementation of herbivores with nutrient sources such as proteins increases the amount of PSMs which the animal can consume. Studies have shown that in controlled experiments, supplements increase the utilization by goats of woody plants rich in tannins (Tjelele et al. 2014). We studied the effect of supplementation with *Digitaria eriantha* hay and protein-lick supplements on bite rate of *A. karroo* by goats. *D. eriantha* is very palatable and among the most preferred grass species by herbivores in South Africa (van Oudshoorn 2009). We predicted that supplemental *D. eriantha* hay and protein licks would increase the bite rate of *A. karroo* by goats.

Materials and Methods

The study was conducted at the Roodeplaat Experimental Farm of the Agricultural Research Council, Gauteng Province, South Africa. Annual rainfall is 650 mm, which mostly falls in the austral summer months.

Twenty-four indigenous female goats (mean ± SE = 33.03kg ± 0.90) were individually penned in a 3m x 1m enclosures. Four groups of six goats per group were allocated the following dietary treatments: 1) control (*A. karroo* only); 2) *A. karroo* and *D. eriantha* hay; 3) *A. karroo* and protein licks; and 4) *A. karroo*, *D. eriantha* hay and protein licks. Every morning branches of *A. karroo* were cut. About twice the weight of *A. karroo* branches relative to *D. eriantha* hay (0.4:0.2 kg) was put in the feeding buckets and fed to the goats. We recorded the number of bites the individual goat made either from *A. karroo* or *D.*

eriantha hay during feeding. Bite rate (bite.s^{-1}) was then calculated as the number of bites made by goats divided by the time spent (s) for that particular feeding behaviour.

Bite rate by goats was then subjected to ANOVA using GLM (SPSS), to determine effects of *D. eriantha* hay supplements, protein-licks and interaction of *D. eriantha* hay and protein-lick supplements.

Results and Discussion

The interaction of *D. eriantha* hay and protein-lick supplementation had a significant effect on mean bite rate (bites.s^{-1}) by goats on the intake of *A. karroo* ($P < 0.011$). A combination of *D. eriantha* hay and protein lick (28.5 ± 0.015 bites.s^{-1}) resulted in significantly higher bite rates ($P < 0.011$) than control (*A. karroo* only) (25.2 ± 0.011 bites.s^{-1}) during feeding of goats on *A. karroo*. Results were consistent with findings from similar studies that showed supplementation of ewes with a high-protein source increased the time of feeding on sagebrush relative to non-supplemented ewes. There were significant interaction effects of *D. eriantha* hay and protein-lick supplements on bite rate (bites.s^{-1}) of *A. karroo* by goats ($P < 0.05$).

Acacia karroo is known to have tannins which reduce the nutritional quality of plants, and also act as a defence against herbivores. However, this study shows that goats were able to utilize and feed more on *A. karroo* when supplemented with both *D. eriantha* hay and protein licks ($P < 0.05$) than goats fed *A. karroo* and supplemented with protein licks, goats fed *A. karroo* and supplemented with *D. eriantha* hay and goats fed *A. karroo* only. Supplements are provided to help animals to better tolerate tannins in *A. karroo*, which was evident from the study where goats supplemented with nutritious protein licks and *D. eriantha* hay were able to better cope with condensed tannins present in *A. karroo* and utilize *A. karroo* as a source of feed.

Conclusions and Implications

Goats feeding on woody plants cannot avoid ingesting secondary compounds. However, supplementation with protein licks and *D. eriantha* hay positively influenced the utilization of chemically defended woody plants. Thus, browsing by goats may be used as an effective way to control encroaching woody plants in semi-arid savannas.

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Effectiveness of Burning and Glyphosate in Enhancing Seeding Establishment in *Agropryon cristatum*

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Key words: Crested wheatgrass, range improvement, fire, chemical, basal area.

Introduction

Crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] has been established on approximately 10 to 26 million acres (3.2-10.4 million ha) in the western U.S. (Zlatnik, 1999). Crested wheatgrass is drought tolerant, palatable and easy to seed which resulted in widespread use both for forage and conservation purposes. However, crested wheatgrass has been reported to decrease plant (Henderson and Naeth, 2005) and avian (Sutter and Brigham, 1998) diversity compared to native mixed grass prairies. Therefore, there is interest in techniques that can be used to restore more native species in crested wheatgrass dominated communities.

Materials and Methods

The research location was located in Perkins County, South Dakota, USA (45° 40'24.40" N, 102° 100'01.91" W) on the Grand River National Grassland operated by the US Forest Service. Vegetation was dominated by crested wheatgrass with an understory of blue grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths].

In spring of 2008, three blocks were randomly located on clayey ecological sites at the research location. Six plots (18.3x27.4m) within each block were identified and three of the six plots in each block were burned and the other three left unburned. Three different treatments were randomly assigned to the three plots in the burned and the three plots in the unburned portion of each block. The treatments were 1) seeding with a native grass mixture followed by spraying with glyphosate (SEEDCHEM); 2) seeding with native grass mixture only (SEED) and 3) an unseeded control (CON).

Burning was done April 17, 2008. Native grass mixtures were seeded on May 12, 2008 using a no-till grain drill. Plots were sprayed on May 20, 2008 which was after seeding but prior to seedling emergence. In July of 2009 and 2011, 10-point frames were used to determine species composition. One hundred frames were sampled in each plot (1000 points). Using total number of vegetative hits the relative species composition was determined for native grasses (NG), native forbs (NF), introduced grasses (IG) and introduced forbs (IF). In July 2009 and 2011, biomass was clipped within four 0.125- m^2 quadrats in each plot. Biomass samples were dried at 50° C, dried for 3 days and then weighed. Data was analyzed as a split-plot with burn as the main plot factor and treatment as the sub-plot factor using PROC GLIMIX (SAS). Treatment means were considered significantly different at $P \leq 0.10$.

Results and Discussion

The objective of the project was to evaluate methods to decrease the amount of the introduced grasses and increase the amount of native species in existing crested wheatgrass stands. Native grasses (NG) made up a relatively small proportion of the relative species composition and there were no differences between burns or treatments. NG averaged 9.9% and 8.9% of the relative species composition in 2009 and 2011, respectively.

There were differences in IG between the treatments (Fig. 1A). IG was a significantly lower percent of the relative species composition in the SEEDCHEM compared with the CON. However, IG was similar for burned and unburned plots (81% and 77% of the relative species composition for unburned and burned, respectively).
Introduced forbs were a relatively minor part of the relative species composition and there were no significant differences between treatments or burns. IF made up 5% and 1% of the relative species composition in 2009 and 2011, respectively.

Amount of native forbs (NF) in the species composition had significant burn by treatment and burn by year interactions. The SEEDCHEM treatments in the unburned plots had over twice the percent NF in the relative species composition compared to burned plots (6.8 vs. 19.3 ± 4.7% for the unburned and burned plots, respectively; P=0.0202). NF in was significantly greater in the unburned plots in 2011 compared to the burned plots (9.8 vs. 3.7 ± 3.2% for the unburned and burned plots respectively, P=0.0653).

There were no differences in biomass productivity between years and burned and unburned plots. However, biomass productivity was significantly greater in the SEEDCHEM treatments compared to the SEED treatment (Fig. 1B).

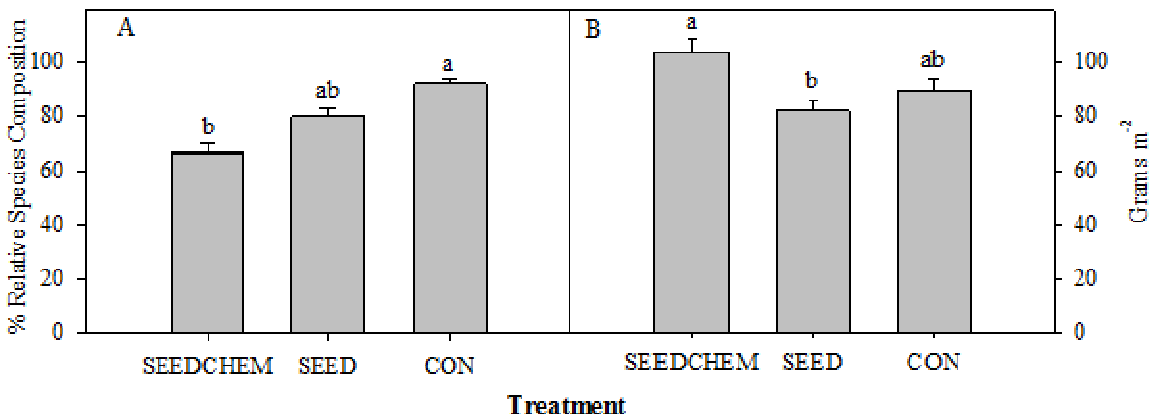

Figure 1. Differences between restoration treatments for A) the percent introduced grasses (IG) in the relative species composition and B) total biomass. Different lowercase letters over bars in each graph indicate significant differences in treatment means at P≤ 0.10.

Conclusions and Implications

Restoring native grasses in crested wheatgrass stands is difficult and expensive which makes finding effective restoration strategies important. The most effective strategy in this study was seeding followed by an application of glyphosate regardless of whether or not fire was used. This option may be attractive to managers in regions where burning is contentious. However, fire can provide other ecological benefits which were not measured in this study. Land managers should be aware of these tradeoffs when developing a restoration strategy.

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Characterization of the Genetic Structure of a Poisonous Forb *Oxytropis ochrocephala* by SSR Markers

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Key words: *Oxytropis ochrocephala*, SSR marker, genetic diversity, population structure

Introduction

Oxytropis ochrocephala is one of the most hazardous locoweed species distributed extensively on grasslands of western China. Furthermore, it is becoming invasive by replacing local forage grass species in natural grassland plant communities. Understanding the genetic structure of invasive plants is important in elucidating their evolutionary history and migration route, and help in explaining the success of invasiveness and predicting its expanding potential. In addition, phylogenetic characterization can be useful in analyzing the effect of human facilitation on spread and thus aid in proper strategic management (Hagenblad *et al*., 2015). In this study, we employed SSR (Simple Sequence Repeat) markers to evaluate the genetic structure of *O. ochrocephala* across western China.

Materials and Methods

A total number of 368 plants of young leaves were collected from 33 sites (n=5-15 for each site) in Ningxia, Gansu, Qinghai, Sichuan Provinces and Tibet from 2012 to 2015 during flowering season and plant genomic DNA extracted. A previous available transcriptomic database was employed for SSR mining and primer design (He *et al*., 2015) using MISA and Primer3. In a preliminary experiment, 16 out of 80 randomly selected primer sets showed high polymorphism and reproducibility. PCR were performed using these 16 primer sets and 368 DNA samples, and amplicons were examined and scored on an ABI-3700 sequencer. Individual-based population assignment was used to identify differentiated genetic clusters using the Bayesian assignment clustering method implemented in STRUCTURE. A phylogenetic tree based on Nei's genetic distance was constructed using the Neighbor-joining method (NJ) using Powermarker with 1000 Bootstrap replicates. AMOVA analyses and Differentiation index (Fst) were performed using ARLEQUIN.

Results and Discussion

Potential genotype clusters (K) were tested from 1 to 15, and the most likely K value equals to 2 by comparing lnP(D). Thirty-three *O. ochrocephala* accessions from various geographical locations were assigned (K=2, Figure 1, Panel A). Accessions from Ningxia, Qinghai and most of Gansu Provinces (red) in the North clustered into one genetically distinct group, while accessions from Sichuan (green) in the South formed another. In the intermediate area of the two groups, accession of GS6 and SC6 showed an admixed pattern of the two genetic divergences, indicating proper genetic communication. Accession from Tibet (XZ1, far left corner, Figure 1, Panel A), which is geographically isolated from both the groups, has genetic consistency to the North divergence. It is likely that the similarity between XZ1 and the North divergence arose from herders transferring from one area to another, given that the anatomic structure of mature *O. ochrocephala* seed pods can facilitate the seeds to be carried over by sheep or cow (personal observation). A phylogenetic tree was also constructed (Figure 1, Panel B), and similar pattern of genetic structure was observed. A bootstrap value of 92 indicated that the clustering is highly reproducible. Based on the genetic distance within the two distinct genetic groups, it is possible that the two groups may have evolved separately at the mean time.

We further calculated Fst for genetic variation. Our results indicated that overall genetic differentiation of *O. ochrocephala* is highly significant (Fst=0.276, P<0.0001). In comparison, 27.6% of the overall genetic variation is attributed to between-population variation, while 72.4% is within-population variation. It is interesting that genetic distance is significantly correlated with geographical distance and elevation (both P<0.01), indicating that gene flow are limited from geographically isolated accessions, and environmental temperature, which is reverse proportional to elevation, may contribute to the evolution of *O. ochrocephala.*

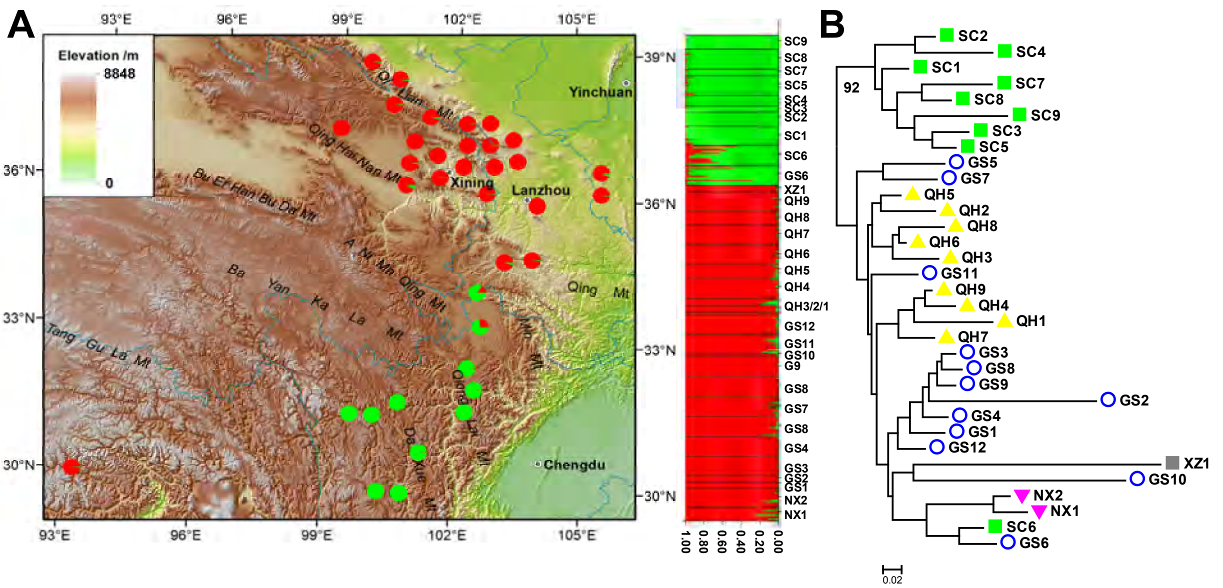

Figure 1. Genetic structure of *O. ochrocephala* in China. A: Geographical distribution of 33 *O. ochrocephala* accessions and their genetic assignment using STRUCTURE (Bayesian analysis). Green and red colours indicate different genetic clusters when K=2. The proportion of each cluster in every accession was represented in pies (left, panel A) or bars (right, panel A). B: Phylogenetic tree (Neighbor-joining) constructed base on Nei's genetic distance. Different colours and labels indicate accessions from five different provinces in China (SC=Sichuan, QH=Qinghai, GS=Gansu, NX=Ningxia and XZ=Tibet).

Conclusions and Implications

Genetic structure analyses of *O.ochrocephala* showed two divergent groups. Containment strategies should be developed to restrict accessions in the intermediate areas between the two genetic groups from accumulating further genetic diversity.

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Vegetation, Soil, and Groundwater Interactions in Western-Juniper Dominated Landscapes

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Key words: Western Juniper, hydrologic connectivity, soil moisture, groundwater

Introduction

The relationships between water and vegetation distribution are highly impacted by the ongoing shift from shrub steppe and grassland to woodland dominated landscapes. The significant expansion of juniper (*Juniperus* spp.) woodlands throughout rangelands of the western U.S. during the last two centuries has disrupted important ecological functions and hydrologic processes occurring on these water-scarce landscapes. Hydrologic connectivity between surface water and groundwater is the most important characteristic related to short- versus long-term water management, and often it is poorly understood or characterized. Hydrologic connectivity, that is, surface water and groundwater flows throughout the watershed, may be an important determinant of ecosystem resilience. The connections between upland water sources, groundwater, and downstream valleys influence the amount of water available to multiple natural processes that drive many ecosystem services (e.g., forage provisioning, wildlife habitat, recreation, etc.). Our long-term ongoing research study in central Oregon has provided critical information regarding vegetation and hydrology interactions in western juniper dominated landscapes.

Materials and Methods

This watershed study comprises an area of approximately 1000 acres and includes one treated (~ 90% juniper removal), one untreated watershed, and a riparian valley where both watersheds drain into. The wet season in the study area occurs between September and April, with the majority of the precipitation occurring as snowfall. Beginning in 2003, the study site has been instrumented to record weather, soil moisture, and groundwater level fluctuations. One weather station has been installed in each of the two watersheds. Four tipping bucket rain gauges have been installed at selected locations across the two watersheds. Five soil moisture stations with vertical nests of soil moisture sensors installed at 20, 50, and 80 cm depth were located at upland and valley bottom locations in both watersheds. In addition, 16 monitoring wells have been installed at the outlet of the two watersheds and in the riparian valley. Also, different field campaigns have been conducted to assess vegetation features such as canopy cover and species frequency.

Results and Discussion

Results from this study show restoration of hydrologic flows in the form of greater soil moisture levels and an increase in shallow groundwater residence time in areas where juniper tree density had been reduced (mechanical removal) when compared to adjacent, heavily encroached, watershed. Study results indicate significant amounts of rainfall are intercepted by juniper canopy (up to 70%). In general, greater soil moisture content and an increase in shallow groundwater residence time were observed in the watershed where juniper tree density had been reduced. Results from an intensive monitoring campaign (2014-2015) of top soil moisture showed there was a significant, although relatively small, difference in soil moisture content in treated vs untreated watersheds. Also, vegetation data collected showed that canopy cover significantly affected soil moisture levels across dry and wet seasons. Perennial grass cover was positively correlated with changes in soil moisture, whereas juniper cover was negatively correlated with soil moisture content. Shallow groundwater response observed in upland and valley monitoring wells indicate there are temporary hydrologic connections between upland and valley locations during the winter precipitation season. Shallow groundwater recharge during the winter season showed a 4 to 6 week delayed response in wells located in a downstream valley when compared to upland well locations. An isotope trace analysis showed similar signature for upland and valley well locations, indicating there are temporary hydrologic connections through the groundwater system.

Conclusions and Implications

Study results provide valuable information towards understanding ecological and hydrological relationships in western juniper dominated landscapes. Study findings can provide useful information to land managers when planning to manage juniper woodlands for multiple ecosystem benefits including forage production and water availability.

Application of Remote Sensing Techniques for Detection of *Hypochaeris radicata* L.

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Key words: Classification model, grassland ecosystem, photosynthetic pigments, spectra characteristic

Introduction

In recent years, exotic plants have spread throughout the semi-natural grasslands and artificial grassy meadows in Tashirotai on the north foot of Hakkoda in Towada Hachimantai National Park. In particular, Flatweed (*Hypochaeris radicata* L.), which was introduced unintentionally, is established in various places. Non-native species in Tashirotai were assumed to be damaging the native species landscape. Understanding the distribution of *H. radicata* is necessary for identifying the impact of *H. radicata* on the ecosystem in Tashirotai. Remote sensing is considered a useful method for determining the distribution of *H. radicata* in the vast Tashirotai. The long-term objective of this study is to estimate the spatial distribution of *H. radicata* on meadows in the Tashirotai area. In this paper, (1) we describe the relationship between spectral properties and physiological characteristics of *H. radicata* and grass. Additionally, (2) we examine the possibility of grass species discrimination between *H. radicata* and grass. Treatment of leaves dring

Materials and Methods

The target plant species are *H. radicata* and grass, namely, orchardgrass (*Dactylis glomerata* L.) and timothy (*Phleum pratense* L.). These plants often grown in the meadow of Tashirotai. The leaf parts of these plants are sampled from the meadow of Tashirotai and from grassland of Kitasato University.

Spectral measurement and development of classification model

Spectral data were measured using a hyperspectral camera (ImSpectorV10, JFE Techno-Research, Japan) and spectrometer (C9913GC, Hamamatsu Photonics, Japan) under illumination of halogen lamps (500 W) within 2 hours of harvesting the leaf. The wavelength range of the hyperspectral camera is 400–1000 nm (resolution: 6 nm), and that of the spectrometer is 900–1700 nm (7 nm resolution). The reflectance data of the spectrometer were measured 100 times for each sample (a single leafy layer of *H. radicata* and grass) and averaged for spectral analysis. The classification model between *H. radicata* and grass was developed using linear discriminant analysis. The explanatory variables for the model were simply selected from all wavebands by stepwise selection using Wilks' lambda.

Observation of chlorophyll quantification and cell structure

After the spectral data were measured, the photosynthetic pigment concentration and cross-sectional structure of the leaf were observed. The pigments of the plant leaves were extracted using N, N-Dimethyl formamide, and photosynthetic pigment concentrations were measured from the absorbance (480.0 nm, 646.8 nm, 663.8 nm, and 750.0 nm) using ultraviolet and visible spectroscopy (UV mini 1240, Shimadzu, Japan). Subsequently, the concentrations of chlorophyll and carotenoid were calculated using the formula of Wellburn (1994). The cross-sectional structure was observed with an optical microscope (BX-51, OLYMPUS, Japan), and the optical microscope image was analyzed using image analysis software (micro MAGIC, micro net, Japan).

Results and Discussion

The reflectance characteristics in the visible and near-infrared (NIR) band are the product of the integrated effects of photosynthetic pigment, age, moisture, and tissue in the leaves; of these, the major factor is the photosynthetic pigment (Nakaji 2009). The concentration of chlorophyll (i.e., photosynthetic pigment) in *H. radicata* was 38.3 ± 1.87 µg/mL, and in grass it was 43.7 ±4.83 µg/mL. The difference between *H. radicata* and grass in chlorophyll was statistically relevant (p <0.05); furthermore, the carotenoid concentration between them also differed (p <0.05). Therefore, the spectral characteristic in the visible band were reflected in the photosynthetic pigment of the leaves. The cross-sectional structure of *H. radicata* and grass are different: while the leaf surfaces on these species are all hairy, the hair on *H. radicata* is very hard and thick. The thickness and epidermal thickness of these species were statistically different (p <0.05). Therefore, we presumed that the spectral characteristics in the NIR were reflected in differences of the internal structure of the leaves.

The spectral data of *H. radicata* and grass in the visible and NIR bands showed similar tendencies to the reflectance characteristics of the plants. The reflectance data of *H. radicata* was approximately 10% lower than grass in the water absorption band (1450 nm). Additionally, the reflectance of *H. radicata* was lower than grass through the entire waveband. We presume that the spectra are reflected in leaf characteristic such as photosynthetic pigment, leaf surface, and structure of the leaf. Most of the wavebands selected for the classification model belonged to the green or NIR range. Including additional wavebands increased the identification success rate until the number of variables reached six; thereafter, it became almost constant (approximately 94 %). In this study, six explanatory variables (712 nm, 662 nm, 692 nm, 702 nm, 561 nm, and 752 nm) were manually determined for the classification model from the change in success rate. In the validation result, the success rate of the model was 94.2 %. This study demonstrated the possibility of classification between *H. radicata* and grasses using reflectance data. The selected wavebands by stepwise selection belong to a region that depends on the wavelength selectivity of the photosynthetic pigment. The concentration of photosynthetic pigment is strongly reflected in classification between *H. radicata* and grasses.

Conclusions and Implications

We considered the difference of spectral characteristics of *H. radicata* and grasses and examined the possibility of classification based on reflectance data. Differences between them in photosynthetic pigment concentration and morphological characteristics were observed, and their reflectance data were different. The classification model was developed using six wavebands that belong to a region in which the wavelength selectivity of the photosynthetic pigment is strong. The success rate of the model was 94.2 %. This study demonstrated the possibility of classification between *H. radicata* and grasses using reflectance data.

Acknowledgements

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Preliminary Framework for Mapping and Monitoring Invasive Weeds in the Savanna Grasslands of Western Highlands, Cameroon

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Key words: invasive weeds, mapping spatial distribution, monitoring, susceptibility, land use change

Introduction

Rangelands cover about 60% of the Western Highlands of Cameroon with its original Savanna grasslands increasingly infested by noxious and invasive weeds. Significantly changing is the plant species composition dominated by *Hyparrhenia* grassland. The high plateau is becoming more susceptible to invasion by invasive weeds (Ndzeidze 2004). Natural variables like grazing and fire suppression have inevitable tantamount perturbations and resurgence of unwanted species. With close to a hundred years of open uncontrolled ranging, the grazing history has passed from pastoral nomadic type to sedentary grazing in communal lands. Rangelands in the Western Highlands are a very important natural resource constituting the prime socio-economic and ecological backbone of this region. Increasingly unchecked, invasive weeds are spreading rapidly and posing threats to rangeland stability and continued livestock production. It's quite evident from the thousands of undocumented seriously damaged heavily infestation grazing areas. Our research is a preliminary survey to map and monitor some of the most pronounced and rapidly spreading invasive weeds never mapped before. No survey has ever been conducted, thus the extent of infestation is only known by estimation. Rangelands here as anywhere in Cameroon are considered as no man's land and classified as state lands that are formally recognized as communal lands meant for use by all and to which different individuals, groups or communities attribute variable more or less appreciative perceptions (Mairomi, 2012, Heifer Project International, Cameroon 2001).

Material and Method

The methodology involved secondary sources from existing literature found in the Regional and Divisional Delegations of the Ministries of Livestock, Fisheries and Animal Industries (MINEPIA), Agriculture and Rural Development (MINADER), Environment and Nature Protection. While primary sources comprised of primary field work, field visits to the study area during which officials of related offices and land users in the study area were contacted. Information collected was by direct field observation, administration of questionnaires and granting of interviews to resource persons. The data collected played a great role in result analysis. First we mapped and tracked weeds locations with GPS point features with the aid of local grazers. Transect quadrants were used to study the edaphic conditions, climate, forage resources and land use in response to seasonal changes in weather and their effects on vegetation productivity. The study was carried out during the main growing seasons at the time when most of the grass species are at the flowering stages. Rangeland health evaluation is best in grasslands between the months of June and July. Field work was done with assistance from a botanist. Plants with a full flowering head and other vegetative parts were collected and identified either by a botanist in the field or at the National Herbarium, Yaounde. All the identified grass species were classified into highly desirable, desirable and less desirable based on the information obtained from the pastoralists and the insights from livestock or veterinary technicians and other literature.

Results and Discussion

Our study reveals rangelands here are extremely susceptible to invasion by exotic weeds. This is due mainly to variables like grazing and fire. There are many exotic weeds but the most problematic are *Pteridium aquililium* in the High plateau and *Chromolaela odorata* in lowland areas. Other aggressively invading species are *Sida rhombiforlia*, *Microglosa angolensis, Vernonia auriculifera, Starchitapheta cayenensis, Saturejasp* and some other *Asteraceae*. Bioclimatic factors greatly determine susceptibility to spread and other risks factors (roads, rivers, fragmentation) determined patch size and density. Weed patch density was highest closest to roads as risk factors. The existing grasses in the study area include *Hyperrhenia rufa, Hyperrhenia diplandra, Hyperhenia bracteata, Hyperrhenia mutica, Pennisetum purpereum, Bracharia mutica, Bracharia ruziziensis, Andropogon gayanus, Andropogon festaccitoris, Sporobuluspyramidalis*or Giant rat's tail grass, *Sporobulusafricanus, Imperata cylindrical, Loudetiaphragmitoides (Gramineae)*. Other herbs *include Biophytum petersianum, Borrrenia scabra, Eulophia impatiens, Pteridium aquilinum, Tephrosia pedicellata, Mellilnis minutiflora, Setaria sphacelata, Paspalum commersonii.*

Conclusions

Pastoral land tenure requires laws that are workable, inclusive and adapted to local values. In fact, legislative dispositions should be acceptable and can be adopted in function of cultural and socio-economic context. Rangeland improvement and integration can be sought for broad-base poverty reduction and livelihood improvement, sustainable management and better community integration. Apart from grazing, rangelands here sustain large dynamic ecosystems supporting varied wildlife and domestic livestock. However, productivity and long-term economic viability of activities is undermined and threatened by growing pockets of unwanted unpalatable vegetation (weeds) at the expense of a palatable herbaceous cover. It's worth noting that a significant difference in C. *odorata* abundance exists between intense risks zones (rangeland fragmentation or croplands, roads, streams) and other further rangeland zones. In fact, besides grazing as a disturbance, cropland within range and streams, proximity to roads in particular projected greater higher relative levels of abundance and therefore an indicator of a strong correlation between risks and spread corridors.

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Bromus tectorum Abundance on Northern Great Plains Foothills Rangelands Is Related to Disturbance, Vegetation Diversity, and Site Characteristics

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Key words: Cheatgrass, Montana, Invasive Plants, Northern Great Plains

Introduction

Cheatgrass (*Bromus tectorum* L.), is an invasive, exotic annual grass found throughout North America. Cheatgrass can alter ecological dynamics through its impact on fire regimes and its invasion has initiated an ecological threshold breach in many rangeland systems (Davies 2012). Cheatgrass alters fuel conditions and decreases fire return intervals (Whisenant 1990) which precludes native species re-colonization. Cheatgrass invaded sites are ecologically degraded with reduced diversity, forage production and quality, and habitat value (Pellant 1996). Cheatgrass has been extensively studied in the Great Basin, where the majority of precipitation comes in winter and early spring, and the vegetation consists primarily of cool-season species. However, very little research has been performed in the Northern Great Plains region, where most precipitation comes in spring and summer, supporting a mixture of cool- and warm-season plant species. As a result, the ecological impacts of cheatgrass in the Northern Great Plains are unknown. In order to better understand cheatgrass ecology in this region, we assessed cheatgrass invasion and abundance in the distinct climate of the Northern Great Plains.

Materials and Methods

Fifteen randomly selected plots were established at each of two locations, one in north-central Montana (Thackeray Ranch, 48° 21' N, 109° 36' W), and the other in southwest Montana (Redbluff Ranch, 45° 30' N, 111° 30' W). Each location exists within foothills rangelands with the vegetation at the Thackeray Ranch dominated by rough fescue (*Festuca campestris*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) while the vegetation at the Redbluff Ranch was dominated by Idaho fescue (*F. idahoensis*) and bluebunch wheatgrass. At each plot we examined cheatgrass abundance, biotic and abiotic site characteristics, and disturbance indicators including vegetation cover and community composition, soil texture, ground squirrel activity, livestock presence, slope, aspect, elevation, and ecological site. Aspect values were sine and cosine transformed to reflect north-to-south (cosine of aspect) and east-to-west (sine of aspect) gradients. Relationships among cheatgrass and the site and disturbance characteristics were evaluated using generalized linear mixed effects regression models. Models incorporating combinations of explanatory variables were ranked by AIC and the importance of each variable determined by the model rank and number of models that included that variable (Importance values closer to 1 indicate increased importance). Models were run separately for Thackeray and Red Bluff ranches.

Results and Discussion

The explanatory variables retained in the best predictive models for each location are presented in Table 1.

Red Bluff

Additional precipitation received in 2015 likely contributed to increased cheatgrass abundance relative to 2014 and was likely responsible for the importance of the year variable in our models. Our data indicated that flatter slopes and burrow activity were associated with increased cheatgrass abundance and these two may be related given ground squirrel preference for flatter slopes (Quanstrom 1971) and the increase in soil disturbance and opportunity for plant invasion associated with ground squirrel burrowing activities. Simpson diversity index was negatively associated with cheatgrass abundance, and this relationship was maintained even when cheatgrass was excluded from the diversity calculations. Greater vegetation diversity increases niche occupancy in space and time and this likely hinders cheatgrass invasion or limits its abundance by preventing access to soil resources.

Thackeray

Cheatgrass abundance was higher on drier, south-facing slopes where it may be more competitive because of the limited soil moisture. Burrow activity appeared to have a negative relationship with cheatgrass abundance, however this association was probably due to two unusual plots that had extensive burrowing in 2014 but much less burrow activity coinciding with overall increases in cheatgrass abundance in 2015. Exposed soil was inversely related to cheatgrass abundance, likely the result of two plots having relatively high levels of exposed soil and also because cheatgrass cover is vegetative cover and thus, not exposed soil. Loamy and rocky ecological sites were associated with elevated cheatgrass abundance. The single loamy site had the highest fecal counts and we expect that with disturbance, cheatgrass can occupy productive sites that would otherwise support a robust perennial community. Rocky sites tended to have deep, well-developed soils but abundant surface rock and skeletal soil properties which may provide more droughty conditions that appear favorable for cheatgrass. Sites classified as droughty exhibited limited cheatgrass abundance, and in spite of the site classification, which indicates skeletal soils, these sites were on steep and north facing slopes which likely limited disturbance while maximizing effective soil moisture.

Table 1. Importance values for explanatory variables associated with cheatgrass abundance. Importance values are calculated as the sum of the Akaike weights over all models including the explanatory variable.

Redbluff Ranch		Thackeray Ranch	
Variable	Importance	Variable	Importance
Year	1.00	Ecological Site	1.00
Burrow Cover	1.00	cos(aspect)	0.98
Slope	0.66	Exposed Soil	0.90
Diversity	0.60	Burrow Cover	0.72

Conclusions and Implications

In ecosystems similar to Red Bluff, rodents such as Richardson's ground squirrels may indicate sites ideal for cheatgrass invasion and proliferation, and may contribute to cheatgrass abundance by providing opportunities for invasion through soil disturbance. Managers should encourage perennial vegetation diversity through grazing management or other tools to prevent cheatgrass from finding suitable niches. On sites similar to Thackeray, south-facing slopes and ecological sites that limit effective soil moisture appear less resistant to cheatgrass invasion and should be emphasized in cheatgrass monitoring activities. Moreover, cheatgrass may colonize disturbed areas where soil is exposed, and can form robust monocultures on productive sites that are disturbed.

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Impacts of Mowing Treatments on Smooth Bromegrass (*Bromus inermis)* Belowground Bud Bank

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Key words: cool-season perennial grass, bud bank, mowing treatment, rhizomatous

Introduction

Introduced in the 1880s for improving forage production and controlling soil erosion, smooth bromegrass (*Bromus inermis* Leyss) has invaded and is threating numerous native prairie ecosystems and wildlife habitats in the Northern Great Plains. Land managers of the mixed-grass prairie ecosystems currently spend significant resources attempting to control invasive species and restore native grasslands with various management strategies including grazing, prescribed burning, herbicide application and seeding native species. Unfortunately, many studies have showed that such management efforts have minimal short-term effects. Without sustained effort, persistence and resurgence of smooth bromegrass is inevitable.

Such invasiveness and persistence may come from two primary sources: seed bank and bud bank. Since few grass seeds persist in the soil more than five years, the persistence of the aboveground component of perennial grasses population persistence is strongly driven by tiller recruitment from the belowground bud bank. Growing evidence demonstrates that the belowground bud banks play a fundamental role in local plant population persistence, structure, and dynamics (Benson and Hartnett 2006). Studying the dynamics of bud banks provides insight into plant community assembly and composition (Rusch et al. 2011), resistance to and resiliency following drought, fire, and or grazing (Vanderweide and Hartnett 2015, Russell et al, 2015). Since bud banks serve as reservoirs for recruitment of future aboveground tillers, understanding the role of the belowground bud bank in regulating the persistence of invasive species in the response to management strategies will lead to adaptive management strategies that sustain long-term control effectiveness. Our objective was to examine smooth brome belowground axillary bud and rhizome production for smooth bromegrass in response to different mowing frequency treatments.

Materials and Methods

This study was conducted at the Oak Lake Field Station in eastern South Dakota, USA (44° 30' N, 96° 31' W). Mean annual precipitation is 583mm and mean annual temperature is 5.9°C. Remnant tallgrass prairie vegetation is dominated by a variety of species such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), sideoats grama (*Boutelua curtipendula*), and purple coneflower (*Echinacea angustifolia*). Our experiment was composed of 4 mowing treatments (no-mowing control, mowing once, twice, or three times per growing season) in a randomized complete block design with four replications in 2013 and 2014 on a stand of smooth bromegrass that was at least 25 years old. Each of four 6m x 6m blocks dominated by smooth bromegrass were divided into 4 plots (3m x 3m), each of which was randomly assigned a treatment. Mowings were conducted when the uppermost node of elongated tillers reached mowing height at 6 cm. For all three mowing treatments the first mowing was done in early June of each year. The second and third mowing treatments were performed again in mid-August. The 3-mowing treatment was mowed for a final time in late October. Developmental stage and tiller density within two 0.1-m^2 sub-plots were recorded before each treatment. Three tillers were randomly selected from each treatment plot and excavated before treatment. For each tiller, the total number of proaxis nodes and total number of buds and their viability were determined. In 2015, three soil cores (10-cm dia. x 10-cm depth) were taken from each plot to evaluate the rhizome production in terms of rhizome length and mass separately in June and October.

Results and Discussion

Mowing treatments significantly reduced the number of proaxis nodes per tiller (Fig. 1A), the number of outgrowth tillers per tiller (Fig. 1C), and viable rhizome biomass (Fig. 1D). The number of total buds per tiller (Fig. 1B) significantly declined only under mowing once at the boot stage. Increasing the frequency of mowing treatments had little impact on bud bank reduction after two consecutive two years. However, viable rhizome biomass decreased as frequency of mowing increased during the growing season (Fig.1D).

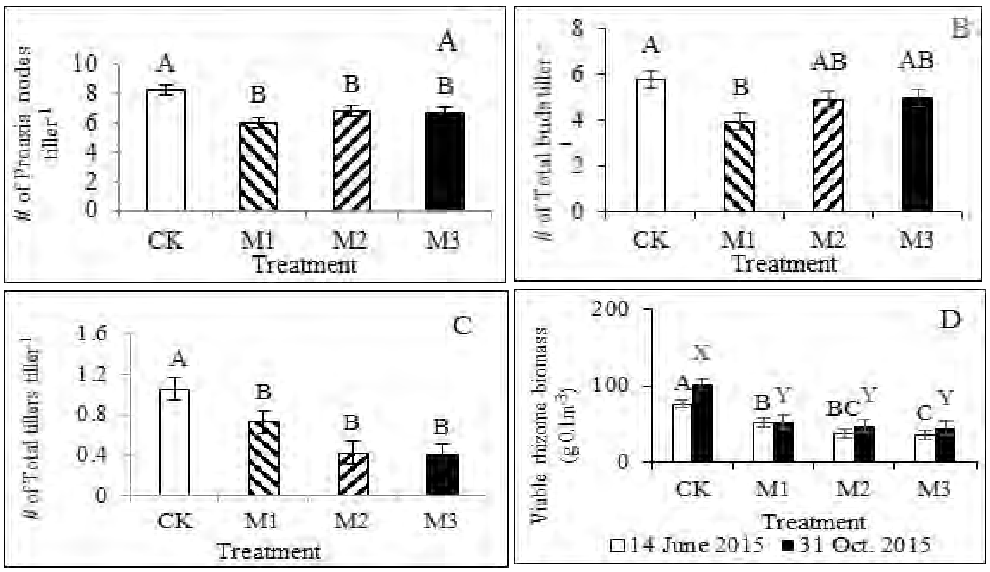

Figure 1. Number of proaxis nodes per tiller (A), number of total buds per tiller (B), total outgrowth tillers per tiller (C), and total viable rhizome biomass (D) in response to mowing treatments. CK=no-mowing control, M1= mowing once, M2=mowing Twice, M3=mowing three times. Different letters indicate difference among treatment means at p<0.05. Bars indicate the standard error.

Conclusions and Implications

Defoliation at the most vulnerable growth stage can effectively hinder axillary bud formation on the proaxis, tiller recruitment, and reduce food reserve in the rhizome of perennial grasses. Our results from this study clearly demonstrated that repeated mowing treatments reduced axillary bud populations and rhizome biomass, suggesting they could form the basis for a long-term management plan.

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Predicting the Potential Distribution of *Eupatorium adenophorum* in Response to Climate Change in China

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Key words: ecological niche model, ecological niche factor analysis (ENFA), prediction, potential probability, displacement, management

Introduction

Eupatorium adenophorum is one of the most invasive plants in large areas of grassland in China. Since its invasion in 1940s, it has caused tremendous ecological and economic losses and contributed to the decline in the numbers of grazing animals and indigenous plants and resulted in a loss of biodiversity (Sun *et al*., 2004). The traditional prevention and control measures are not effective and the expansion of the weed has not been slowed (Zheng and Ma, 2010). One reason could be that the expansion trend of *E. adenophorum* is not clarified and the potential invaded regions are not identified. Furthermore, the weed's responses to climate change have not yet been taken into consideration.

In this study, Maximum Entropy (Maxent) model (Jane *et al*., 2011) was coupled by the ecological niche factor analysis (ENFA) (Hirze *et al*., 2004) as a method for generating potential distribution patterns of *E. adenophrum* from the recent past to 2080s under different climate change scenarios, which will be fundamental to management of this problematic plant.

Materials and Methods

A total of 106 occurrences of *E. adenophorum* were collected using the Global Biodiversity Information Facility (GBIF) website (http://www.gbif.org/), and published literature. The recent and the future climate datasets (Scenario A1B, downloaded from the WorldClim database [http://www.worldclim.org]) were used to determine the climatic factors that limit the distribution of the *E. adenophorum* and determine its potential distribution to the climate change ENFA was coupled in the Maxent model. Mapping was done using the center movement route of *E. adenophorum* in response to climate change (Yue *et al*., 2011).

Results and Discussion

Integrating the score matrix of ENFA, percent contribution and Jackknife test, the results indicated that winter temperatures restrict the spread of *E. adenophorum* most. The Receiver Operating Characteristic curve with the area under curve value confirmed that it could successfully predict the potential distribution of *E. adenophorum.*

The prediction indicates that *E. adenophorum* mainly distributes in Yunnan, Guizhou, Guangxi, Sichuan provinces, and will spread to Tibet, Chongqing, Shananxi, Hainan by the 2080s. Accordingly, the area of likely to be invaded by *A. adenophorum* (L3) will expand from $8.73*10^4$ km^2 currently to $10.13*10^4$ km^2 in 2080s (Fig.Left). At present, the management cost of *E. adenophorum* is conservatively 1800 RMB per hectare, if not controlled now the management cost could reach 7.7 billion RMB in the 2080s.

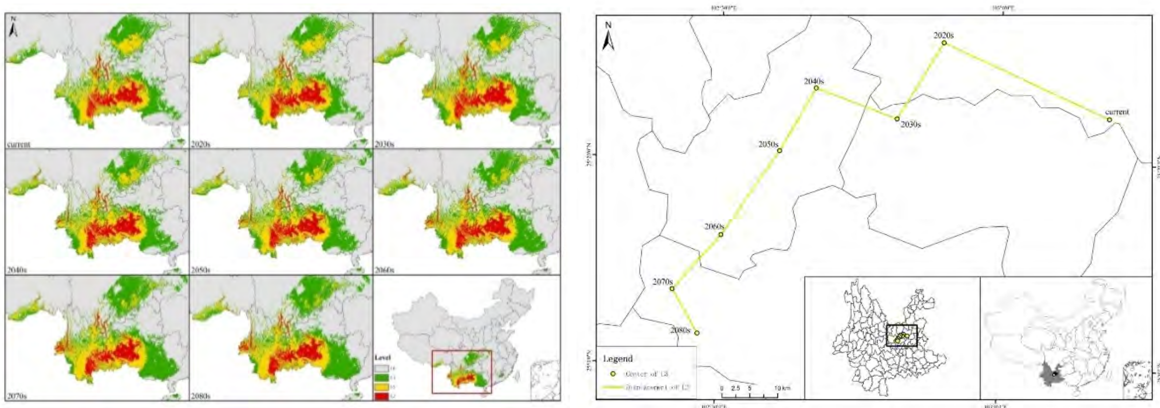

Figure 1. Left: Recent and future (2020s-2080s) predicted distribution of *E. adenophorum*. Note: the potential distribution probability was divided into 4 levels (L0-L3), with the probability of 0-0.3(least potential), 0.3-0.5(moderate potential), 0.5-0.7(good potential), and 0.7-1.0(high potential), respectively. Right: Center displacement of high potential probability from the recent to 2080s.

Conclusions and Implications

Former management measures include ecological restoration by competitive replacement and efficacy of biological control agents against *E. adenophorum*. However, without targeting critical areas, all these measures will be ineffective as they do not suppress the spread of *E. adenophorum* and fail to treat the regions that are most susceptible. Consequently, a great amount of money and other resources are wasted. Therefore, identifying the main invaded regions is fundamental in helping allocate resources to control and prevent further spread of the weed. In this study, by mapping the probable expansion from the recent past to 2080s, it is possible to trace the invasion route, locate the most vulnerable regions and take measures to control *E. adenophorum*. By mapping the center movement of the *E. adenophorum*, the center of most likely invasion (L3) will move 53 km southwest by the 2080s (Fig. Right). We hope that the confirmation of crucial constrains of expansion, the spreading route and the prediction of distribution regions can provide guidance for the prevention and control of *E. adenophorum*.

Acknowledgements

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Gap Size between Perennial Herbs as an Index of Cattle Grazing Impact across Rangelands of the Great Basin Sagebrush Steppe

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Key words: AUMs (Animal Unit Months), SEM (Structural Equation Modeling), Plant gaps

Introduction

Steppe communities worldwide may experience two coarse scale disturbances: fire and grazing. In the Great Basin, grazing has accompanied the establishment of the annual exotic grass, *Bromus tectorum* (L.) (Pyke et al. 2016). In the presence of *B. tectorum*, fire frequency increases to levels where non-sprouting native *Artemisia* L. (sagebrush) is extirpated. Identifying factors leading to site resistance to invasion by *B. tectorum* is crucial to sagebrush ecosystem sustainability.

Looking at grazing allotments in Oregon, Reisner et al. (2013) demonstrated that site resistance to *B. tectorum* is influenced by perennial herbaceous composition and distances between perennial herbs' canopies (gaps). Using a piosphere approach, perennial herbaceous cover and gap size were related to cattle grazing intensity. The study investigators tested the efficacy of using gaps between perennial herbs as an index of grazing impact on sagebrush steppe across the Great Basin. The conceptual hypotheses (Figure 15) was tested with a structural equation model (SEM) to account for correlations that might mask relationships of interest (Grace 2006).

Materials and Methods

The study area consists of the sagebrush steppe of Oregon, Idaho, Nevada, and Utah. We used Bureau of Land Management lands on loamy soils that experienced a single fire in recent history. In 2012 and 2013, 15 sites were visited, each within a single grazing allotment, covering a range of grazing intensity as represented by dung frequency (Knutson et al. 2014). Distance to water was used as an additional proxy for grazing intensity and measured in ArcMap 10.2 using a combination of 1-m resolution National Agriculture Imagery Program imagery and the National Hydrography Dataset (accessed 10 February 2016; http://nhd.usgs.gov). For each allotment, we obtained the animal unit months (AUMs) that were active or suspended and relativized them by the number permitted (estimated grazing capacity) from the Rangeland Administration System (accessed 1 December 2015; http://www.blm.gov/ras/). A minimum of three burned and three unburned plots at each site (99 plots total) were sampled.

Plots consisted of three, 50-m transects beginning 5 m from a central point and separated by 120°. All perennial vegetation and *B. tectorum* cover was estimated visually (to the nearest 1 %) within 0.5-m^2 quadrats at 10-m intervals along transects (15 quadrats per plot). Standard deviation of the average gap between perennial herbs was used as an index of grazing impact (Knutson et al. 2014).

SEM (AMOS v. 23.0.0) separated direct and indirect effects of AUMs (ratios of the number suspended due to fire over the number permitted and ratios of the number active over permitted), distance to water, dung frequency, and perennial herb cover on the ability of gaps to maintain site resistance to *B. tectorum* (Figure 15). Only half of the surveyed sites were burned and most, but not all, experienced some level of grazing before the fire. All variables included in the hypothetical model were standardized by their standard deviation.

Pathways were determined to be significant if P < 0.05. Only significant pathways were included in the final model.

Results and Discussion

The final model fit the data well (Chi-square = 6.3, df= 9, P = 0.71, Figure 15). Plots further from water had less dung and dung frequency was positively associated with increased gap size between perennial herbs. An increase in AUMs suspended (due to fire) was associated with a reduction in perennial herb cover. Increased perennial herb cover was associated with a decrease in gap size. Increased gap size was associated with increased cover of *B. tectorum*. The ratio of active to permitted AUMs did not show a significant relationship with perennial herb cover or gap size.

a.) b.)

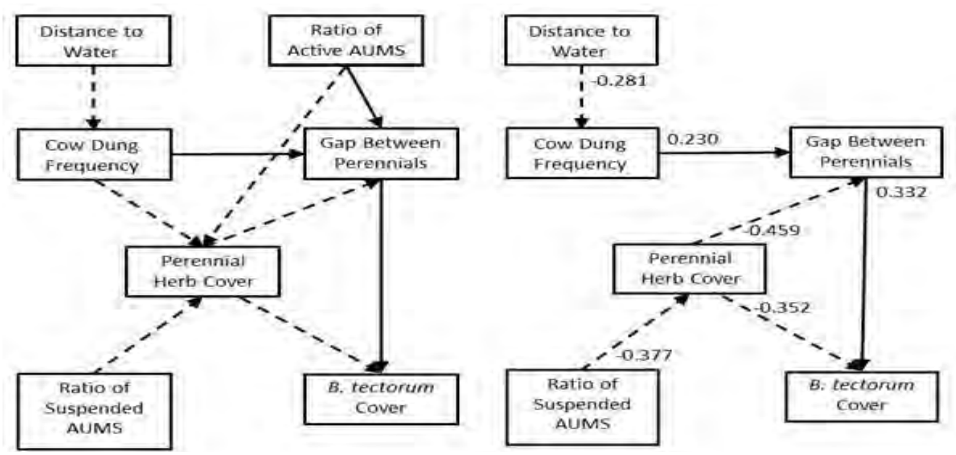

Figure 15. Structural Equation model diagrams of (a) hypothesized and (b) the most parsimonious models examining impact of cattle grazing, as represented by distance to water, dung frequency and the ratios of active and suspended over permitted AUMs, on perennial herb cover and the gap between perennials in maintaining site resistance to invasion by *Bromus tectorum*. Dashed and solid lines represent negative and positive relationships, respectively.

We found that grazing effects, as represented by gaps between perennial herbs, led to reductions in site resistance. Reductions in grazing pressure as represented by a ratio of the number of temporarily suspended AUMs over the number of permitted AUMs reflected a loss of vegetation cover on these sites that translated into reduced site resistance to *B. tectorum*. Management aimed at minimizing gaps between perennial herbs might be considered to minimize annual grasses and sustain perennial herbs.

Conclusions and Implications

This work confirms and expands to the Great Basin region, including burned sites, findings from Reisner et al. (2013) that size of gaps between perennial herbs can be used as an index of cattle impacts, specifically the ability of perennial herbs to maintain site resistance to *B. tectorum*. We demonstrate that this relationship holds when considering burned sites. Future work should aim to understand mechanisms by which increases in gap size between perennial herbs reduce site resistance.

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Behavior of Four Vegetation Parameters of Fodder Shrubs in a Silvopastoral System

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Key words: Aerial cover, growth, aerial phytomass, survival, fodder shrubs

Introduction

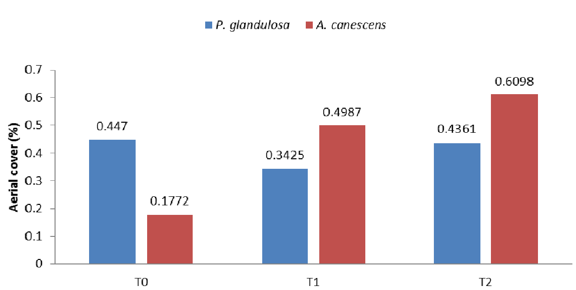
Plant species in arid areas of Mexico are mostly shrubs, which form bushes in combination with grasses, which constitute the rangelands. Permanent grazing and open land for cultivation have caused degradation of the original vegetation and invasion of undesirable species, which has reduced forage availability for livestock. Therefore, the objective of this study was to study the behavior of four parameters of vegetation in fodder shrubs in a silvopastoral system.

Materials and Methods

This experiment was carried out at El Cuervo ranch, in Parras, Coahuila, Mexico, located at 25° 04 '10 "N latitude and 101° 36' 08" W longitude, at an altitude of 1850 m above sea level. The climate is semi-arid with summer and fall rains and drought in winter and spring. The mean annual temperature is 19.2° C and 376 mm of annual rainfall. Study investigators planted and studied five shrub species: *Atriplex canescens, Prosopis glandulosa, Porlieria angustifolia*, *Agave scabra* and *A. atrovirens*. The parameters evaluated were: aerial cover using Canfield Line; Aerial phytomass with the Adelaide technique; growth, measuring the diameter of the stem and the length of the stalk. Survival was measured recording the number of live plants at the end of the year. When planting the shrubs, Enraizador Nutriment (Raizal 400®) (T1) and Humic substances (Humitrón 12L®) (T2) and the control (T0) were used. Data collection for aerial cover and growth took place in March, June, September and December; for aerial phytomass in September and survival in December. Data were analyzed using a completely randomized block factorial arrangement 3 x 4 x 3 (treatments, times and replications). An analysis of variance with Statgraphics Plus 6.0 statistical program was applied to assess the significance of treatments for each species. The survival of shrubs was analyzed using a nonparametric statistical test.

Results and Discussion

Results of only four species are presented as *Porlieria angustifolia* did not survive. The results showed no significant treatment effect on species, therefore, the data presented refer to numerical differences. Regarding aerial cover (Fig.1), T0 showed the best result for *P. glandulosa* and *A. atrovirens*; T2 for *A. canescens* and T1 for *A. scabra.*



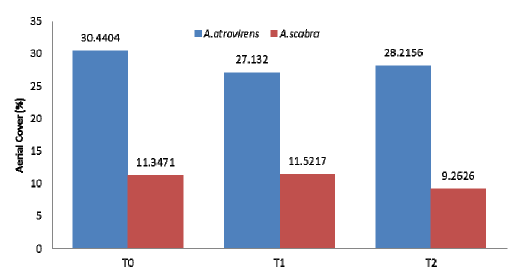
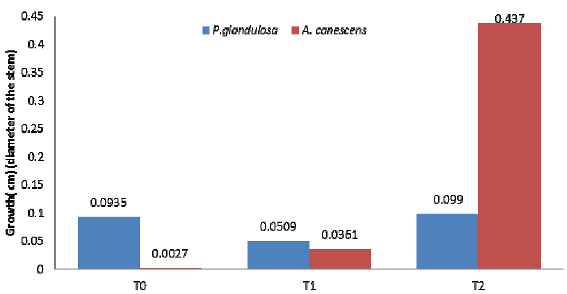


Figure 1. Means of aerial cover for the four shrub species studied.

Flores et al. (2002) report superior results, because in *A. atrovirens* and *A. scabra* increased in the control (T0) and T1 but not in T2. Both *P. glandulosa* and *A. canescens* decreased in the three treatments. Regarding growth (Fig. 2), T2 showed the best result in *P. glandulosa* and *A. canescens* and T0 and T1 for *A. atrovirens* and *A. scabra*, respectively. Leon et al. (2010) found that, for *A.atrovirens* T1 was the best treatment, followed by T0 and T2; in *A. scabra*, T2 was the best treatment compared to T1 and T0. For *A. canescens*, T2 gave the best results followed by T1 and T0 did not survive. For *P. glandulosa*, the order was the same as in this study: T2, T0 and T1. Regarding phytomass production, T0 showed the best results in *P. glandulosa*, *A. scabra* and *A. atrovirens,* and T2 gave the best results in *A. canescens*. As far a plant survival is concerned T0 and T1 did not differ for *P. glandulosa*; values obtained for T0 and T2 for *A. atrovirens* survival were the same; for *A. scabra* T1 was better. T1 and T2 offered the best results for *A. canescens*. Leon et al. (2011) found that the species with the highest survival was *A. atrovirens* with 75%.



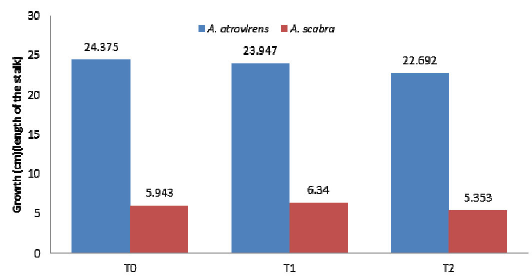


Figure 2. Means for growth displayed by the four shrub species studied.

Conclusions and Implications

The data showed no statistical significance between species or treatments, but numerical differences were detected, namely: For aerial cover, T0 was the best in two shrub species. For growth, T2 was the best in two shrub species. For three shrub species, T0 was the best regarding aerial phytomass. For plant survival, T1 was the best for *A. atrovirens* and *A. scabra.* Overall, T0 (control) was better than T1 and T2.

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4.5 Wildlife Conflicts and Commercial Wildlife Utilization Opportunities

Indigenous Nomadic Rangeland Practices and Its Impact on Rural Livelihood

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Key words: sustainable rural livelihood, Fulani herdsmen, migratory pattern, free rangeland practice

Introduction

Nomads have been an integral part of most African societies of which Ghana is no exception. In recent times, the free range practices by these Nomads have impacted negatively on rural livelihoods. Fulani herdsmen as they are called herd different types of livestock including sheep, goats, cattle, horses, donkeys, or camels hence they require grazing fields and source of water bodies for their livestock. These groups of herdsmen depend on animal rearing as their main source of economic livelihood.

Fulani herdsmen are indigenous West African herdsmen who span across Burkina Faso, Mali, Niger, and Senegal as a result of their migratory pattern. Since 1960 till date, these Fulanis have had to migrate to countries such as Ghana, Nigeria and Cote d'Ivoire in search of conducive environment for themselves and their cattle (Yembilah & Grant, 2014; Fabusoro & Sodiya, 2011). However, these migratory patterns have intensified as a result of a number of factors - Regional conflict, outbreak of epidemics, commercial agriculture, water scarcity and the growing threat of climate change on rangeland ecosystems have negatively affected the access to rangelands within their respective countries in West Africa.

Adopting the livelihood asset framework, the essence of this paper is to critically examine the impact of these migratory practices on indigenous livelihood.

Background and Problem Statement

In Ghana, the Fulanis initially were found in the northern regions of the country but have gradually relocated to southern parts of Ghana particularly, the Ashanti, Brong Ahafo, Eastern and Western regions as the rangelands in the north depletes.

The free range nature of cattle rearing has led to the destruction of farm crops, arable land and the pollution of water bodies. Affected persons who confront these herdsmen about the destructive nature of their activities are sometimes injured or in worse situations killed. Furthermore, there have been reported incidences of some of these Nomads raping females within their host communities. Infectious disease among some of these herdsmen and the prevalence of cattle death also poses some form of environmental and health challenges to the residents of the communities affected by the activities of these Fulani herdsmen. Thus, the continuous stay of these Fulani herdsmen within these regions has triggered some form of insecurity within their host communities resulting in conflicts, disruption of properties, loss of productive man hours and lives (Olaniyan, 2015).

Agogo in the Ashanti Region and the Adaklu traditional area in the Volta Region of Ghana are a few of the farming communities within the country that have experienced various forms of attack. Media reports in 2016 indicate destructions of properties and clashes between residents and the herdsmen. The inhabitants of these regions in Ghana are mostly farmers hence depend on farming for livelihood. These clashes have had untold hardships on the affected communities as it has led to the destruction of farms and pollution of water bodies and general unrest within these affected communities. It is against this backdrop that this study sought to access the implication of indigenous free range cattle rearing practices and the livelihood dynamics of affected persons.

Methodology

The study was purely qualitative. A structured questionnaire was used to interview respondents from the Adaklu Traditional areas in Ghana. This study area was deemed appropriate for the study because it is a farming community, whose lands and farms are being affected by the activities of the Nomads. Twenty affected farmers were purposively selected. The snowballing sampling technique was used to identify farmers whose lands had been affected. The data collected was analyzed using themes that had originated from the stories of the affected communities.

The sustainable livelihood framework modified by DFID (2000) was adopted as the theoretical framework for the study. Five livelihood assets were identified; Economic, Natural, Social, Physical and Human.

Results and Discussion

Findings of the study revealed that the crops of most farmers were destroyed by these livestock, which greatly affected the total crop yield by about 50%. This impacted on their expected revenue hence their inability to save and cater for their basic needs. The respondents of the study indicated that on the average they used to harvest between 600 -700 kg (6-7bags) of maize per acre of land. Income losses is estimated between GHC 510 (US$ 133.6) - GHC 1,020 (US$267.2) per acre of land.

With regards to their natural capital, findings of the study indicated that the river which is the source of drinking water for the community has been polluted by the cattle. This finding is supported by the work of Yembilah & Grant (2014). This is because the residents share this water body with the livestock. Residents now resort to use of another water body, Tordze stream as their main source of portable drinking water. This has disrupted access to formal education for some children of school going age because of the challenge of getting water. These children have to travel from their community in search of water. Also, medicinal plants and herbs which are used by these residents for their domestic activities have also been greatly affected by this indigenous free range system.

Conclusion

Indigenous free range system of animal grazing can have enormous implication on the livelihood dynamics of affected persons. These activities impoverish the host communities and sometimes result in conflict leading to very devastating outcome. It is therefore imperative for policy makers and regulators to enact policies which will restrict the free range grazing of animals in communities. The various Local Government units within the confines of the operations of these Nomads should enact bye laws, which prohibit the destructions of lives and properties by their activities.

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Grazing Resource Partitioning on the Eastern Slopes of Alberta

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Key words: Forage, elk, livestock, horses, grazing

Introduction

Alberta's Equine Management Zones (EMZs) are large tracts of primarily public land along the eastern slopes of the Rocky Mountains that support feral horse populations. In addition to recreational use and industrial uses such as forestry and oil and gas activity, the land base allows for forage allocation to domestic livestock as well as wild ungulates and feral horses. For the long-term sustainability of the plant communities and overall ecosystem health, stocking rates must be kept at a moderate level (Willms et al. 1985).

Logging is the some EMZs result in cut blocks that provide a temporary source of forage. As time goes on, forage productivity decreases significantly as trees regenerate, canopy closes, undergrowth productivity decreases, and the community begins to take on the characteristics of a forested system. In some areas, surge logging and salvage harvesting following wildfire has resulted in a large number of cut blocks at a similar age, temporarily increasing this habitat type to artificially high levels in relation to standard harvesting practices for the region.

In many of the EMZs, total forage demands by elk, feral horses, and livestock have not been collectively been evaluated resulting in hindered management. With forage abundance changing due to cut block succession and no available estimates on the scale of forage resource reduction associated with that succession there is a need to investigate what forage resources will be available to foraging animals into the future. Questions that this study will address include (1) what is the (estimated) total amount of forage being utilized by feral horses, livestock, and elk? (2) Are there geographic areas where the level of forage demanded is too high in comparison to forage available? (3) Will areas that have shrinking forage production on cut blocks be able to sustain current ungulate populations? This information is essential for the long-term viability of these rangelands.

Materials and Methods

On grazing allotments on public land, plant community inventories have historically been collected by certified third party contractors who work in consultation with provincial rangelands staff. Annual livestock stocking data is available for each allotment in the form of Rocky Mountain Forest Reserve Stock Return Forms that are submitted to provincial rangelands staff on an annual basis. Feral horse numbers in each EMZ are obtained in March from aerial counts performed annually (or semi-annually depending on the historic size of the population) using a minimum count methodology. When a feral horse or feral horse group is spotted a GPS point is taken along with the number of horses, the general age classes of horses in the group, allowing for a spatial distribution map of horses. Although wildlife population numbers are complex to determine, elk have the largest overlap in dietary requirements with domestic livestock and feral horses (Salter and Hudson, 1980). Elk population numbers are estimated from aerial visual count numbers. Population estimates of livestock, feral horses, and wildlife will be used to determine forage demand. Additionally, cut block succession and harvesting schedules will be modelled to determine changes in the forage available to these species.

Local plant community carrying capacities has been established by Environment and Parks through the allotment inventories. All identified variables for forage availability will be overlaid in GIS software to identify areas of concern and give insight into carrying capacities for each species.

Results and Discussion

Overall forage demand on the landscape will likely be high and potentially much higher than recognized ecologically-sustainable stocking rates. It is anticipated that resource demands will be localized to preferred habitat, creating localized areas of very high stocking rates and resulting grazing pressure. Feral horses utilize conifer cut blocks during fall and winter months (Girard et al. 2013), potentially because there is little remaining forage left on the landscape (Salter and Hudson 1979). The total forage available from cut blocks, the preferred habitat of feral horses (Girard et al. 2013), will be decreasing in the near future due to a disproportionally large amount of cut blocks that will succeed to forested plant communities with unproductive undergrowth. With decreases in cut block productivity, some EMZs may experience increased pressure on other back-up forage resources. Overlap with livestock is expected to be dependent on the stocking rate of both feral horses and livestock as feral horses may need to be less selective of their foraging areas.

High pressure areas will have heavy use that could limit wintering habitat for elk and other ungulates. Therefore, estimated grazing capacities need to reflect a need for wildlife allocated forage, even if it is not currently being utilized. Additionally, it is prudent to ensure that a portion of the forage resource is maintained as carryover to allow for proper ecosystem function in future.

Conclusions and Implications

A thorough understanding of pressures on forage resources in the EMZs can help guide land management decisions and sustain range health and ecosystem function. Areas of concern with high stocking rates can be identified as increased risk and could help land managers efficiently monitor range health and implement any necessary management strategies.

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Agriculture Conflicts with Rocky Mountain Elk in the Cariboo-Chilcotin

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Key words: Elk, range lands, crop, depredation, Cariboo Chilcotin.

Introduction

During the 1700s, to early 1900s, elk (*Cervus elaphus*) were the dominant large ungulate throughout much of the province and historically, they ranged across much of the grasslands and forests of the Cariboo-Chilcotin region (Spalding, 1992). The mid-1800s through the mid-1900s, elk populations in this region declined to small relict herds southeast of Nazko, in the Canim and Mahood Lakes area and along the Quesnel River (Spalding, 1992). An increase in elk populations and range expansions within the Cariboo-Chilcotin are likely attributed by a series of mild winters, an increase in early-seral stands resulting from wildfire and forestry activities and predator control (BCMFLNRO, 2014, Spalding, 1992). Recently, there has been an increase in elk sightings of smaller herds, likely accounting for estimated 50-100 animals, while an estimated 200 elk ranging in larger herds near the Cottonwood/Fraser confluence and along the Quesnel River to Gravelle Ferry (BCMFLNRO, 2014).

As elk populations increase in the Cariboo-Chilcotin region, crop and fence damage, competition with livestock and stored feed depredation are becoming a common occurrence attributing to economically significant problems (Hegel et al., 2009). In areas containing small or large elk herds, roughly 23 agriculture producers report some type of damage to forage and range lands and/or feed stack yards directly related to animal density (Hegel et al., 2009). Becky Cadsand, Wildlife Biologist (pers. commun.) of the Cariboo-Chilcotin Natural Resource District mentioned that the Ministry initiated a collaring program in March 2014 to study life history, behavior, seasonal movements and habitat use for managing elk as a recovery species with a management goal of conservation, meeting First Nations and local hunter interests (BCMFLNRO, 2014).

Materials and Methods

Elk herds located in Narcosli Creek, Cottonwood/Fraser confluence and Quesnel River locale were identified by agriculture producers as impacting their activities and assisted biologists in focusing their collaring efforts to target these herds. Cadsand (pers. commun.) stated adult female elk were captured and fitted with Global Positioning Satellite collars (ATS G2110E Iridium GPS Location Collars; Advanced Telemetry Systems, Isanti, MN). In March of 2014 and 2015, helicopter net-gun capture was employed and adult females were located from air (Hegel et al., 2009) assisted with bait bales, were fitted with GPS collars, colour combination ear tags, health and body condition assessments and samples (blood, fecal and hair) were taken for health indication and parasite testing(Cadsand, pers. commun.). Collars were programmed to acquire animal locations at 4-hour intervals over a 2-year battery life and were transmitted via the Iridium satellite system every 3 days to allow for data viewing and analyzing (Cadsand, pers. commun.). Currently, 14 collared elk are collecting data, four units failed with success rates for individual collars varying from 88% to 97% (Cadsand, pers. commun.).

Cadsand (pers. commun.) mentioned they quantify seasonal ranges for elk using the fixed kernel home range algorithm of Worton (1989). In fixed kernel analyses, kernels were calculated from the 95% probability density of all locations and delineate areas of higher use (Cadsand, pers. commun.). Since late winter and calving periods contain low location points, seasonal ranges were pooled across animals rather than calculated by individual to increase the total number of points to reduce bias (Cadsand, pers. commun.). Home ranges are presented as overlays on satellite images of the study areas, such example as Fig. 1 Spring home range, with colours depicted in the kernels, grade from blue to red to reflect increasing use of an area (Cadsand, pers. commun.).

Results and Discussion

Agriculture and range lands in the study area containing highly palatable forage were real attractants, particularly fields located close to forests provide favorable environmental conditions used by this species (Hegel et al., 2009). Elk sought out agriculture land most often in spring (~25% of locations) as areas were likely first to green up containing high forage values and were used in summer (~15%) once calves were mobile and crops have been replanted that were in growing phase while range lands were used consistently during spring and calving periods (~15% per season) (Cadsand, pers. commun.). Cadsand (pers. commun.) mentioned several challenges of habitat thickness (poor visibility), low densities, variable behaviors and winter conditions, mild for the last 2 years, have made it difficult for reliable counts resulting in inconclusive population counts. Similar cluster analysis of animal distribution as an objective technique defining population units for guiding management decisions has been applicable for elk in the Cypress Hills (Hegel et al., 2009) allowing extrapolation and forecasting populations of herd densities and locations for the Cariboo-Chilcotin regional management plan Cadsand (pers. commun.). Home range kernel results illustrate where elk were concentrating seasonal densities in relation to affirming the impacts to forage and crop depredation of agriculture and range lands.

Figure 1. Spring home range. Cottonwood/Fraser confluence Image: Cadsand 2014.

Conclusions and Implications

Historical relic elk herds of the Cariboo-Chilcotin region are seeing an increase in their population and distribution in relation to forage availability, habitat, environmental conditions and predator management. Analyzing home range kernels will be redefined further as additional elk are collared, contributing to achieving conclusive population counts, habitat requirements, locations and scientific approaches in developing a regional management plan to address First Nations, local interests and agriculture producer impacts and concerns. The implications of allowing a recovering species to increase in population and expand their range will be froth with acceptance and frustration by the First Nations, hunting and agriculture community of the impacts that high densities of animals will have on agriculture and range lands of the Cariboo-Chilcotin region. Currently, the British Columbia Ministry of Forests, Lands and Natural Resources provides stack yard fencing materials to impacted agriculture producers of the Quesnel Natural Resource District to protect their stored feed are not providing appropriate resolutions to a growing problem, but only bides time and shifts the elk to impact other producers and rangelands. There are no true solutions, only further implications that affect appropriate management of range lands as elk densities and range expansion increases.

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Response of Vegetation to the Increase in Guanaco Density after Sheep Removal in North-eastern Patagonian Rangelands, Argentina

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Key words: guanacos, sheep, overgrazing, arid Patagonia.

Introduction

In arid Patagonia, unsustainable practices in sheep production have typically led to vegetation and land degradation. Guanaco (*Lama guanicoe*) is the dominant native herbivore inhabiting these ecosystems. Lastly, ranchers and some government agents perceive this herbivore as a threat to livestock production and alerted on a hypothetical risk of vegetation deterioration by guanaco overgrazing because of the growth of some of their populations. In this work, we annually monitored during seven years the cover and composition of four plant communities in a wildlife reserve that was previously a typical sheep ranch. After sheep removal at the time of the reserve creation, a rapid increase of guanaco density was registered (Marino et al., 2015).

Materials and Methods

This study was conducted in the wildlife reserve San Pablo de Valdés (SPV), located in Península Valdés (PV) (42°36’ S; 64°15’ W), Argentina. SPV was created to protect representative environments of PV and their biotic interactions. Before sheep removal in 2005, SPV bred 51 sheep.km^{-2} and showed signs of overgrazing (Codesido et al., 2005). Guanaco density within SPV rose from 3.95 (SE 1.05) in 2006 to 26.3 (SE 6.82) guanacos.km^{-2} in 2012, and then stabilized around 26.7 during the 2012-2015 period. This last value results in a stocking rate similar to that of sheep before the reserve creation (assuming an equivalence of 1 guanaco = 2 sheep). Thus, under the hypothesis of guanaco overgrazing, this sudden rising of guanaco density would have led to degradation of plant communities in SPV. We annually monitored four plant communities at fixed sampling sites since 2009: two shrub-grass (VC1 and VC2) and two perennial-grass dominated steppes (VC3 and VC4). VC1 and VC2 showed lower guanaco densities than VC3 and VC4. Moreover since 2013, VC3 showed a male-group proportion tenfold higher than the other communities (Marino et al., 2015).

Total canopy, bare soil and perennial-grass cover were annually assessed in two 50-m linear transects at each sampling site using the point-quadrat method (250 points per transect). We drew control charts (Manly, 2009) for each variable at each plant community and calculated the 95% and 99% confidence intervals to identify significant differences from the mean for the entire period. We used Principal Component Analysis (PCA) in order to unveil correlations among cover variables, annual precipitation and guanaco density (estimated through the group encounter rate).

Results and Discussion

In VC2, VC3 and VC4 all variables showed temporal oscillations with significant both negative and positive deviations from the mean (at both significant levels evaluated), while VC1 did not show significant oscillations (Fig. 1a). Canopy and perennial-grass cover showed similar temporal trends in all

VC (only canopy shown). VC3 was the only one showing clear temporal trends, but only for the last two years: negative for total canopy and perennial-grass cover and positive for bare soil (Fig. 1a).
In VC1, VC2 and VC4, annual precipitation correlated positively to plant covers (canopy and grass) and negatively to bare soil cover, while guanaco density was unrelated to them (Fig. 1b). Thus, for these three plant communities we did not find evidence of vegetation deterioration due to guanaco overgrazing. However, in VC3 guanaco density correlated positively to bare soil and negatively to both plant cover variables (Fig. 1b). We argue that this may be due to more intense use of forage resources by the unterritorial male groups established in this plant community since 2013 (beginning of vegetation changes). Territoriality has been proposed as a mechanism for keeping guanaco population density under environmental-carrying capacity (Marino et al., 2015).

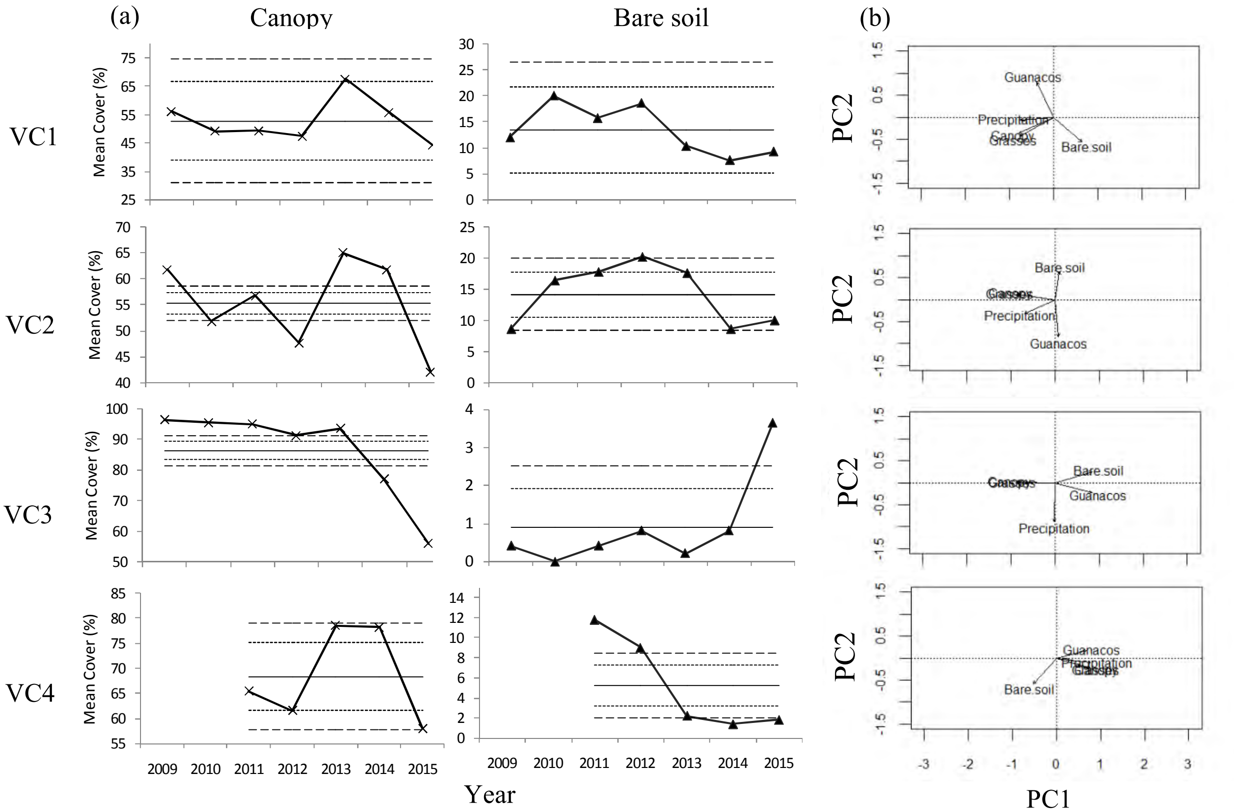

Figure 1: (a) Mean values (symbols joined by solid lines) (n=2) for total canopy and bare soil at each plant community. Dotted and dashed lines indicate 95% and 99% confidence intervals, respectively. Values falling outside them indicate significant deviations from the mean. (b) PCA for each plant community. VC1 and VC2: shrub-grass steppes; VC3 and VC4: perennial-grass dominated steppes.

Conclusions and Implications

Plant communities supporting territorial family groups of guanacos did not show signs of overgrazing. Unterritorial male groups deserves further attention because the observed negative effect on plant cover could be counterbalanced by high potential for medium-term displacement at landscape scale.

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Range and Forage of High Latitudes and Altitudes

Mountain Grazing on Alpine Summer Farms in Switzerland Ecosystem Services of a Pasture Landscape

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Key words: Abandonment, climate change, intensification, rough grazing

Introduction

Alpine summer pastures – the seasonally used mountain grasslands just below unproductive rock and ice – are a distinctive feature of the cultural landscape of many European countries. In many locations, those marginal grasslands are associated with "High Nature Value" farming, which is often threatened by either abandonment or by intensification (Oppermann et al., 2012).

Materials and Methods

In Switzerland, summer pastures make up one third of the agriculturally used land. They are mostly (95%) located between 1000 and 2500 m a.s.l. and usually grazed during three months from June to September. The inter- and transdisciplinary research programme AlpFUTUR (www.alpfutur.ch) investigated past and future land use and related ecosystem service demand and provision of the summer pasture regions. AlpFUTUR consisted of 22 disciplinary projects (agronomy, ecology, economy, food science, history, sociology), which were co-ordinated towards an overall synthesis (Lauber et al., 2014; Seidl et al., 2015).

Results and Discussion

High societal demand for services provided by summer farming

Both, farmers and non-farmers, were interviewed with respect to their expectations regarding summer farming. The three most important reasons for farmers (n=731) to heard mainly cattle, sheep and goats on summer farms were related to production services: (i) fodder resources, (ii) positive effects on the health of the animals and (iii) better distribution of the workload between the home farm and the summer farm. The next two major reasons were related to socio-cultural services, namely (iv) the pleasure farmers take by working the summer farms and (v) the commitment to this tradition.

The non-farmers consisted of a representative sample of the Swiss population (n=1525). The three statements which obtained the highest agreement were: "Summer farming is a genuine part of Switzerland", "I would regret the abandonment of summer farming" and "Summer farming is a genuine part of Switzerland". Those statements underline the consensus of society to support the summer farming tradition, which is reflected by a recent increase in subsidies supporting this practice.

Partial abandonment of summer pastures will continue

In spite of the public support for summer farming and the dedication of a majority of farmers, 2400 hectares are abandoned every year and – if they are located bellow the tree line – they turn into shrub land and forest. As long as the abandonment is limited to hazardous and remote pastures, the abandonment may contribute to the overall economic viability of summer farms. A certain degree of abandonment may even provide benefits for biodiversity. Koch et al. (2015) showed that the species number of plants and arthropods peaked at 50% shrub cover. Maintaining such a mosaic of shrubs and grassland, however, requires careful management by a combination of herding and manual labor.

Climate change may increase the attractiveness of summer farming in the future

The climate in Switzerland has been changing over the last decades. We interviewed elderly herders and extension officers about their respective experience. They confirmed that the summering season now starts earlier in spring (about one week) and that fodder production has increased, although they all insisted that management has also partly changed and that discriminating between effects of climate change and management is difficult. Climate projections for Switzerland predict higher variability of temperature and prolonged summer dryness, with stronger effects in the lowland than in the highland. Fodder growth in the mountains may thus be less affected by climate change and summer pastures might help to buffer reduced fodder availability in the lowlands (Blanke & Herzog, 2012).

Engaging skilled and motivated herders will remain a key challenge for the maintenance of summer farms

Interviews were conducted with 99 hired summer farm herders on their motivation and job satisfaction. They could coarsely be distinguished into four contrasting groups: “Traditionalists” are mostly local farmers who make it a habit to work on a summer farm every year; “Nature lovers” often have an urban background and seek the occasional experience of herding and cheese making; “Cross border” workers come from neighboring countries and are motivated by the comparatively attractive salary and “Loners” seek the contrast to busy city life (Calabrese et al., 2013). Engaging skilled and motivated herders will remain a key challenge for the future maintenance of summer farms.

Conclusions and Implications

Although summer farming is deeply rooted in traditions, it has evolved over time and will continue to do so. AlpFUTUR results are communicated in a synthesis book (Lauber et al., 2014), in a documentary film and in three short movies (Herzog et al., 2016), addressing professionals, the public at large and herders, respectively.

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Strategies to Improve Rangelands in High Altitude Regions of India for Livestock Production: Herders' Perceptions

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Key words: Fodder production, Ladakh, *Medicago*, pasture management

Introduction

The high altitude regions in India represent a diverse climate, topography, vegetation, ecology and land use pattern (Rawat, 1998). Winter temperature can reach as low as -30^{0}C whereas summer temperature rarely exceeds 27^{0}C. The annual average rainfall varies from 80 mm in Ladakh to over 200 cm in some parts of Himachal Pradesh and Uttar Pradesh. In this region, Ladakh is a unique land that has distinct physical features, ecology, environment, ethnicity, agricultural systems and livestock rearing practices.

Rangelands and livestock farming are extremely important economic drivers in high altitude regions of the country. Livestock rearing is practiced under sedentary and migratory systems. Crop residues, alfalfa (*Medicago* spp.), *Melilotus*, *Hyphophae* and several species of grasses/ pastures are the major forage resources. Tree leaf fodder of willow is also used as forage. However, with the exception of alfalfa which is cultivated in ~ 4000 ha; the resource base of other range-based forages has deteriorated, mainly on account of overgrazing. Sustainable fodder production and strategies for rangeland improvement are needed to optimize livestock production.

In this paper, various options for sustainability in fodder production and strategies for improvement of rangelands in such high altitude regions of the country are discussed.

Materials and Methods

Published literature on range fodder resources and their utilization pattern in high altitude regions of India was scanned. Structured oral interviews with 30 herders each belonging to 4 communities (total 120) Based on such inputs entire scenario of were conducted to know about their perceptions on importance of rangelands and future strategies. Based on this entire, scenario of range fodder resources and their utilization patterns was analyzed and relevant strategies for improvement of rangelands and sustainable fodder supplies for the livestock are suggested for the region.

Results and Discussion

The people of the high altitude regions in India, including Ladakh, have traditionally used land base resources and livestock. Traditional agriculture is a blend of crop-livestock management and conservation of natural resources and environment. After India became an independent country there has been a decline on dependence on land resources. One of the main reasons for such a shift in opinion of herders is lack of interest of present generation in livestock profession and increased tourism in Ladakh (Chaudhuri, 2000).

Rangelands and forests that comprise 50 to 70 per cent of the total geographical area are the major sources of forage for sheep, goats, rabbits, cattle and other animals. Sub-alpine and alpine pastures are used by the nomadic graziers (*Khadwals, Gaddis, Gujjars, Khas*) for rearing their livestock. The herders mentioned that due to more number of animals and deterioration in quality of rangelands, there is a decline in carrying capacity (Tewari and Joshi, 2013) .

The research work done by various organizations on this aspect in the region suggest that degraded pastures may be rehabilitated to yield higher (7-25 times) if there is proper management and institutional support (Pathak, 2002). Alfalfa, the mainstay for the livestock in the region, is now a mix of *Medicago falcata* and *Medicago sativa*. There is a need to exploit the great variability encountered in this species and identify suitable plant types that are able to provide maximum fodder and nutrition in stressed environments. Apart from alfalfa, there is a diversity of introducing seasonal fodder like oat, cowpea, corn, grasses, shrubs and trees in the existing farming systems practiced by the farmers (Uniyal *et al*.,2005). Herders mentioned that field boundaries are an ideal niche for this purpose. Several other technologies like silage making, enrichment of crop residues and leaf meal etc. may be introduced in the region for optimum utilization of the available bio-resources.

Pasture improvement is difficult in high altitude regions. However, a well-planned, long term, inter-disciplinary approach can accomplish the task. Adoption of other range management techniques like application of nitrogen (60 kg ha^{-1}) and phosphorus (30 kg kg P_2O_5 ha^{-1}) (Singh, 1995) and following rotational or deferred grazing (Koranne and Singh, 1989) may give desired results. As the herder communities were not aware about such interventions, it is recommended that such a package of practices is formulated and disseminated to the farmers and other stake holders.

There is a need to conduct detailed studies on phenology and reproductive biology of important pasture species encountered in the region. The growth pattern, seed dispersal mechanisms, seed bank of soil and related studies on these species can determine the method and time for their sowing. All the studies have to assure the active participation of farmers and other stake holders who can later assure better management of the improved pastures in the prevailing climate change scenario in the region.

Conclusions and Implications

Although high altitude regions have challenging terrain, a harsh climate and a dwindling natural resources base; the local population still depends on the natural resources for their livelihood. Therefore, there is an urgent need for various research and development interventions which can assure sustainable fodder supplies to livestock without degrading the natural resource base. The available research work suggests that appropriate management may provide a sustainable livestock industry. The research organizations located in this region play an important role in working with local organizations for improving rangeland condition.

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Effects of Three Plant Litter Water Extraction on Plant Community Characteristics in the Alpine Meadow of Qinghai-Tibetan Plateau

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Key words: Plant litter, plant community, grazing, Alpine meadow

Introduction

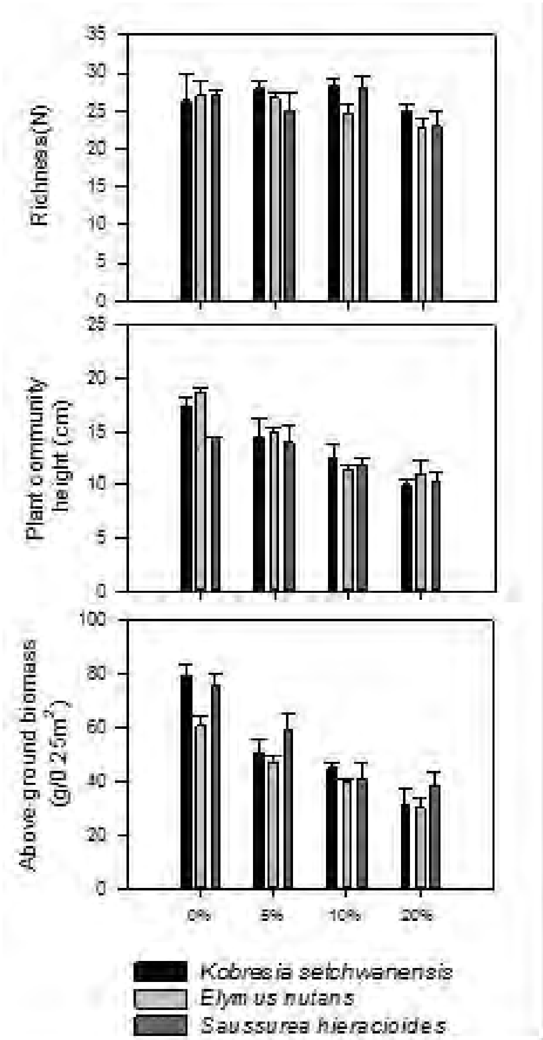
The Qinghai-Tibetan Plateau is the largest and tallest plateau in the world, where the average elevation is about 4000m (Liu et al., 2015). Grazing and trampling of livestock can change species composition and biomass of plant community directly or indirectly (Hou et al., 2006). Plant litter is a bridge to connect the soil and green plants, and the accumulation of litter may affect the plant community structure and dynamics (Hobbie et al., 2015). Litter alters the physical and chemical environment. The decomposition of litter may release both nutrients and phytotoxic substances into the soil. The physical changes produced by litter also alter the activity of decomposers, resulting in an indirect effect on the chemical environment. The accumulated litter reduces soil temperature (Hobbie et al., 2015). The majority of studies on the effects of litter have been focused on forest ecosystem, only few for grassland ecosystem. In this study, we explored the effects of three plant litter water extraction on plant community characteristics in the alpine meadow of Qinghai-Tibetan Plateau.

Materials and Methods

The research area locates at the northeastern boundary of Qinghai-Tibetan Plateau at Hongyuan Station (N31°47'34", E102°33'07", 3650 m a.s.l.), Hongyuan County, Sichuan Province, China. The soil types were classed by dark felty soils. The mean annual temperature is 0.8℃ and the mean annual precipitation is 690 mm. The randomized complete block design was used in the experiment. We set up four concentration gradients of 0, 5, 10, 20% using litter accumulated from three different species (*Kobresia setchwanensis*, *Elymus nutans*, *Saussurea hieracioides*). Each plot was 2 x 2m and the isolation bandwidth of each plot was 1m with 4 replications. Plant community species composition, density, height, aboveground biomass were measured for each species by monthly harvesting six 0. 5 x 0.5 m quadrats at ground level in each paddock. All statistical analyses were carried out in SAS, Version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

From the data analysis, we found different gradients of plant litter concentration affected plant community height, above-ground biomass significantly (P<0.05) (Fig.1). There was no effect of concentration gradient of plant litter on plant richness (P<0.05) (Fig.1). For the same concentration gradient of plant litter, there was no difference of measured traits among the three plants (P<0.05)(Fig.1). Both plant community height and plant above-ground biomass had a negative linear relationship with concentration gradient of plant litter. For plant community height, the prediction models by plant litter *Kobresia setchwanensis:* y=-35.704x+16.74 (R^2=0.9643***), *Elymus nutans:* y=-37.457x+17.27, (R^2=0.7841**), *Saussurea hieracioides* : y=-21.926x+14.623, (R^2=0.9496***), respectively. For above-ground biomass, the prediction models by plant litter *Kobresia setchwanensis:* y=-217.16x+70.549 (R^2=0.8348**), *Elymus nutans:* y=-146.28x+57.253 (R^2=0.7841**), *Saussurea hieracioides :* y=-183.12x+69.677, (R^2=0.8061**), respectively.



◀ Figure 1. Effects of different concentration gradients of plant litter on plant richness, plant community height, and above-ground biomass.

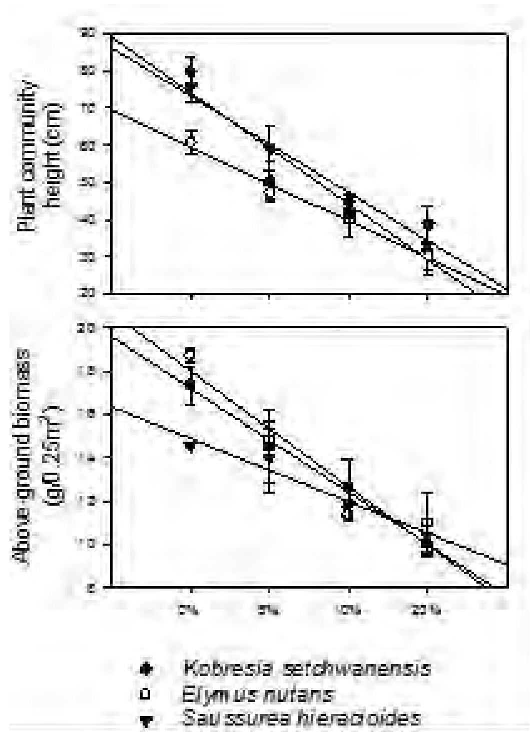


Figure 2. The relationship between concentration gradient of plant litter and plant community height and above-ground biomass.

Conclusions and Implications

In alpine meadow of Qinghai-Tibetan Plateau, plant litter effect plant community characteristics significantly. It had a negative linear relationship among *Kobresia setchwanensis*, *Elymus nutans*, *Saussurea hieracioides*.

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An Ecological Site Approach to Select Range Improvement Practices on Andean Rangelands

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Key words: Ecological sites, paddocks, mountain rangelands, management strategies

Introduction

Ecological sites are mapping units, which provide information to rangeland managers of ecological condition, and estimations of forage production and carrying capacity. Using sites as management units has restrictions since boundaries of sites do not necessarily match the boundaries of a paddock. Since the basic management unit for rangeland managers is a paddock and managers make decisions based on them, it is necessary to integrate information of ecological sites and paddocks to develop range management and improvement plans (Flores, 2000). In this context, the present study aims to design an approach based on ecological and spatial criteria to estimate rangeland potential to implement improvement practices.

Materials and Methods

The study was conducted in rangelands of the Yurajhuanca Communal Cooperative, located in the central Andes of Peru, at altitudes from 4200 to 4400 m.a.s.l. The study area comprises 4 289.5 hectares, enclosed by fences and divided into 18 paddocks (Fig.1). Livestock population was composed of 5632 sheep, 2405 alpacas, 77 cattle, and 39 horses.

To delineate ecological sites, slope, physiography, vegetation type, and geology information was overlapped using ArcGIS 10.2 software. Sites with similar botanical composition and soil surface characteristics were integrated into a single unit (Huerta, 2000). Condition and trend of ecological sites were estimated using an equation based on the proportion of forage species, plant vigor and vegetation cover (Florez and Malpartida, 1980). To identify rangeland improvement practices, a matrix of restrictive attributes of ecological sites was built based on information of an expert panel. Restrictive features were: altitude, slope, land use, rangeland condition, vegetative cover, erosion and presence of weeds (Table 1) (Zarria and Flores, 2015). To determine applicable strategies, restrictions were compared with information of the sites features. The spatial layers, "paddocks" and "ecological sites" were overlapped to select intensive strategies (cultivated pastures, re-seeding of native species, inter-seeding of legumes, fertilization, and weed control) and extensive strategies (grazing systems: complementary grazing and deferred-rotation, rest-rotation, prescribed burning, and management of water sources). When two or more exclusive strategies were applicable to the same paddock, the selection criteria was an estimation of a weighted condition score based on its relative area, and evaluation of vegetation, soil, and topographical features.

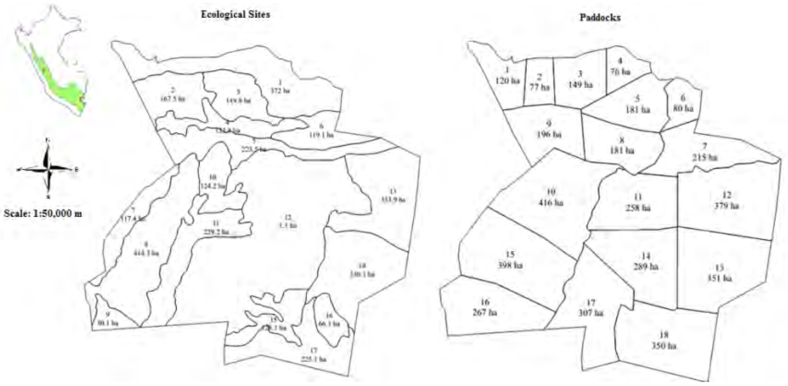

Figure 1. Distribution of ecological sites and paddocks of Yurajhuanca Communal Cooperative.

Results and Discussion

Based on physiographic and soils characteristics, and data from vegetation evaluations, 17 ecological sites were identified (Fig. 1). The approach suggested as adequate strategies for all sites: a deferred-rotation grazing system and management of water sources, with inter-seeding of legumes restricted to only three sites. Main restrictive factors for implementing other strategies such as cultivated pastures and fertilization were elevation, soil acidity, and vegetation type (Zarria and Flores, 2015). This suggests the need to adjust the matrix of restrictive attributes by assigning numerical values to vegetation, soil, and topographical features, and utilizing a weighted score. The deferred-rotation grazing system and management of water sources were applicable to 18 paddocks, while inter-seeding of legumes were applicable in only five paddocks. Selection of rangeland strategies was difficult when a paddock included more than one ecological site because the site features affect the level and speed of response time of strategies. Thus, ecological sites can be used as stratum for sampling soil and vegetation attributes to estimate paddock potential.

Conclusions and Implications

The approach allowed selecting rangeland improvement strategies according to ecological site characteristics and potential for improvement. Selection of strategies for paddocks composed of two or more ecological sites may include an estimation of a weighted condition based on the area of each site. The approach may be improved by incorporating economic (Net Present Value, Internal Rate of Return, and Partial Budget) and social criteria (experiences and perceptions of ranchers). To implement improvement strategies, rangeland managers may consider long-term planning horizon because response time of Andean rangelands is usually slow.

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Table 1. Conditions for applying range improvement practices.

Indicator	Cultivated Pastures	Re-seeding of Native Species	Fertilization	Weed Control	Inter-seeding of Legumes	Rest-rotation	Deferred-Rotation Grazing System	Complementary Grazing System	Prescibed Burning	Management of Water Sources
Altitude (m.a.s.l)	<4200	< 4400	< 4400		< 4400			<4200	4200	
Land Slope (%)	<20	<30	<10		<30	<60	<60	<30	<20	
Waters Sources Distance (m)	<300								< 50	125(lakes), 50 (river), and 100 (streem)
Vegetation Type	Tall and Short Grasses				Tall Grasses	Tall and Short Grasses, and Highland Wetlands	Tall and Short Grasses, and Highland Wetlands	Tall Grasses	Tall Grasses	
Rangeland Condition		Poor, Extremely poor	Excellent, Good	Poor, Extremely poor	Excellent and Good	Poor, Extremely poor	Excellent, Good, Fair	Excellent, Good	Excellent, Good, Fair	
Presence of Weeds (%)		>60%		>40%						
Aerial Biomass Production (kg/ha)									>1250	
Land Capability Classification (USDA)	VI		VI		VI			VI		
Soil Depth (cm)	>25		>25					>25		
Soil Erosion (%)		Severe and Severe-Moderate	Null		Null to Slight (<10)			Null to Slight (<10)		
Vegetative Cover (%)		<60	>90		>90			>90		
Stoniness (%)	<5	<20	<20		<5			<5		

A Community-Based Approach to Identifying Grazing Pressure and Land-Use Management Structures among Herders in the Altay Mountains, Mongolia

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Key words: Land use management, Mongolian Altay, participatory mapping, transhumance

Introduction

In the Mongolian Altay region, three transhumant ethnic groups herd goats, sheep, cattle, yaks, camels, and horses. Nowadays, goat-dominated herds are the norm, as households join the cash economy through cashmere production (Lkhagvadorj et al., 2013). As selective feeders, the increased number of goats negatively impacts the rangelands and decrease biomass availability. Using community-based approaches and participatory mapping, this study identified the use of high-altitude summer pasture by grazing livestock and factors affecting herd management, in order to understand grazing land allocation, determine grazing pressure and assess the overall sustainability of rangeland use.

Materials and Methods

Between June and August 2014, we interviewed 31 households at *Tsunhal Nur* summer pasture (46°40'N 91°35'E, 2392-3097 m a.s.l.) using a participatory mapping exercise in QGIS, an open source geographical information system software (http://www.qgis.org/en/site/), on an electronic tablet and a hardcopy questionnaire. On a Google Earth satellite image, respondents identified where their small ruminants, bovines, horses, and camels grazed. Households were interviewed twice on the topic of herd management and rangeland use, coinciding with their stay at each of two *ger* (camp) sites in the study area. Herd management characteristics, such as motivation for visiting the region, rationale for choosing the site, self-identified ethnicity, and perception of rangeland quality were recorded and analysed.

In addition, headcounts were conducted of each household's small ruminants and bovines; by relating animal numbers to the respective grazing area, household-specific seasonal stocking rates were calculated. These were overlaid for all households in QGIS to identify heavily stocked areas. Based on above ground net primary production (ANPP) determined prior to livestock grazing in June, we calculated seasonal grazing pressure as the animals' fodder demand (stocking rate times herbage requirement of 5 kg DM d^{-1} per sheep unit; Zizhi and Degang, 2006) divided by the supply (ANPP).

Results and Discussion

Long-standing tradition was noted by 71% of respondents as the motivation for choosing *Tsunhal Nur* as their summer pasture. Households reported choosing their *ger* sites based on: tradition and social network (households herd together in a unit known as an *ail*), fodder available for herd, altitude (lower altitude with warmer climate preferred), good terrain for herding activities (i.e., riding horses or motorcycles, sightline to herd from *ger*), and water availability. Small ruminant herd size, aggregated over an *ail*, varied between 185 and 830 with a median of 390 animals, excluding young (<6 months). Ethnicity played a role in herd composition. *Uriankhai* households tended to keep (more) yaks in addition to cattle, *Torguud* tended to own more horses than their peers, and *Kazakh* tended to have the largest small ruminant herd sizes. Average ANPP per herd ranged from 424 to 1053 kg DM ha^{-1} with a median of 611.

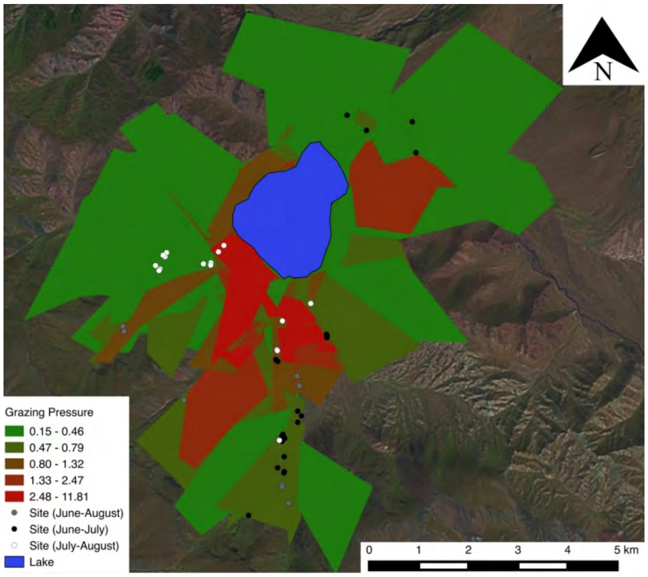

Figure 1. Spatial variation in grazing pressure (stocking rate times herbage requirement divided by above ground net primary production) at *Tsunhal Nur* summer pasture in 2014. Map based on Google Earth (2014).

Grazing pressure was highest in the southern valleys, where the majority of households prefer to reside in the early summer, and along the lake (Figure 1). The long-standing tradition of visiting *Tsunhal Nur,* particularly these preferred sites, has likely contributed to rangeland degradation as the southern valley and the south and east lakeshore have large pockets of low ANPP (<500 kg DM ha^{-1}); the east side of the lake is also used as a road. Intuitively, these low-lying areas should show high ANPP, as they are water, soil and nutrient catchments (Sankey et al., 2009). In order to reduce the pressure to these areas, herders are encouraged to actively take their herds to under-utilized areas in the higher elevations and further from the lake.

Sixty-eight percent of herders believed there was plenty of vegetation for their animals when they arrived at *Tsunhal Nur* in June 2014. Nonetheless, the most frequent herder-implemented strategy to cope with poor rangeland quality is to change *ger* and grazing site within in the region. A few households mentioned leaving early to the autumn range; 13% reported that no action is taken in the event of poor rangeland quality. Herders' suggested strategies to mitigate rangeland degradation included (number of mentions): change site and pasture more often (10); more rainfall/watering of rangelands (9); reduce animal numbers (3); manage stocking rates with fencing (3); more government regulation and protection of rangelands (2); improve livestock reproductive performance (1); reduce insect pests (1); move further between sites (1); pray/religious ceremonies (1).

Conclusions and Implications

Participatory mapping proved useful to identify pasture areas vulnerable to overgrazing and to discuss feasible countermeasures implemented by herders. In addition to their current strategies, herders should be incited to increase their small ruminants' grazing radii so as to reduce degradation of vegetation near preferred campsites and spread grazing more homogenously across the whole summer pasture. This could imply self-organized systematic grouping and alternating the herding tasks and workload.

Acknowledgement

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Transhumance Implications in the Upper Noun Drainage Floodplain Wetlands in Cameroon

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Key words: Livestock, transhumance, savanna grassland, floodplain wetlands, land use change

Introduction

Over time immemorial, wetlands have remained the main haven for cattle during unfavorable dry season in the intertropical regions of the World. Transhumance is widely practice in sub Saharan Africa, especially in Cameroon and in the Upper Noun Drainage basin as a traditional practice (Ndzeidze, 2004). In the Upper Noun Drainage basin, cattle move in from the immediate surrounding upland areas and other areas of the western high plateau (Ndzeidze 2004; Ngwa 1985; Ngang 1998; Lambi 1999). This usually results in various stages of interaction leading to diverse environmental implications on Savanna grasslands, wetlands, animal life, and the population as well as the transit line of movement between the up hills and the wetlands. The Upper Noun Drainage basin popularly known as the Ndop flood plain, received about 21,000 cattle in 2006. The species of fodder which attract animals here include: *Pennisetum purpureum, Leersia hexandia, Scirpus jacobi* etc. This study focuses on transhumance and related environmental, socio-economic and cultural mutations within the drainage basin within the savanna grasslands of Cameroon.

Materials and Methods

Data was collected from both secondary sources like Ministry of Agriculture and Rural Development and Ministry of Livestock, and secondary sources; and primary sources that was principally field work. The primary field visits were conducted for firsthand information through direct field observations, administration of questionnaires and granting of interviews to resource persons. Field work was carried out in three phases which were carefully planned to coincide with the two main seasons (rainy season from the 5th of September to the 10th of October 2005) which was before transhumance. The second phase involved observation of the wetlands during the dry season. This trip was from the 11th of December 2005 to the 15th of January 2006 and January 2007. There was observation of the cattle movement from their rest places to the grazing areas and to drinking places. There was equally the observation of how transhumance influences wetlands and how wetlands influence transhumance. The third trip was from the 1st to the 5th of April 2007. This was meant to observe the state of wetlands after transhumance and also to observe the behavior of grazers at this time. In the second phase questionnaires were also administered. Data analysis was through the use of descriptive statistics.

Results and Discussion

Some of these observed implications are both positive and negative. Negatively, there is soil compactness, habit destruction and retardation of vegetal growth, pollution of water, river bank destruction, wetland siltation and acute farmer/grazier conflicts. Positively, transhumance generates and boosts the economic processes and rural dynamics. These include the buying and selling of cattle dung, creation of job opportunities, acquisition of cheap beef and dairy products. Culturally, the indigenes have learnt and are fully involved in cattle rearing which was formally a Fulani practice. The latter became sedentary and have also learnt how to devote themselves to agriculture. This daily movement of the animals to and from the streams does not only strip off the vegetation from the hills but as well excavate the soils through trampling with their hooves, making the soils loose especially as they move on specific tracks. This coupled with the heavy rainfall during the rainy season gives way to erosion. Natural conditions and environmental characteristics have made it in such a way that, there is great discrepancy in pasture endowment between areas of origin and destination of animals in transhumance. The discrepancy effect is much pronounced during the dry season when transhumance the only option to most grazers and has far reaching implications in the different environmental variables that determine the quality, type, availability and diversity of pasture upon which animals depend for survival. These variables include: climate, soils, vegetation, hydrology as well as temporal changes in land use. Findings also show that transhumance has almost contributed to the disappearance of wild animals from the wetlands due to habitat disturbance during grazing. The animals that used to migrate into the wetlands during the dry season from the western highland grass fields rarely visit the wetlands, again in large numbers. The few that still come, do so only in the night due to habitat disturbance during the day, and consequently cause mutation in the wetland environment. Finally, "transhumance had led to changes in land use pattern", is the last hypothesis for this study. The wetlands of Ndop Central were at first farming land but the introduction of transhumance has changed this land use type to mixed farming. Also the cultivation of maize and groundnut which used to be in late January to early February is no more practiced. This has as well adjusted the agricultural calendar of the area.

Conclusions

Transhumance has a close relationship with wetlands and need to be well coordinated in the Sub Saharan Africa to ensure biodiversity conservation and to create societal awareness of the importance both ecosystems interdependence. Our study focused on cattle movement from Savanna grasslands and results actually reveal environmental, socio-economic and cultural perturbations with observed persistent wetland loss and degradation. This satisfactorily agrees with the hypotheses "transhumance accounts for mutation in wetlands environment". The implications of transhumance on the biodiversity have been very significant in Upper Noun Drainage basin due to grazers daily routine of moving from place of rest to grazing areas contribute immensely in degrading the ecosystem. Lack of coordinated grazing pattern of movement and conservation strategies account for the excessive siltation or rivers and streams. Farmer/grazer conflicts are obviously the order of the day. Crops are destroyed and there is also animal cruelty since both grazers and farmers depend solely on the limited wetlands. At times there is blood sheds with a far reaching influence on the socio-cultural life of the people in this area. Some of these conflicts end in the jailing of some victims.

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Investigation of Vegetations of Protected and Grazed Areas Fronting on Different Directions in Alpine Rangelands

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Key words: Botanical composition, invasive species, hay

Introduction

Alpine pastures consist of large grazing lands starting from forest upper boundary and reaching to the summits of mountains. Due to severe climate conditions and generally steep terrain structure, the most productive usage of these areas is grazing.

The fact that pastures have been ploughed and turned into agricultural land, and that decreasing pasture areas have been grazed early before their time and over their capacity have caused the vegetation to move away from the climax and resulted in decreased yield and quality.

Rehabilitation and management should be carried out first in order to bring our pastures up to the demanded status. These works are based on determining the vegetation status of the said pastures. In the study, botanical composition, pasture condition and health, hay yield and grazing capacity of the protected and grazed areas were examined. These areas were compared in terms of vegetation. Thus, what kind of effects of grazing and reaping were investigated on areas.

Materials and Methods

This study was conducted on the Alpine pastures in Giresun, Dereli town, Tamdere village (latitude 40° 30’ N, longitude 38° 20’ E, altitude 1711 m). The pastures were named according to their direction. Four areas were studied; E-P, fronting on east and protected, W-P, fronting on west and protected, E-G, fronting on east and grazing, and W-G, fronting on west and grazing. Using an average of the last 60 years maximum temperature average was 14.7 °C in August and minimum temperature average was -1.2 °C in February. Annual total precipitation per square meter was measured as 1554.4 kg/m^2 (TMS, 2013).

Soil texture classes of the four pasture areas were the same (sandy-loamy), and organic matter, Nitrogen, Iron, Nickel and Copper quantities were higher in the protected pastures than grazing pastures.

Proportion of any species found in botanical composition was determined by dividing total number of encountered species. Proportion of Any Species (%): (Encountered Any Species Number / Total Number of Species Encountered) x 100

Pasture condition was determined by two different methods developed by De Vries et al. (1951) and Koç et al. (2003). In determining the pasture health, on the other hand, the method developed by Koç et al. (2003) was used.

Samples of plant were dried in 70°C drying oven for 24 hours. These samples were weighed and hay yield was found.

Grazing capacity is number of animals that can be grazed without damaging vegetation, soil, water and other natural resources in a particular area and time intervals. Grazing Capacity (Animal unit) = (Pasture area (ha) x feed yield in unit area (kg/ha) x utilization percentage (%) x Slope) / (Daily feed need of the animal to be grazed (kg/day) x Grazing days).

The values were put to variance analysis by using MSTAT-C package program according to the randomised parcels experimental design in order to compare the values obtained from four different sections in the study area. The statistically significant factor averages according to the results of variance analysis were compared with L.S.D. test.

Results and Discussion

132 taxa belonging to 30 families and 7 of which were endemic were determined in total in the four different areas studied (Table 1). Due to high number of invasive species, it is said that vegetation of both protected and grazed areas is deteriorated, because these areas were unconsciously used for centuries.

Table 1. Element, Family, Status and Life Length of the species identified, on the research field.

Element	Family	Status	Life Length
21.80% Europe-Siberia	29 Poaceae	26 Decreasing	117 Perennial
4.52% Iran-Turan	19 Fabaceae	26 Increasing	14 Annual
1.50% Mediterranean	13 Asteraceae	80 Invasive	1 Biennial
72.18% is not known	71 Other families		

According to the results of the variance analyse on the basis of column, values of botanical composition (%) and hay yield (kg/ha) were given in Table 2.

Table 2. Botanic composition (%) and hay yield (kg/ha) of four different areas.

	Poaceae	Fabaceae	Other Families	Hay Yield
E-P	26.42a	20.64a	53.03a	3025.6 a
W-P	36.22a	12.33a	51.30a	3100.8 a
E-G	50.80b	10.49a	38.67b	1993.6 b
W-G	29.81a	11.84a	58.35a	1017.6 b

Same letter are not statistically different from each other within $p \leq 0.05$ fault limits according to LSD test.

Upon review of the above information, values of poaceae and other families belonging to E-G show statistical difference comparison to other areas. There is statistical difference between protected and grazed areas in terms of hay yield.

The conditions of the protected and the grazing pastures were qualified as poor according to the data obtained from the method developed by De Vries et al. (1951). On the other hand, the conditions of the protected and grazed pastures are in the medium class according to the method developed by Koç et al. (2003). All of the pastures studied were in healthy class in terms of pasture health. In conclusion, it can be assumed that a healthy pasture may not be a good class pasture.

The grazing capacities of research field were given in Table 3.

Table 3. The unit area grazing capacities of different pasture areas studied (Animal unit) and the required pasture sizes for 1 Animal unit.

	Unit Area (1 ha) Grazing Animal unit Capacity	Pasture Area Required for 1 Animal unit (ha)
E-P	0.6a	1.1a
W-P	0.6a	1.1a
E-G	0.4b	1.7b
W-G	0.2c	3.4c

Same letter are not statistically different from each other within $p \leq 0.01$ fault limits according to LSD test.

Although the pasture condition and health of the protected and grazing pastures fronting on different directions were detected as the same, it can be said that using the pasture for reaping damages the grazing capacity less than using for grazing.

Conclusions and Implications

Study results were shown that characteristics of research areas are similar to one another. But values of grazing capacity and hay yield were found higher in protected area when compared with grazed area. In order to ensure sustainability in the current areas, the critical periods of spring and autumn should be considered and the pastures should be grazed with animals in the appropriate number and type for their capacities and vegetation. Studies should be made on the determination of the most appropriate reaping time in the pastures used as reaping area.

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Integrated Approach to Cheatgrass Suppression on Great Basin Rangelands

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Key words: Wildfire, weed control, rangeland rehabilitation

Introduction

Cheatgrass (*Bromus tectorum*), native to central Eurasia, is a highly invasive annual grass that has invaded millions of hectares of rangelands throughout the Intermountain West (Young and Clements 2009). Cheatgrass has revolutionized secondary succession by providing a fine-textured, early-maturing fuel that increases the chance, rate, spread, and season of wildfires (Young et al. 1987). Whisenant (1989) estimated the presence of cheatgrass has reduced the interval between wildfires from an estimated 60–110 years down to 5 years. Aldo Leoplold (1949) recognized more than a half century ago the dangers of cheatgrass-fueled wildfires. The best known method to suppress cheatgrass is through the establishment of long-lived perennial grasses (Young and Clements 2009). Innovative and aggressive weed control practices must be applied in most rangeland restoration/rehabilitation efforts to decrease cheatgrass seed bank and above-ground densities for any hope to establish perennial grasses (Young and Clements 2009, Clements et al. 2013).

Timing of Seeding

When a big sagebrush (*Artemisia tridentata*) community burns, the presence of big sagebrush burns hot enough for a long enough period to kill a portion of the cheatgrass seed in the seed bank, which opens the window for long-lived perennial grasses to compete in these lower cheatgrass densities. If the site was previously dominated by cheatgrass, the wildfire simply burns too fast to kill the cheatgrass and viable cheatgrass seeds remain present on the surface of the soil as well as in the seed bank. In northern Nevada we tested this by seeding a recently burned Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) dominated community. We tested the seeding of various species the first fall following the wildfire compared to waiting and seeding the second fall. We seeded four treatments: 1) Crested wheatgrass (*Agropyron cristatum*) (8 kg/ha), 2) Sherman big bluegrass (*Poa ampla*) (2.3 kg/ha), 3) Squirreltail (*Elymus elymoides*) (4.6 kg/ha) and 4) A mix of crested wheatgrass (4.6 kg/ha), Sherman big blue grass (1.1 kg/ha), squirreltail (2.3 kg/ha), Indian ricegrass (*Achnatherum hymenoides*) (1.1 kg/ha), 'Immigrant' forage kochia (*Bassia prostrata*) (0.6 kg/ha), Wyoming big sagebrush (0.3 kg/ha), and 'Ladak' alfalfa (*Medicago sativa*) (0.3 kg/ha). The mix plots experienced the best results with the establishment of 9.9 plants/m² followed by the crested wheatgrass plots, 9.6 plants/m². Sherman big bluegrass, 0.99/m², and squirreltail, 1.3/m² were both unsuccessful. Seeding the first fall following the wildfire resulted in more seedling recruitment compared to seeding the second fall even though the site received only 14.5 cm of precipitation the first year compared to 23.5 cm the second year. For example, seedling recruitment and establishment in the second fall plots decreased in the mix plots down to 4.9/m² while the crested wheatgrass plots decreased to 4.3/m². Cheatgrass densities were suppressed to 14.4 plants/m² in the first year seeded crested wheatgrass plots but increased to 32.7/m² in the second year seeded plots. The control plots reported a cheatgrass density of 213.5/m².

Mechanical Fallow

Discing the seedbed to bury cheatgrass seeds deeper in the seed bank can also be a helpful tool at decreasing cheatgrass seed bank densities. The objective of this method is to disc the site before cheatgrass seed ripening (early May), decreasing that year's seed production while at the same time burying a portion of the remaining cheatgrass seed bank to depths that reduce cheatgrass germination the following fall and spring. The ability to reduce the cheatgrass seed bank decreases the competition for limited resources needed by the desirable seeded species you are trying to establish on specific sites. We investigated this application by discing three cheatgrass dominated sites in northern Nevada. On average, discing reduced cheatgrass seed bank densities by 72%. The un-disced plots averaged 418.3 cheatgrass seeds/m² in the seed bank whereas the disced plots were reduced to 117.1/ m². When our seeded species germinated and sprouted they competed against less above-ground cheatgrass densities; 46.6/m² in un-disced plots versus 10.8/m² in the disced plots. On average, seeded perennial grass species such as Siberian wheatgrass (*Agropyron fragilla* ssp. *sibiricum*) and Sherman big bluegrass established in disced plots at 19.8/m² compared to 1.8/m² in the undisced plots. The success of establishing these perennial grasses resulted in 90% reduction of cheatgrass densities and fuels.

Chemical Fallow

Herbicides are also very useful tools in rangeland restoration and rehabilitation practices, but they must be approached very carefully and experimented with on a small-scale, replicated manner in various habitat conditions (soil types, climates, etc.). Two of the more popular herbicides we use for cheatgrass control are *Imazapic* (Plateau) and *Sulfometuron methyl* (Landmark XP). These herbicides are not selective but can be effective at controlling cheatgrass and opening a window to successfully seed species in lower cheatgrass densities. We apply these herbicides in early fall and then fallow the site for 1 year as the herbicides are active for about 15 months. This application is very effective and largely eliminates fall, winter, and spring germination of cheatgrass. The following fall the treated site is seeded to competitive/desirable species in an effort to reduce cheatgrass densities and fuels. We tested these two herbicides at two separate cheatgrass dominated sites in northern Nevada on 24m x 60m replicated plots. *Imazapic* was applied at 420g/ha while *Sulfometuron methyl* was applied at 122.5g/ha. *Sulfometuron methyl* yielded as much as 98.7% control of cheatgrass, whereas *Imazapic* experienced as much as 95.6% control of cheatgrass. Seeded perennial grass species resulted in an average of 16.2/m² in the *Sulfometuron methyl* treated plots and 10.8/m² in the *Imazapic* treated plots.

Conclusion

An integrated approach of controlling cheatgrass seed bank and above-ground densities using natural events as well as mechanical and chemical treatments can yield very favorable results, especially when in conjunction with proper seeding methodologies. The ability of resource and land managers to apply these techniques in rangeland restoration/rehabilitation efforts can vastly improve the future of degraded Great Basin plant communities by decreasing cheatgrass fuel loads and associated catastrophic wildfires.

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The Effect of Bio-digester Slurry on Chemical Composition of Napier Fodder at Different Growth Stages

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Key words: bio-digester, slurry, Napier, stage of maturity, quality

Introduction

Shortage of feed and its poor nutritional quality are the two most important constraints faced by smallholder livestock farmers during the dry season. These farmers cannot afford to purchase conventional feed supplements. Biogas production has gained popularity in many countries around the world (FAO, 1992) and bio-digester slurry has been used to irrigate many crops (Krishma, 2001). The present study was conducted to determine the effect of bio-digester slurry on the chemical composition in Napier grass harvested at different maturity stages.

Materials and Methods

The Napier fodder was grown at Maila (22.933°S and 30.467°E) in Elim, 35 km south of Louis Trichardt in the Limpopo province in South Africa. Two treatments of irrigation with poultry bio-digester slurry and no slurry were used in a complete randomised block design. At each site, six plots of 5 x 4m for each treatment were demarcated. Napier cuttings with three nodes were planted, two nodes in the ground and one above ground level at an angle of about 30 - 45° and spacing was 75cm between the inter-row and 75cm intra-row. The irrigation was done weekly using 10 litre watering cans at a rate of 5 litres per row in both treatments for sixteen weeks.

The Napier fodder leaves samples harvested at different stages of maturity were oven-dried to determine matter (DM). The dried leaves samples were then analysed for crude protein (CP) and ash following procedures by (AOAC, 2000). Neutral detergent fibre and Acid detergent fibre samples were determined following Goering and Van Soest (1970) procedures. The statistical model for nutritional composition of Napier forages from Maila at different stages of maturity was as follows:

$$Y_{ijk} = \mu + T_i + S_j + (T \times S)_{ij} + \varepsilon_{ijk}$$

Where Y_{ijk} = Observation e.g. Chemical composition (g/kgDM); μ = overall mean; T_i = Effect of the i^{th} treatment (bio-digester slurry and no bio-digester slurry); S_j = Effect of the j^{th} stage of maturity and $(T \times S)_{ij}$ = Interaction between treatment and stage of maturity and ε_{ijk} = Random error

Results and Discussion

There were no interactions between the stage of maturity and bio-digester treatment on all the chemical components. The chemical composition (g/kgDM) of Napier grass irrigated with or without poultry bio-digester slurry at different growth stages are summarised in Table 1. DM of Napier fodder increased with maturity and it dropped at late stage. CP increased ($P < 0.05$) at the late stage where the value of CP showed a significant difference between bio-digester slurry and no bio-digester slurry. NDF and ADF were constant in all the stages of maturity though the values vary, but these variations were not significant ($P > 0.05$). DM increased with maturity and dropped at the late stages of growth. There was no significant difference ($P > 0.05$) in NDF content among the treatments.

Table 1. Chemical composition (g/kgDM) of Napier grass irrigated with or without poultry bio-digester slurry at different growth stages at Maila in South Africa.

	DM (g/kg)	Ash	CP	NDF	ADF
			Treatment means		
Bio-digester slurry	337	113	147	693	430
No slurry	350	106	143	703	383
SEM	1.4	1.9	0.4	1.2	3.4
Significance	ns	ns	ns	ns	ns
			Stage of maturity		
Early stage	210^{c}	100	170^{a}	705^{ab}	405
Intermediate stage	450^{a}	105	120^{c}	670^{b}	430
Late stage	370^{b}	120	145^{b}	720^{a}	370
SEM	2.1	2.3	0.5	1.4	3.4
Significance	**	ns	**	*	ns

[a b c] Mean values with different superscript letters in the same column differ significantly (P<0.05) SEM = Standard error Mean; DM = Dry matter; NDF = Neutral detergent fibre; ADF = Acid detergent fibre; CP = crude protein; ns = Not significant; * = P<0.05 ** = P<0.01

NDF and ADF values indicate how much substrate will be available for fermentation. In the current study, irrigating the Napier fodder with the bio-digester slurry had no effect ($P > 0.05$) on chemical composition. However, the results found in this study for DM are similar to those reported by Azim *et al.,* (1989). Higher CP values ($P < 0.01$) were found in leaves harvested at early stages of growth. Ash content was not significantly different among the stages and between bio-digester slurry and no bio-digester slurry.

Conclusions

The chemical composition of Napier fodder was mostly affected by the stages of maturity compared to the bio-digester treatments but CP content in the Napier fodder irrigated with biogas slurry tended to be higher. However, the bio-digester slurry, when available e.g. in dairies, could still be used as fertilizer to irrigate fodder for the animals to avoid environmental pollution.

Acknowledgements

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Milking Performance of Transhumant Cattle × Yak Hybrids Grazing High Altitude Rangelands in the Eastern Himalayas

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Key words: Cattle, yak, cattle × yak hybrids, transhumance, Himalayan Mountains

Introduction

Hybridization of cattle (*Bos taurus*) with yaks (*Bos grunniens*) is the traditional practice used by the high mountain herders in Nepal (Palmieri, 1987). The females thus produced are locally called Chauries and are kept under traditional transhumance system, which means the source of livelihood (Dong et al., 2009). Under the transhumance system, animals utilize the rangelands of higher altitudes; up to 5500 m during summer, gradually moving towards lower altitudes ~2000 m. The intensity of animal movement and camping for herding at different pastures varies by animal species, pasture availability and prevailing weather conditions. The cattle × yak hybrids have similar high altitude tolerance capacity to purebred yaks with rather persistent higher milk yield even at lower altitude (Barsila et al., 2014) and have the advantages of heterosis in milk yield and fat content in comparison to purebred yaks (Wang et al., 1994). In the Kanchenjunga Conservation Area of Nepal, the herders of Olangchung Gola usually bring the herd at 4100 m (Mauma pastures) in July during upward movement and the same sward is also grazed in September during the downward movement. The major objectives of this experiment were to document the effect of grazing by season, the parity on milk yield as it relates to the composition of cattle × yak hybrids, and to suggest the optimal selection of lactating animals for commercial herding.

Materials and Methods

In Kanchenjunga Conservation Area (KCA) of Nepal, a traditional transhumant route was identified in consultation with the local yaks and Chauries (cattle × yak hybrid females) herders and a pasture of high altitude (4100 m) selected. Before bringing the animals to the pasture during upward movement at 3600 m, a herd milk production record was established and daily milk yield was recorded for a period of 15 days. Milking hybrids of 2nd, 4th and 6th parities were selected. Animal selection was further aimed at similarity in daily milk yield, days of parturition and for similar body length, girth and height within each parity group. Each group consisted of six lactating hybrids, selected from a herd of 60 animals. Measurements were carried out in July (summer) in the same pasture during upward movement and again in the same swards (regrowth) in September (early winter) representing downward movement. One day before the herd arrived to the experimental pasture site at 4100 m, the botanical composition and plant cover (using Braun-Blanquet cover abundance scale) estimated from a total of 100 random transects of 1 m^2 frame. Altogether, 85 different vascular plant species were recorded (excluding unknown ferns and algae), whilst 60 could be determined to species level and 25 to genus level only. The representing forage samples were later oven dried and subjected to chemical analyses (nutritive value). Daily milk yield and composition were further realized for a period of 7 days respectively at both measurements periods following a 7 days of adaptation period for both periods. Lactating hybrids were milked twice a day without calves both in the morning and evening as accordingly to the herders traditional practice. Body weight and daily milk yield were recorded using digital balance (99% accuracy) and milk composition by ultrasonic Lactoscan for 7 days. Further, energy corrected milk, daily fat, protein and lactose yield were calculated. Data was analyzed using mixed procedure of SAS (version 9.1) and mean differences obtained at 5% level of significance using Tukey's test.

Results

Both month of grazing and parity level had significant effect ($P<0.05$) on body weight of lactating hybrids. As expected, the initial body weight was recorded highest for 6th parity hybrids in September and daily weight gain was rapid for the 4th and 6th parity hybrids in comparison to the youngest parity groups (2nd parity) in September. In general, parity had similar effect on daily weight gain within the months of measurement but effect of season on parity was significant ($P<0.05$). Daily milk yield, energy corrected milk yield (ECM) and fat content were significantly affected ($P<0.05$) by season and parity and their interactions. Highest daily milk yield was obtained from 6th parity hybrids (about 5 kg/day) in July and the least was observed for 2nd parity groups in September (about1.5 kg/day). There was similar daily milk yield (2.74 vs. 2.44 kg per day) in 4th parity lactating hybrids respectively in July and September. There was also similar trend in energy corrected milk yield. Milk fat content was highest at September for 4th parity hybrids (about 8%). Milk protein and lactose content were higher at July (3.32% protein and 4.67% lactose) than at September (3.22% protein and 4.54% lactose respectively as expected due to advancing lactation and vegetation. The daily output of fat (185.10 g in July vs.149.37 g in September), protein (91.03 g vs. 61.60 g and lactose were significantly affected ($P<0.05$) by season, parity and their interactions. The highest daily output of fat was 185.10 g, about 91.03 g protein and 128.30 g lactose were recorded in July, whilst only 149.40 g fat, 61.60 g protein and 86.60 g lactose respectively observed in September.

Discussion

There have been several reports on the response of milk yield and milk composition to variations in seasonal changes associated with feed quality, breed and parity and so on for cattle. However, these information are lacking in case of yaks and their hybrids as these animals are kept in remote areas of the Himalayan Mountains of Nepal. Concerning daily milk yield and composition, the altitude effect would have been inseparably included with forage quality and forage allowance to changes in stage of lactation in the present study. Adaptation to seasonal change and pasture quality might depend upon age of animals. The massive decline in milk yield and rapid body weight gain in 6th parity groups, and significant negative weight gain and the lowest milk yield in 2nd parity hybrids would be the hint of rapid changes in body reserves for production than that of mid-parity lactating hybrids. It would further hint for the altitude tolerance of mid parity hybrids than the younger (2nd parity) and relatively older animals (6th parity) when grazed at pastures of high elevation at 4100 m in eastern Himalaya Nepal.

Conclusion and Implications

This experiment carried out in the eastern Himalaya of Nepal revealed that the cattle × yak hybrids above 4th parity could be promising for commercial herding as has been shown from their higher daily milk yield and daily outputs of milk constituents. However maternal lineages (Schutz et al., 1992) and heterosis in milking performance are yet to be determined for cattle × yak hybrids grazing in the eastern Himalayas at rangelands of higher altitude in Nepal. Moreover, a detailed range inventory and grazing behavior studies are needed to confirm the findings of this experiment.

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An Analysis of Seasonal Pattern Variation in the Diet of Free Range and Herded Livestock on a High Altitude Island in the Kamiesberg, Namaqualand, South Africa

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Key words: Diet selection, free range, herding, Kamiesberg

Introduction

The Kamiesberg in Namaqualand along the semi-arid South African north-west coast is one of few places where seasonal altitudinal transhumance (between the lowlands and uplands with herding, as well as free ranging herds) can still be found. With the introduction of fencing with camp systems as a rangeland management tool in the 1930's, the use of herding became less favoured in modern farming systems. Fencing with multi-camping systems is promoted in formal agricultural training and on newly established land reform farms. However, herding does offer various advantages including improving rural livelihoods, reviving customary practice, reducing stock theft, reducing predation and improving biodiversity management as pointed out by Salomon et al. (2013). This study was conducted to determine the variation in diet between free-ranging and herded grazing animals (sheep and goats) in the dry and wet season in the Kamiesberg.

Material and Methods

Study area

The study was conducted in Leliefontein village commons (30°18'49.70"S and 18° 5'0.40"E) in the Namaqualand region of South Africa. Leliefontein village is situated in the Kamiesberg at about 1300 m.a.s.l. The climate is Mediterranean and the characteristic features of the area are the warm, dry summers, and cold, wet winters. The village receives a mean annual precipitation of 392 mm. The vegetation is dominated by non-succulent shrubs and an emergence of ephemerals during winter.

Methods

Herds were observed in the field whilst grazing and the plant species consumed were recorded and biomass samples were collected. Four herds of free-ranging goats and sheep and four herds of herded goats and sheep were observed. In total, 16 herds were observed in each of the cold wet winter and the hot dry summer season (See Samuels et al. 2015 for detailed methodology). For herbaceous plants, leaves, flowers and stems were collected for chemical analysis. For perennial plants, leaves, flowers and browsable stems were collected. Oven dried samples were analysed for CP, NDF, ADF, Ca, P, Na, Mg, and K. Also, dry matter intake, dry matter digestibility, metabolisable energy and relative feed value were calculated. Redundancy analysis (RDA) was applied to extract the main pattern of variation in growth form availability, diet growth form composition, chemical and nutrient composition of forage, and the intake of growth forms weighted by quality. Procrustes Analyis was used to compare the extent of agreement between PCAs of diet on offer and selected, and diet quality on offer and selected. Herds with the largest disagreement (measured by Euclidean distance) between diets on offer and selected in different seasons were identified.

Results and Discussion

Higher levels in nutrient concentrations in forage plants are associated with the wet season and during the dry seasons, fibre levels in are high (Fig. 1). Herded goats consumed a diet with high levels of secondary compounds whereas sheep consumed a diet that is intermediate between anti-nutritional and nutritional concentrations.

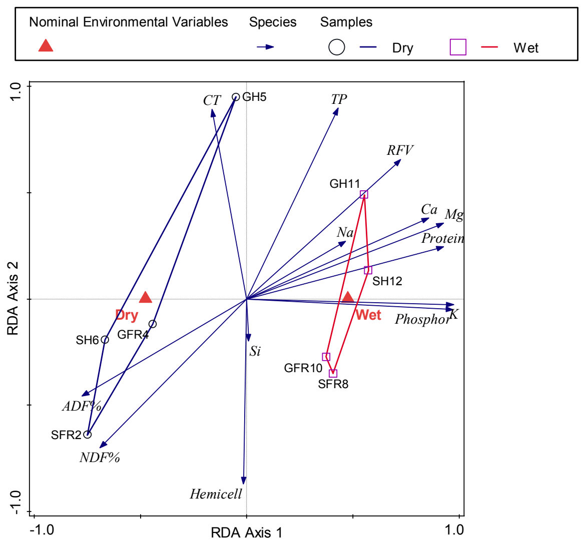

Figure 1. RDA of effect of season on mean content of diet chemical / quality variables weighted by proportion in diet.

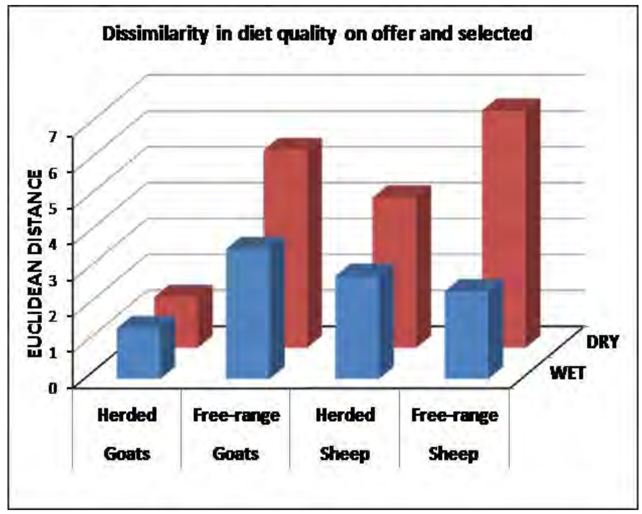

Figure 2. Euclidean distances between dietary quality elements on offer and selected by herds in the wet and dry season.

Overall, in the Procrustes Analysis, there was a high (69.9%) agreement between diet composition available and selected, but only an a 49% match between dietary quality on offer and selected by herds. This is largely due to free-ranging livestock (FR) selecting a different quality diet than what was on offer (as denoted by the larger Euclidean distances in Figure 2), especially during the dry season. Herded animals, especially goats, were best able to match their diet quality to the nutrients available at sites, and consumed a diet with relative forage value more than 50% higher than free-ranging animals of the same species.

Conclusion and Implications

This study indicates that the use of herding as a livestock management tool contributes to livestock having options to a better quality diet. We therefore suggest that herding should be considered as rangeland management tool as it could result in a higher forage quality diet by livestock, which could potentially lead to improved animal production. Promoting herding could possibly also lead to more job opportunities in impoverished rural communities and would cut input costs through lower infrastructure (fencing) investment.

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Estimate of Diet Composition, Herbage Intake and Digestibility of Sheep Grazing on Typical Inner Mongolian Steppe

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Key words：Grazing sheep; diet composition; herbage intake, Inner Mongolia.

Introduction

The malnutrition of grazing sheep during autumn to winter is often observed in the northern area of China, due to reductions in herbage yields and nutritive value. In order to improve the performance of sheep production in this region, it is be essential to know the nutrient intake. However, it is very hard to estimate the herbage intake, diet composition and digestibility of livestock under grazing conditions. The N-alkane technique is known as a valid estimation method that has proved an effective and accurate for analysis the herbage intake and digestibility of grazing sheep (Mayes and Dove 2000). The herbage intake of sheep grazing on desert grassland was studied, it proved to be a simple and flexible method (Hu, 2014; Wang, 2000), so the aim of this study was verify the seasonal changes of the herbage intake, diet composition and digestibility of grazing sheep in typical steppe. This information will potentially provide a scientific, theoretical and practical basis for the nutritional regulation of grazing sheep.

Materials and Methods

The experiment was conducted for 3 periods: the spring (the beginning of June when grass begin to become green), the summer (the beginning of August when grasses have largest biomasses) and late winter (March next year when grasses are fully withered). Six grazing Mongolian sheep (mean weight, 45.0 ± 1.0 kg) were herded, and swallowed an intra-ruminal controlled release capsule (Captec Alkane Capsule for Sheep, Captec (NZ) Ltd, Auckland, New Zealand) containing C32 and C36 alkanes were given by oral drenching(Dove and Mayes 2005). Each measurement period included 7 d adaption and 5 d of sampling. At the same time, fecal was collected from all the animals for 5 days by the bags installed between hindquarters in advance. Thirty-minute observation was carried out five times a day during the experiment in order to determine the species and quantity of grasses to be collected. At the same time, grass and feces samples were collected. Samples were prepaired and analysed by the alkanes estimating method (Dove and Moore, 1995). Statistical analyses were performed using SPSS19 (SPSS Inc., Ireland).The data was analyzed by means of one-way analysis of variance (ANOVA). Significance levels were taken at $P<0.05$ to $P< 0.01$.

Results and Discussion

The results showed that *fringed sagebrush* was the most important dietary component of sheep in three seasons (Table 1). *Fringed sagebrush* constituted 33.46, 28.69 and 50.10% of the sheep's diet in summer, autumn and winter, respectively. *Carex* was minor component of sheep's diet in three seasons. In summer, the sheep showed preference for *fri*nged *sagebrush*, which together with *Carex*,*stipa krylovii* and *leymus chinensis*, comprised more than 90% of the diet. In su mmer and winter, the sheep consumed mostly *fringed sagebrush* (28.69 and 50.10%), *Carex* (18.41 and 19.19%) and *stipa krylovii* (14.81 and 18.39%). The *leymus chinensis* and *potentilla tanacetifolia* had been consumed only in spring. And *potential acaulis* and *thyme* had been consumed only in summer. In spring and summer, the free-choice feeding sheep were grazed on the grassland, due to the botanical species around experiment site were abundant but only *fringed sagebrush* (36%), *cleistogenes* (15%), *carex* (10%) and *stipa krylovii* (25%) were detected in the botanical composition in winter.

Table 1. Diet composition of grazing sheep according to season (%) (mean±SED).

Season	*fringed sagebrush*	*cleistogenes*	*potential acaulis*	*carex*	*stipa krylovii*	*leymus chinensis*	*potentilla tanacetifolia*	*thyme*
Spring	33.46±1.30[a]	——	——	21.23±1.07	17.88±0.95[a]	17.57±0.96	9.82±0.54	——
Summer	28.69±2.05[a]	10.77±0.91[a]	8.09±0.95	18.41±0.85	14.81±1.22[b]	——	——	19.19±0.83
Winter	50.10±1.44[b]	15.31±0.91[b]	——	19.19±1.18	18.39±1.10[a]	——	——	——

† Different superscript letters indicate a significant difference between seasons (*P* 0.05).

It was observed that the herbage intake reached 1.83 kg/d in spring, followed by 1.73 kg/d in summer and 1.21 kg/d in winter (Table 2). The herbage intake was not different between in spring and summer (P>0.05) and it showed significant higher than in winter (P<0.05). As the herbage grows, the digestibility of herbage reduces. The digestibility of herbage in spring, summer and winter are 71.44, 68.39 and 36.37%, respectively.

Table 2. The herbage intake and digestibility of grazing sheep in different season.

	DM intake (kg DM d−1)	DM digestibility (%)
Spring	1.83±0.11[a]	71.44±1.63[a]
Summer	1.73±0.18 [a]	68.39±1.31[a]
Winter	1.21±0.10[b]	36.37±1.29[b]

†The different letters (a,b) indicate significant differences in different season at $P < 0.05$.

Conclusions and Implications

The results from the present study showed that *Fringed sagebrush* were the most dominant diet component in native pasture, with different proportions in different seasons. The herbage intake and digestibility in grazing sheep were significantly lower in winter with high correlation between herbage intake and digestibility.

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Biological Performance Evaluation of *Astragalus adsurgens* (var. Telmen-1) Seed in Forest-Steppe Zone of Mongolia

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Key Words: Genotype, milk-vetch, Mongolian rangelands, nutritive value

Introduction

Mongolia has 70 species of *Astragalus* (milk-vetch) out of 564 species of which 128 are genuine pasture plants (Turtogtokh, 2004). Most of the *Astragalus* (milk-vetch) species are an important component of fodder resources for animal (Damiran, 2005). Recently, an *Astragalus adsurgens* germplasm has been registered as new forage variety Telmen-1. This paper reports the biological performance including field germination, vitality, overwintering and bush seed yield of the registered variety Telmen-1 in Forest-Steppe zone of Mongolia.

Materials and Methods

We conducted field experiments for two years at Batsumber soum of Tuv aimag Mongolia which is situated between latitudes 48º and 50º N, and longitudes 106º and 108º E at 1000-1100 masl and belongs to a continental climate region of Mongolia characterized by warm sub-humid summer, and cold winter. Plant phenological studies were carried out as per Beideman's (1974) method; field germination, overwintering, plant green and hay mass, seed yield, and cold and drought resistance were evaluated. Seeding was carried out in late June before the summer rainfall, at the depth of 1.0-1.5 cm for the replicated (n = 6) plot of 45 × 45 cm.

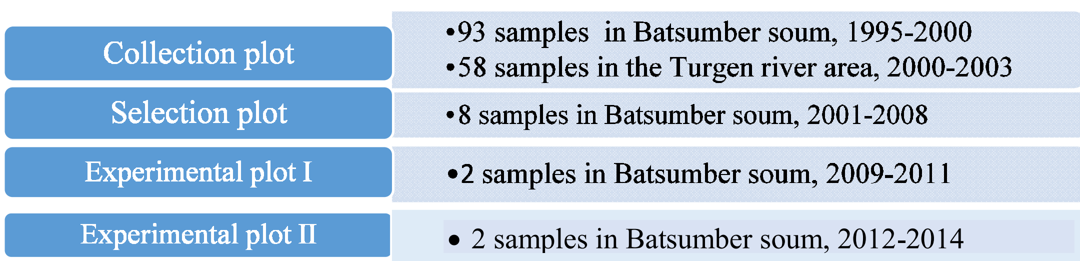

Figure 1. Plant variety development scheme for *Astragalus adsurgens* Telmen-1.

After appearance of second and third leaf, we cut them and left only one leaf. Dry matter and ash content was evaluated by AOAC (1990), protein determined by Kjeltec titration method and crude fiber was estimated by Ankom Fiber Analyzer.

Results and Discussions

An average air temperature was 16.4ºC, which was higher by 1.2ºC compared to multiyear average, precipitation was 55.1 mm or same as multi-year average for the June of 2009 which was favorable in terms of climate conditions for planting perennial fodder plants. Emergence was observed 18-23 days after seeding of the samples of *Astragalus adsurgens* Telmen-1. First trifoliate leaf appeared around 25-30 days and third trifoliate leaf occurred between 43 and 52 days after seeding.

Weather conditions created good circumstances for field germination of the samples tested, as air temperature remained 18.5ºC during the June of 2009. Second year regrowth was noted on 5th of May in 2010. Regrowth, branching, budding, flowering and seed formation were observed at 15-18, 20-25, 20-25, 20-25, 25-30 days after seedling of the samples, respectively. Whole growing period of the tested samples of *Astragalus adsurgens* Telmen-1 was 105-121 days. There was no significant difference on growth stage among the local samples *of Astragalus adsurgens* Telmen-1. Laboratory and field germination of the tested samples were at 54.0-55.5% and 75.1-79.0% respectively and vitality rate ranged between 96.4 and 98.0% and overwintering varied at 90.7-93.05% (Table 1).

An average air temperature of May of 2010 was 11.7ºC, higher by 0.8ºC compared to multi-year average, precipitation was 27.4 mm or higher than multiyear average by 15.3 mm, which created favorable conditions for second year spring regrowth of the planted samples. Bush seed yield, green mass and weight of 1000 seed averaged out at 7.3 g, 67.2 g, and 1.0-1.2 g respectively.

Table 1. Seed biological characteristics of the *Astragalus adsurgens* (var. Telmen-1) in Forest-Steppe Zone of Mongolia.

	Collection Plot				Selection Plot				Experimental Plot			
	Field germination, %	Overwintering, %	Seed yield, g/bush	Crop yield, g/bush	Field germination,	Overwintering, %	Seed yield, g/bush	Crop yield, g/bush	Field germination,	Overwintering, %	Seed yield, g/bush	Crop yield, g/bush
	43.3	80	1.5	46.5	66	90	2.27	53.5	79	93.1	6.2	67.2
SEM	0.96	2.22	2.01	0.36	2.43	3.08	2.84	3.16	1.94	2.54	3.38	2.53
P-value	<0.01	0.30	0.02	<0.01	0.04	0.02	0.01	0.15	0.18	0.03	0.64	0.60

The results of this experiment indicated that *Agtragalus adsurgens* Telmen-1 variety showed significant increase in field germination and overwintering in the selection and experimental plots over the collection plot by 22.2-35.7% and 9.6-13.5%, respectively. Similarly bush seed yield and green crop yield also increased by 0.8-4.7 and 7.0-20.7 g/bush, respectively for this variety during transferring from germ collection plot to experimental plot. Crude protein and crude fiber of *Agtragalus adsurgens* Telmen-1 variety was 16.8 and 21.1% (data not shown) respectively for the flowering period (Udval, 2014). One kg *Astragalus adsurgens* Telmen-1 contains 9.6-10 MJ metabolic energy and 70-101 g protein which illustrates its high nutritive value.

Conclusions

Growing period of the Telmen-1 new variety of *Astragalus adsurgens* ranged from 105 to121 days in non-irrigated conditions in forest steppe zones of Mongolia. *Agtragalus adsurgens* Telmen-1 contains high protein and energy value as other legume fodder plants and its field germination rate increased from collection plot through selection to experimental plots. In forest-Steppe zone of Mongolia, *Agtragalus adsurgens* Telmen-1 seed vitality and overwintering rates were at 79.0 and 98.0%, respectively.

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Effects of Glyphosate on Forage Dry Matter Yield, Nutritional Content, and Drying Time of Oat and Barley Harvested as Yellowfeed

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Key words: Yellowfeed, glyphosate, spray-topping, desiccation.

Introduction

Yellowfeed is the practice of spraying a cereal greenfeed forage crop with glyphosate to stop development and preserve quality until it can be cut and baled. Yellowfeed has been promoted as a useful practice in years when frequent rains delay swathing of greenfeed or are expected to slow the drying of greenfeed in the swath resulting in loss of quality. There is little research available on this practice in Canada.

Objective

The objective of this study was to investigate the effect of glyphosate application on forage dry matter yield (DMY), quality and dry-down time of oat (*Avena sativa* L. cv. Baler) and barley (*Hordeum vulgare* L. cv. Cowboy), harvested as yellowfeed in northeastern Saskatchewan.

Materials and Methods

A field experiment was completed for three consecutive years (2012-2014) at the Agriculture and Agri-Food Canada, Melfort Research Farm, Saskatchewan (52^{O}44'N 104^{O}47'W), on a thick Black Chernozem (Udic Boroll) silty clay soil. Oat and barley were seeded, at 114 kg ha^{-1} and 108 kg ha^{-1}, respectively, on May 28, 2012, May 30, 2013 and June 18, 2014 on wheat stubble. All plots were fertilized at recommended rates. Treatments were arranged in a split plot design, with four replications. Individual plots measured 4 m x 10 m. At the late milk stage for oat and early dough stage for barley, each crop was sprayed at 2.47 L ha^{-1} with glyphosate 540 g a.e.L^{-1} (Roundup Transorb®). These plots were sampled for dry matter yield (DMY), protein (P), total digestible energy (TDN), mineral and moisture content (MC). Crops were considered dry enough to bale at 16% MC. The data on forage DMY, TDN, P, Calcium (Ca), Potassium (K) and Magnesium (Mg) was subjected to analysis of variance (ANOVA) using PROC GLM procedure of SAS. Least significant difference ($LSD_{0.05}$) was used for mean separation for each parameter.

Results and Discussion

Effect of glyphosate on yield, protein and energy

Figures 1-3 compare DMY, protein and energy (TDN) of yellowfeed oat and barley at spraying and baling during 2012-2014. In 2012, the crops were sprayed August 14 and baled September 16 (30 days). DMY, from spraying to baling, declined 22% for both oat (10975 to 8531 kg/ha) and barley (13014 to 10089 kg/ha). Oat and barley protein content declined 2.6 and 2.5 percentage points, respectively. TDN of oat and barley declined 3.4 and 2.7 percentage points, respectively. The yield and quality decline was probably the result of weathering and respiration losses during dry-down. In 2012 there was a total of 25.5 mm of precipitation that occurred on 8 days during the dry-down period. These rain events ranged from 1.1 mm to 8 mm/day. In 2013, the crops were sprayed August 27 and baled September 17 (21 days). DMY, from spraying to baling, decreased 2.4% for oat (12601 to 12297 kg/ha) and 9.1% for barley

(11182 to 10167 kg/ha). Changes in DMY, protein and TDN in 2013 were not significant for either oat and barley. In 2013 there was only one rain event totaling 3.8 mm during the dry-down period.

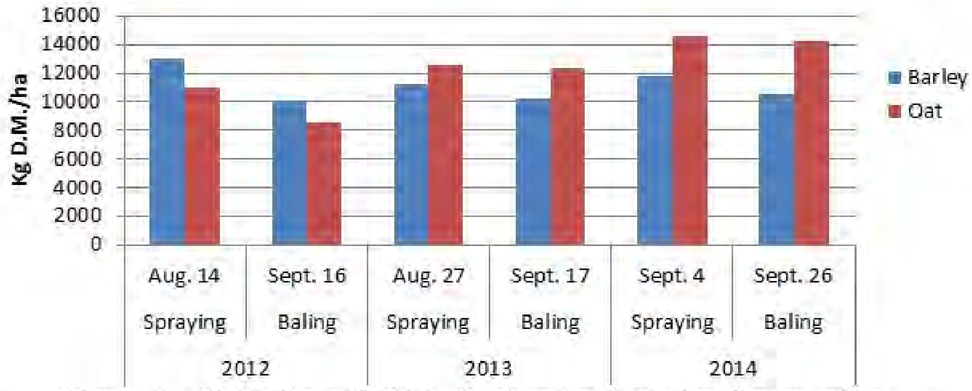

Figure 1. Yield (kg D. M./ha) of oat and barley forage when sampled spraying and baling at Melfort, Saskatchewan.

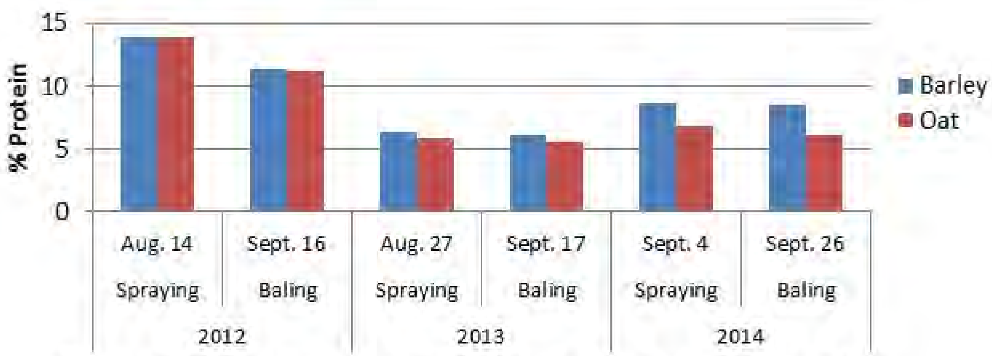

Figure 2. Protein content (%) of barley and oat forage when sampled at spraying and baling at Melfort, Saskatchewan (.

Figure 3. Total digestible nutrient content (% TDN) of barley and oat forage when sampled at spraying and baling at Melfort, Saskatchewan).

In 2014, the crops were sprayed September 4 and baled September 26 (22 days). DMY, from spraying to baling, declined 3% for oat (14593 to 14202 kg/ha) and 11% for barley (11801 to 10555 kg/ha). Changes in DMY and protein were not significant in 2014 for either crop. TDN of both oats and barley increased approximately five percentage points. Unfortunately termination of the project occurred prior to the oat being dry. It is possible that further changes to oats may have occurred after the end of September. In 2014 there were four rain events totaling 6.3 mm during the dry-down period.

Rate of forage dry-down after glyphosate application

In 2012-2014, crop dry-down took 20 to 30 days depending on the moisture content of the crop at spraying and weather conditions after spraying. Dry-down was more rapid in 2013 (20 days) compared to 2012 (30 days) or 2014 (22 day for barley). In 2014 yellowfeed barley dry-down took 22 days. Unfortunately the project was terminated on September 26 when oats was still at 43% moisture content. In all three years, oats was higher in moisture content than barley when sprayed and tended to dry slower than barley. This was probably due to the difference in the stage of each crop at spraying.

Effect of glyphosate on mineral content

The application of glyphosate had little effect on the plant mineral content. Mineral contents were generally higher in 2012 compared to 2013 and 2014. However, changes of mineral content between spraying and bailing were significant only for K in 2012 and in 2013, and for Mg in 2014.

Conclusions and Implications

In this project during 2013 and 2014, when weather conditions were relatively warm and dry after spraying, there were only slight changes in yield or feed quality of yellowfeed. However, in 2012, when weather conditions were relatively cool and wet after spraying, there was a decline in yield, protein and TDN. Even with this decline, under wet harvest conditions there may be an advantage in having the crop stand as yellowfeed to reduce weathering and mold growth rather than lie in a swath as greenfeed.

Crop dry-down took 20 to 30 days depending on the moisture content of the crop at spraying and weather conditions after spraying. Producer experiences suggest the application of glyphosate may not result in faster drying times than swathing alone or cutting and crimping in some years.

There are additional costs to harvesting cereal forage as yellowfeed compared to greenfeed, such as product and application costs of glyphosate. However, one of the cost savings of yellowfeed is the opportunity to swath rather than mow and condition the crop.

Cross-border Analysis of Biomass Availability and Stocking Densities on Seasonal Pastures in the Chinese-Mongolian Altay-Dzungarian Region

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Key words: GPS tracking, grazing itineraries, herbage allowance, small ruminants, transhumance

Introduction

Transhumant pastoralism in the Chinese-Mongolian Altay-Dzungarian region relies on consecutive grazing of seasonal pastures. Spring pastures in desert steppes or at mountain foothills (1400-2000 m a.s.l.) are of major importance for the lambing females. In summer animals graze alpine meadows (2000-3000 m), where they are fattened and cows, does and occasionally ewes are milked to process cheese and butter. In autumn, decreasing biomass and temperatures make animals move to the floodplains (1000-1100 m) of the Bulgan (Mongolia) and Qinghe River (China) where grass-rich pastures enable them to further build up body reserves. In winter, biomass in the desert steppes (1100-1900 m) is low but usually available to livestock due to low snow cover (Brown et al., 2008; Behnke et al., 2011). Despite these similarities in transhumance patterns, cross-border differences manifest in precipitation and socio-political conditions. The Chinese government involves in pasture management through fencing programs, conversion of autumn/winter pastures into irrigated cropland, resettlement of pastoralists and regulation of herd size and duration of pasture utilization (Brown et al., 2008; Liao et al., 2014). In Mongolia, economic privatization in the 1990s resulted in rising animal numbers, especially of cashmere goats, and lowered the frequency of short-distance herd displacements (Behnke et al., 2011; Lkhagvadorj et al., 2013). Given these disparities, we compared (i) seasonal and daily mobility patterns of small ruminant herds, (ii) biomass yields on the main seasonal pastures and (iii) stocking rates and herbage allowances resulting from these two aspects.

Materials and Methods

The study focused on the counties of Qinghe (46.67°N, 90.38°E), China (C) and Bulgan (46.09°N, 91.54°E), Mongolia (M), which both cover parts of the central Altay Mountains and the Dzungarian Desert basin. A survey in >150 rural households per site revealed that small ruminants were most important for income generation across ethnic groups, and at both sites groups of >30 families utilize the same seasonal pastures. Therefore we selected one typical herder family per site, and one representative goat within their small ruminant herd was equipped with a GPS collar, to capture daily and seasonal mobility patterns during three years (2012-2014). Following GIS-based data processing, daily walked distances, number and size of utilized grazing areas within seasonal pastures, duration of stay and stocking rates (as obtained from animal counts) were calculated. Before herds moved to a seasonal pasture, the herbaceous biomass in 0.25 m² frames placed at grid-nodes spaced 500 m x 500 m was clipped to 1 cm above ground and its dry matter (DM) determined. In the GIS, biomass data from 359 (C) and 510 (M) sampled spots on the main seasonal pastures was spatially interpolated and, combined with tracking routes and stocking rates, used to calculate seasonal herbage allowance.

Results and Discussion

A small ruminant herd comprised 75.6 ±70.1 (n=175) and 103 ±63.3 (n=122) animals in China and Mongolia, with the ratio of sheep to goats being 4.2 : 1 and 1 : 3.7. Annual precipitation amounted to 174 ±50 mm and 75 ±34 mm in the towns of Qinghe and Bulgan, whereas on the respective summer pastures (at 2121 m and 2432 m) an average annual precipitation amount of 160 mm and 305 mm was measured (2013, 2014), along with an average annual air temperature of -1°C and -5°C. While overall precipitation was higher on the Mongolian than on the Chinese summer pasture, precipitation before summer pasture utilization summed up to 71 mm (C) and 32 mm (M), pointing to low soil moisture in late spring and early summer at the latter site. Average daily air temperatures of -11°C (M) and -2°C (C) before summer pasture utilization were further delaying vegetation growth in Mongolia.

Cumulative annual long-distance movements of the herds amounted to 395 ±136 km (C) and 412 ±97 km (M), while averaged daily grazing orbits ranged from 6 to 12 km across sites and seasons, with by trend shorter movements in Mongolia. Average stay on spring, summer, autumn and winter pasture lasted 71, 85, 69 and 140 days in China and 83,65, 77 and 144 days in Mongolia. While Chinese herd changed grazing location two to three times on spring, summer and autumn pasture, they remained stationary on the winter pasture. Mongolian herds, on the other hand, remained stationary on the autumn pasture, and changed grazing location three times during winter and two times during spring and summer. These differences were interpreted as a result of governmental regulations and confirms findings of Liao et al. (2014). The average size of utilized grazing areas within the seasonal pastures varied from 18 to 68 and 8 to 73 hectares in China and Mongolia, from which average seasonal (3-months) stocking rates of 0.3 to 1.5 and 0.3 to 2.1 sheep units (SU) per hectare were calculated.

In China, herbage yields on spring, summer, autumn and winter pasture averaged 1.4 ±0.90, 1.7 ±0.75, 1.1 ±0.87 and 0.9 ±0.66 t DM ha^{-1}, whereas the respective herbage yields were in most cases lower on the respective Mongolian pastures (1.2 ±0.82, 0.5±0.42, 1.9 ±0.84 and 0.6 ±0.34 t DM ha^{-1}). In consequence, yearly average herbage allowances (kg DM SU^{-1} day^{-1}) averaged 52 (M) and 65 (C), whereby only on the spring pasture the Chinese value was 33% lower than the Mongolian one.

Conclusions and Implications

Official regulations on animal numbers, timing of pasture utilization and allocation of specific seasonal grazing areas to individual herders seem to contribute to higher herbage yields on the Chinese site, but higher spring temperatures and rainfall also play a role. On the other hand, enforced regulations may prevent flexible adaptation to inter-annual variation in precipitation and sudden adverse weather conditions. In Mongolia, increased goat numbers, reduced livestock mobility within seasonal pastures and thus high seasonal stocking rates in combination with low temperatures and precipitation until May affect biomass yield and herbage allowance to small ruminants. Apart from intensified culling of surplus and old animals, which in cashmere goats is no realistic option, increasing the animals' daily grazing radius by actively herding sheep and goats may reduce grazing pressure and improve pasture productivity especially on the spring and summer pastures.

Acknowledgement

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Affects in Rangeland Productivity, High Mountain Area

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Key words: Vegetation coverage, plant species, biomass, grazing area

Introduction

The natural rangeland in Mongolia is a very sensitive structure, easy to be overgrazed and degraded, and with a low productivity depending on climate change and influence of human activities. In years 2008-2010, about 22.6 percent of Mongolia's rangelands were degraded out of which 3.3 percent are at heavy, 11.2 percent at medium and 8.1 percent at a slight level of degradation (Enkhmaa 2011). The global climate change has accelerated the desertification and the boundary of desert areas is expanded by 3.4 percent (Adyasuren 2002). Despite these facts, the yield volume is fluctuating from year to year depending on natural factors like drought, precipitation thus causing difficulties to foresee and value the state of rangeland. An instable yield is the main cause for limiting the livestock number and therefore it is important to foresee the drought and other natural factors to estimate the pasture's carrying capacity for yaks and sheeps.

Materials and Method

The research is to control pastures, through monitoring; identifying positive and negative effects on productivity, data's climate change, plant cover changes, density of individual plant species. The study of rangeland monitoring plots established fescue-herbs type in rangeland of high mountain area and overgrazed area (herb-grasses) were selected ungrazing (in explosure) and open grazing area. The summer productivity and vegetation coverage was measured August 10-15; five plots were sampled.

Results and Discusion

Weather characteristic

During the plant growing season the sum of rainfall for the high mountain area was 180 - 250 mm. Comparisons with rainfall between 2008- 2015 and average of long term (compared to 210 mm and for 1990-2010) measurements was decreasing by 18-114 mm. The average temperature is increased 0.6-1.8 ^{0} C. Aridity undex was from May to September in years average mean P= 1.08. Our research years (2008-2015) aridity index was between P=0.52-1.77. Drought occurs 2008, 2015 when sufficient rainfall needed to sustain an area is not available. Generally, the growing seasons weather was dried and warmly (Fig 1).

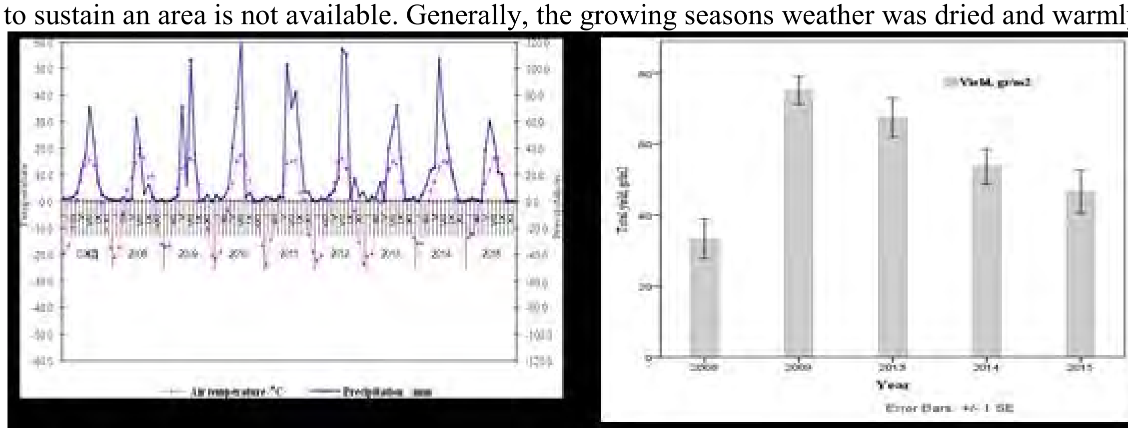

Figure 1. Climadiagram of study area from 2008-2015, and storage yield.

Yield of fecsue-herbs type
According to the research results, yields were between 350-750kg per hectare in fescue-herbs vegetation community (Fig 1). The yield depends on weather, however, as rangelands yield fluctuate from year to year depending on climate conditions, it is important to consider the differences of humidity in normal and dry year when estimating the carrying capacity which is crucial to livestock husbandry development. Our result shows that during humid years about 10 percent increase and during drought year 40 percent decrease should be expected and herd number managed accordingly.

Affects rangeland utilization
An intensive grazed area was protected during 2 years, to compare differences of yield storage between non-grazing and grazed areas. The protected area hold 58.3±3.51% vegetation cover, an increas by 30% from the grazied area. Also, yield increased 33.5 percent (p=0.001). Forage species such as Festuca ovina, Koeleria macranta, Poa pratensis were increased by 18 percent. The portion of litter that is in contact with the soil surface provides a source of soil organic material and raw materials for on site nutrient cycling. Litter is directly related to weather and utilization rate. In the grazed area the numbers of dominant forage grasses were reduced and bare ground areas increased. Increases in bare ground nearly always indicate a higher risk of soil erosion (Herrick et.al 2005). It also provides a risk for increasein invasive plants. Regarding our research, density of invasive plants such as *Araneria cappilarus, Potentilla bifurca Artemisa frigida, Carex duriuscula* were increased in the grazied areas. After protection, forage grasses mostly recovered. Specially, size of sedge was decreased and size of grass, legumes was increased in non grazing area (Fig 2). It shows that forage plant increases and recover of plant community.

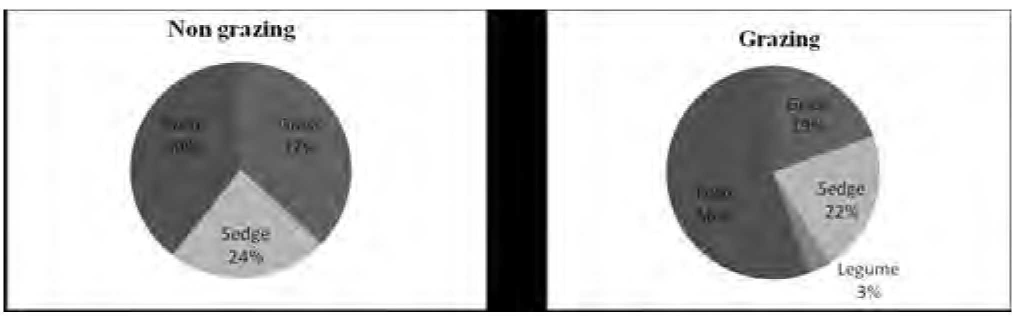

Figure 2. Comparable of the percent of Functional group forage plants.

Lkhagvajav (2006) observed an increase of endemic species number and vegetation cover, when comparing overgrazed areas of high mountain zones with non-degraded pastures. Both the presence of functional groups and number of forage plants have a significant effect on ecosystem processes (Tilman et al. 2011). The protected area has identified the possibilities of recovery, if growth conditions were provided for overgrazed rangelands.

Conclusion
The combined affects of climate change and overgrazing increased rangeland degradation in high mountain area. Dominant forage species already threatened, such as *Festuca ovina, Koeleria macranta, Poa pratensis* are likely to come under greater danger and present a very high vulnerability to climate change and overgrazing.

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Economy and Biology of Native Fodder Plant Varieties Collected from Wild Populations

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Key words: Gene pool, variety, biology, morphology

Introduction

Mongolia stretches across Central Asia and occupies an area of 1.6 million square kilometres of mountains, steppe and desert. The country is located between 87°41'and 119° 56' of the eastern longitude, and 41°35' and 52°09' of the northern latitude. January is the coldest month of the year with a mean temperature of -35°C in the northern parts (with the lowest temperature of -50° at the Depression of great Lakes and mouth of the Tes River) and -10°C in the Southern Gobi. Summers are short. Mean July temperature ranges from 18-26°C with a maximum of 40°C. Mean annual precipitation is 200-300 mm in the northern region of Mongolia, 400-500 mm in the high mountains, and less than 100 mm in the southern region of the country. More than 80% of the precipitation falls between May and September (Jigjidsuren and Johnson, 2003).

Mongolia has a harsh climate of Central Asian highland, and an abundant gene pool of wild plants of temperate zone, and various plants of 2823 species, 564 types and 128 families. (Gubanov, 1996) Approximately 600 plant species are considered as important forage crops for cattle. Research Institute of Animal Husbandry of Mongolia had arranged field expeditions for the purpose of gathering seeds of fodder plants of Mongolia for nine times in 1976, 1983, 1984, 1987, 1988, 2003, 2004, 2009 and 2014, respectively, and collected 718 samples of 342 species in 76 families from 10 geographic zones (double-counts included, Joint creation., 2011). Over 500 samples of the gene pool had been planted in forest-steppe, steppe and Gobi regions under irrigation and non-irrigated conditions, and selected through economic and biological evaluations.

Mongolian-American joint expeditions had been arranged three times in 1994, 1996, and 1998, which have managed to gather 1430 samples of 319 species and 46 families from 14 geographical zones for planting by seeding and sowing in three different natural regions (between 2001 and 2008) under irrigation and non-irrigated conditions. This enabled us to reveal many plants of vital significance to improve pastureland and hay fields of Mongolia, and establish grounds for creating new varieties of local fodder plants through economic and biological evaluations.

This research aims to develop varieties of perennial plants to support cattle industry and, improve degraded pastureland and hay fields. Specifically,

1. Selection of plant materials, which are drought and frost-resistant, and have high content of protein, and produce high seeds and hay.
2. Creation of 3-4 varieties of perennial grass and legume that are adapted to soil and climate conditions of forest-steppes and high mountains regions of Mongolia.

Materials and Methods

The plant phenological studies were carried out as per Beideman's (1974) method. Field germination, overwintering, plant fresh and hay mass, seed yield, and cold and drought resistance were evaluated. Seeding was carried out in late June before the summer rainfall, at the depth of 1.0-1.5 cm for the replicated (n = 6) plants space of 45x45 cm. After appearance of second and third leaf, we cut them and left only one leaf. Dry matter and ash content was evaluated using methods described by AOAC (1990), protein content was determined by Kjeltec titration method, and crude fiber was estimated by Ankom Fiber Analyzer.

Results and Discussion

After many years of studies, our research team have collected data on high yielding plants with high protein content, and completed economic, biological and morphological evaluations of promising source materials of fodder plants. We were able to release following varieties: *Agropyron cristatum.*L 'Sumber-1' in 2007; *Agropyron cristatum.*L 'Chuluut', *Bromus innermis.*L 'Tamir', *Stipa sibirica.*L 'Nart-1', *Psathyrostachy juncea.*Fish 'Mandal-1' in 2011; and new variety of *Melilotus dentatus.*Nill 'Selenge-1', *Astragalus adsurgens.*Pall 'Telmen-1', *Elymus sibiricus.*L 'Kherlen' in 2014. The variety Selenge-1, *Melilotus dentatus.*Nill, is a biennial herbaceous leguminous plant which has an overwintering rate of 78.1-83.3 percent. It produces seed yield of 280 kg/ha, with a 1000 seeds weight of 2.0 g. This species grows for 110-118 days. At plant bloom stage, it contains 9.5 percent protein, and 31.7 percent fiber. One kilo dry matter of hay contains 8.5MJ exchange energy, and 54 g of protein (Table 1).

Table 5. Economic and biological indicators of local variety of fodder plant /2011-2015/.

Name of plant genus	Name of variety	In percent			Crop kg/ha		1000 Seed weight /g/	Plant growth period /days/
		Regrowth	Overwintering	Protein	Hay	Seed		
Melilotus dentatus. Nill	Selenge-1	78.1	83.3	9.51	-	280	2.0	110-118
Astragalus adsurgens. Pall	Telmen-1	79.0	93.0	11 .3	3800	95	1.2	105-115
Elymus sibiricus .L	Kherlen	83.1	90.7	8.04	2350	195	3.6	106-112

The variety Kherlen of *Elymus sibiricus.*L is a perennial grass, which has an overwintering rate of 83.1 - 90.7 percent. It produced 195 kg/ha of seeds with a 1000 seeds weight of 3.6 g. Plant growth lasts 106-112 days. This grass is a drought and frost-resistant grass containing high nutritional value. For example, one kg dry matter of hay of *E.sibiricus.*L contains 8.7 MJ exchange energy, and 43g of protein. The variety Telmen-1 of *Astragalus adsurgens.*Pall, a perennial legume, has an overwintering rate of 79.0-90.7 percent. It produces 95 kg/ha of seeds, and 3800 kg/ha of hay. Its 1000 seeds weight is 1.2 g. It has a growth period 108-125 days, and also showed a good drought and frost-resistant. One kilo dry matter of hay contained 9.6-9.9 MJ exchange energy, and 70-101g protein.

Conclusion

In regions of Mongolia where drought is frequent due to global warming, it's vital to plant above varieties of perennial fodder plants that are adaptable to particular areas. And it has been possible to harvest an abundant hay and seeds for 5-10 successive years from these varieties. It is possible to increase economic benefit by producing these species.

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Effects of Diet Mixing on Intake of Tannin-Rich Plants by Goats in African Savannas

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Key words: Woody plants, complementarity, herbivory, plant defences, condensed tannins

Introduction

Although goats are anatomically and physiologically suited to thrive in shrub-dominated ecosystems, the extent to which they consume savanna shrubs is still limited by the presence of plant secondary metabolites (PSMs). Research aimed at understanding how herbivores contend with plant chemical defences indicates that consuming a diverse mixture of plant species (diet mixing) may increase goats' ability to cope with dietary negative effects of PSMs and thus result to increase chances for the animals to meet their metabolic needs. While the benefits of diet mixing have been in North America and Mediterranean systems that are predominantly characterised by nitrogen-based PSMs, very little is known about the effects of diet mixing in the African savannas that are dominated with carbon-based PSMs. This study tested the prediction that goats offered diverse species in the diet consume more woody plants and condensed tannins (CTs) than those exposed to single species diets. This information is crucial for the management of both goats and rangelands in the African savannas.

Materials and Methods

A total of 24 indigenous goats (South African veld goats) with a mean weight of 26.6 kg ± 0.51 (SE) were used in this study. The goats were individually kept in 2 m^2 for the duration of the experiment. They were randomly divided into four groups of six goats each. One of the four groups was offered either of the following diets (diet 1: *Searsia lancea*; diet 2: *Seasia pyroides*; diet 3: *Euclea crispa*; diet 4: a combination of the three diets. Fresh clean water was also provided *ad libitum* throughout the experiment. Condensed tannins of six samples of each of the study species were determined by acid-butanol proanthocyanidin assay with purified sorghum as a standard for CT estimation (Hagerman1995). To estimate CT intake of each plant species by goats, the CT percentage composition and dry matter intake of each plant species were used. Dry matter intake (g) and CT intake (g) were used as a dependent/response variables in general linear models where diet/treatment (i.e., three forage species offered individually and a mixed diet) was used as an independent variable.

Results and Discussion

The mean dry matter intake significantly varied among treatments ($P < 0.001$) with the highest intake being observed for the mixed treatments (Figure 1). Goats offered a mixed diet consumed more CTs ($P < 0.001$) than those offered individual forage species (Figure 2). These results are consistent with findings from similar studies showing that herbivores feeding on mixed diets cope better with plant secondary metabolites (PSMs) than animals provided with only one plant species (Villalba et al. 2004; Regosic et al. 2006; 2008). Thus, the current results support the postulation that animals foraging in mixed diet systems consume more (PSMs) and achieve higher dry matter intake than animals confined to monocultures or single species feeding systems.

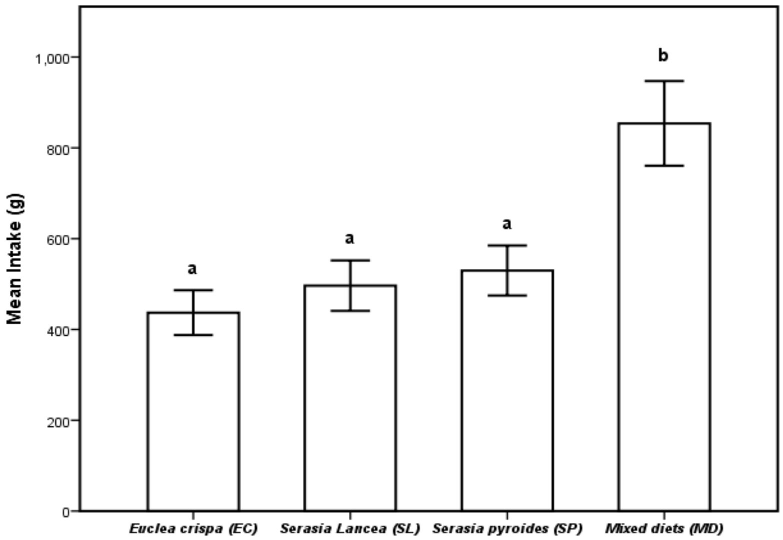

Figure 16. Effects of diet mixing on DM intake (gDM) by indigenous goats in a South African semi-arid Savanna. Error bars are standard Errors while different superscripts represent significantly different means.

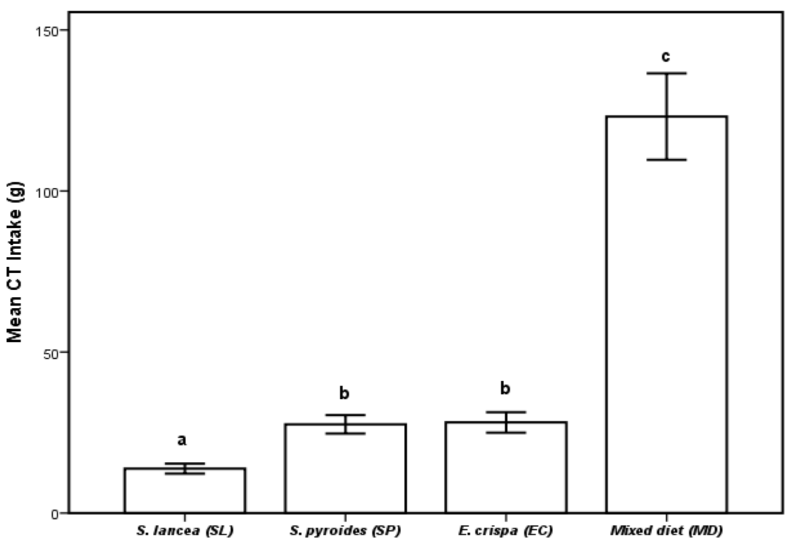

Figure 2. Effects of diet mixing on condensed tannin intake (gDM) by indigenous goats in a South African semi-arid Savanna. Error bars are standard Errors while different superscripts represent significantly different means.

Conclusions and Implications

Providing goats with a mixed diet increased overall total intake of browse material. Thus, animal practitioners in African savannas should provide animals with mixed browse materials and not feed them individual plants species. From the results of this study it is evident that diet mixing can be used as a tool to control bush encroachment and/or to make use of tannin-rich woody plant species that are often unpalatable to herbivores dominating our ecosystems. Goats should be allowed to forage in rangelands with diverse woody plant species. This may allow them to forage more and mitigate the possibility of any feeds deterring factors. Diverse mixtures of plants may benefit physical health of animals, the environmental health of rangelands and the economic health of the farmers.

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Conceptual Framework and Methodology for Estimating the Health of High Andean Wetlands

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Key words: High Andean wetlands, health, ecosystem services, attributes.

Introduction

Studies on the ecosystem health status of High Andean Wetlands are scarce despite the many environmental benefits they provide and being the main source of forage during the dry season for livestock in the Peruvian Andes. However, High Andean Wetlands will be severely struck by the impacts of climate change, particularly by the melting of glaciers in the incoming decades (Flores et al., 2015). Therefore, it is very important to evaluate how the hydrological function, biotic integrity and system stability will vary over time and to develop a conceptual framework to assess the health status.

Materials and Methods

The study was conducted in the central highlands of Peru, an area located 3800 meters above sea level, in nine High Andean Wetlands. Wetlands were in different states of conservation, representative of the highlands of the northern, central and southern regions of the Peruvian Andes. In order to develop the conceptual model, all existing theories were reviewed as well as the definition of all the attributes that provide better information on the structure and functioning of bofedales. Once these were defined, a panel of experts, assigned values of importance to each of the attributes and indicators proposed. Attributes and indicators were ranked according to their influence on the maintenance of ecosystem structure and function. Finally, metric validation was performed by comparing the health status predicted by the model with that resulting from assessing the state of health of High Andean Wetlands (good, regular and poor) with data obtained from standard methods (Parker 1954, Milton et al. 1998, Pyke et al. 2002).

Results and Discussion

Our conceptual framework (Figure 1) considers three states: healthy, healthy with management problems and unhealthy, each with corresponding biotic and abiotic thresholds. Health status was estimated from attributes: biotic integrity, hydrological function and system stability, and 12 indicators (Table 1).

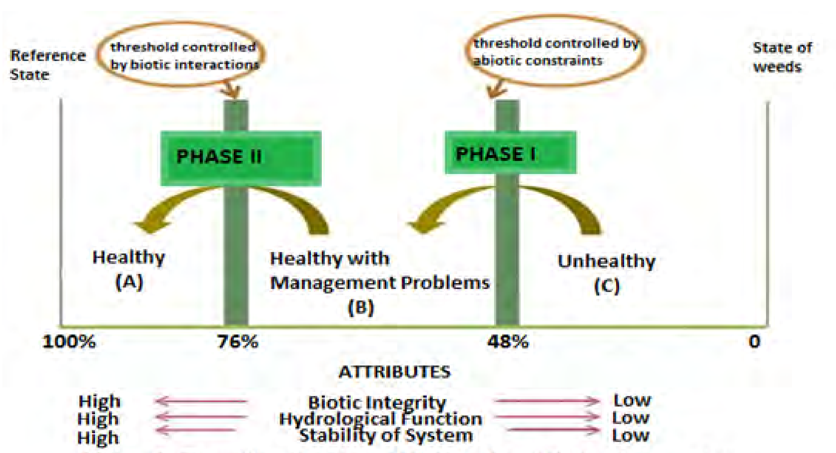

Figure 1. Transitional states of High Andean Wetlands ecosystem

Table1. Relationship of Attributes and Indicators Health of Bofedales

Attribute	Indicator	Parameter	Method
Biotic Integrity (11.9%)	Biomass	Kg DM / ha	Manual cut-off and separation
	Litter	Kg DM / ha	Manual cut-off and separation
	Organic Matter	%	Oxidation with potassium dichromate
	Carbon	%	Estimate from organic matter
Hydrological Function (33.1%)	Water Quality	Temperature, pH, total solids (TDS) and electrical conductivity (EC)	Multiparameter
	Infiltration capacity	mm / sec	Infiltrometer
	Soil density	g / cm^3	Method cylinder
Stability of the System (54.9%)	Signs of Erosion	%	Visual appreciation
	Land Cover	%	Visual evaluation in nested quadrat
	Invasiveplants	%	Modified point frame
	Habitat fragmentation	%	Visual appreciation
	Species diversity	Floristic, Richness	Shannon Index

The scores were obtained by applying the model to High Andean Wetlands in different states of health and compared with those obtained using the standard methods (Table 2). Results reveal that the attributes and selected indicators and the weights given to each of them by the expert panel provided health status scores that were generally consistent with the other three methods.

Table 2. United Health obtained with different models

Methods	Evaluated High Andean Wetlands								
	1	2	3	4	5	6	7	8	9
Parker (1954)	57.9	83.9	62.3	59.6	77.4	68.8	49.5	31.4	35.95
	Good -	Excelent -	Good -	Regular +	Good +	Good -	Regular -	Poor +	Poor +
Milton et al. (1998)	3.9	3.6	3.7	3.2	3.4	3.4	1.7	2.4	2.3
	Good	Good	Good	Intermediate	Intermediate	Intermediate	Poor	Poor	Poor
Pyke et al. (2002)	17	17	14	9	9	11	13	13	12
	None to Slight			Slight to Moderate	Slight to Moderate	Moderate	Moderate to Extreme		
Proposal	93.0	84.0	95.6	74.6	54.9	65.4	37.2	25.3	47.9
	Healthy			Healthy with management problems			Unhealthy		

Conclusions and Implications

The proposed methodology provided scores of health status that were consistent with the conservation status of the high Andean wetland. The proposed methodology also indicated that the ranges of percentage scores 0% to 48% describe the unhealthy state, 49% to 75% describe healthy with management problems, and scores of 76% to 100% describe healthy status.

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Effects of Grazing on Plant C, N, P Stoichiometry in an Alpine Meadow on the Tibetan Plateau

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Keywords: Grazing, plant functional groups, stoichiometory, nutrient cycling, alpine meadow

Introduction

Livestock grazing is a prevalent use of grasslands, which substantially influences structure and function of grassland ecosystems. Previous studies have shown that grazing may change the plant tissue C, N and P concentrations and stoichiometry through a host of plant–soil feedbacks and shifts in species composition of the community, which can further influence nutrient cycling (Frank 2008). Alpine meadow is characterized by low temperature, intense solar radiation, nutrient limitation and species-rich vegetation (Zhang et al. 2013). However, the mechanistic interpretation of the herbivore effect on the C, N and P contents and stoichiometry in plant tissues is less well known in an alpine meadow on the Tibetan Plateau (Bünemann *et al*., 2010). To explore the underlying mechanisms of how grazing affects plant C: N: P stoichiometry. In this study, we examined the effects of grazing on leaf C, N, and P contents and stoichiometry in plant functional groups and community level.

Materials and Methods

The study was conducted on a flat area of the Alpine Meadow in MaQu County (N33°59′, E102°00′), which is located in the eastern part of the Tibetan Plateau, at 3,500 m above sea level, China. The mean annual temperature is 1.2 ◦C and the mean annual precipitation is 620 mm. A flat 1 ha alpine grassland was enclosed in the study area in May 2012 as the control treatment. Outside of the enclosure, vegetation was free grazed by ungulates with mainly yaks, as the grazed treatment. Each treatment had three repeated plots (10 m×15m) with 2-16 m walkway. All the plots were set randomly. Samples were taken in the middle of August 2014. Based on previous studies, the 21 most common species were chosen for C, N and P analysis. These species accounted for more than 80% of the community aboveground biomass. For each species, we randomly selected 1 mature individual in the each plot, and leaves were sampled for C, N and P analysis.

Results and Discussion

Sedges in grazed plots had lower leaf C content compared to enclosed, ungrazed plots (Fig. 1a), which may be due to a reduction in photosynthesis as a result of green biomass removal (Wang et al. 2015). Under grazing, leaf N content of most species tended to increase with a more pronounced effect in unpalatable than in other groups (Fig. 1b), and leaf C,P content remained unchanged by grazing (Fig. 1a,c), resulting in significantly decrease C/N and increase N/P of forbs, unpalatable and community and unchanged C/ P in each groups (Fig. 1 d,f,e). This result was consistent with Frank *et al*. (2008), indicated that animal grazing increased leaf N content but had no effect on P content in grasslands of Yellowstone National Park. For the palatable, the compensatory growth of plant stimulated reallocation of reserved nitrogen-containing compounds (Wang et al. 2015), causing increased in leaf N content after grazing. For the unpalatable, grazing significantly increased in leaf N content. The main reason is that unpalatable species are subjected to a low frequency and intensity of herbivory, which gives then competitive advantage upon them for nutrients within grazing community (Moretto et al. 1997).

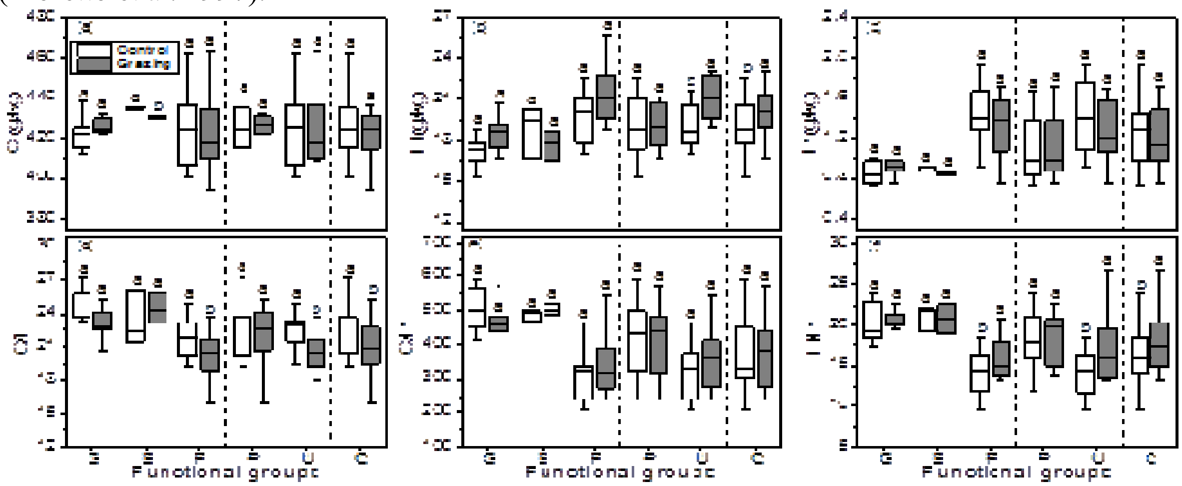

Figure 1. Boxplots showing the Effects of grazing on leaf C, N, P contents and stoichiometory at plant functional groups and community levels. Different letters indicate significant differences ($p < 0.05$) based on t-test. G, graminoids ; S, sedge; F, forbs; P, palatable; U, unpalatable; C, community.

Conclusions

Leaf N content of most functional groups tended to increase after grazing. For the palatable, plants allocate more N to aboveground parts for the compensatory growth of plant. The decrease in relative biomass of palatable led to more opportunity to uptake soil available N for low competitive unpalatable.

Acknowledgements

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Aboveground Net Primary Production in High Altitude Pastures on the Tibetan Plateau

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Key words: ANPP, cage, grazing, sheep, yak

Introduction

Many yaks (*Bos grunniens*) and sheep (*Ovis aries*) graze on the Tibetan Plateau. However, in recent years, the number of grazing yaks and sheep is increasing along with the growth of the human population in that region. Major issues have emerged as a result of these changes, such as decreasing grass productivities in the rangeland, more bare soil, and smaller livestock body mass. To develop a feasible grazing plan for this region, it is important to understand the herbage mass production. The goal of this study was to determine the aboveground net primary production (ANPP) in the region by examining the spatial and seasonal variations of grass mass within and between several yak and sheep grazing plots.

Methods

We calculated ANPP based on the biomass measurement of moved temporary cages (McNaughton et. al. 1996). In 2014, a grazing experiment was conducted in a pasture approximately 4,350 m above sea level in Qinghai Province, China. In June 2014, immediately after the snow melted, approximately six ha of grassland was divided into six equal plots including three yak and three sheep grazing plots. Four yaks weighing about 100 kg each and 14 sheep weighing about 30 kg each were allowed to graze day and night on a 10-day rotation. Stocking density was about 140 kg/ha per animal. Rotational grazing was continued from early June to the end of September in 2014 and 2015. Three moved temporary cages (0.25 m²) were installed in each plot to prohibit grazing.

In August 2014, and May, June, July, August, September 2015, a vegetation survey was conducted in each of the six grazing plots using the line transect method. In addition, 50-cm square quadrats were created inside and outside the cages at three locations in each of the yak and sheep grazing plots. Grass mowing and measurement of dry matter for live and dead herbage were performed. We determined acceptability as food of native plant species according to Zhou et al. (2005).

Results

The herbage mass in uncaged grazed plots was increased from May to July and decreased from August to September (Fig. 1). This result indicated that the growing season of herbage is very short in this high-altitude area. The ANPP were varied from 76 to 83 gDW/m² in 2014 and 59 to 64 gDW/m² in 2015 (Table 1). Results of the full factorial ANOVA showed a difference in herbage mass between ungrazed and grazed (F = 11.32 P = 0.0011) plots. However, no difference was noted between the yaks and sheep (F = 0.39, P = 0.53). Average grazed mass through three-month grazing were varied from 20 to 28 gDW/m² in 2014 and 20 to 29 gDW/m² in 2015.

The dominant species, such as *Stipa* and *Kobresia* spp. were good herbage for grazing animals, and only limited weed species were noted, such as *Lancea* and *Oxytropis* spp.

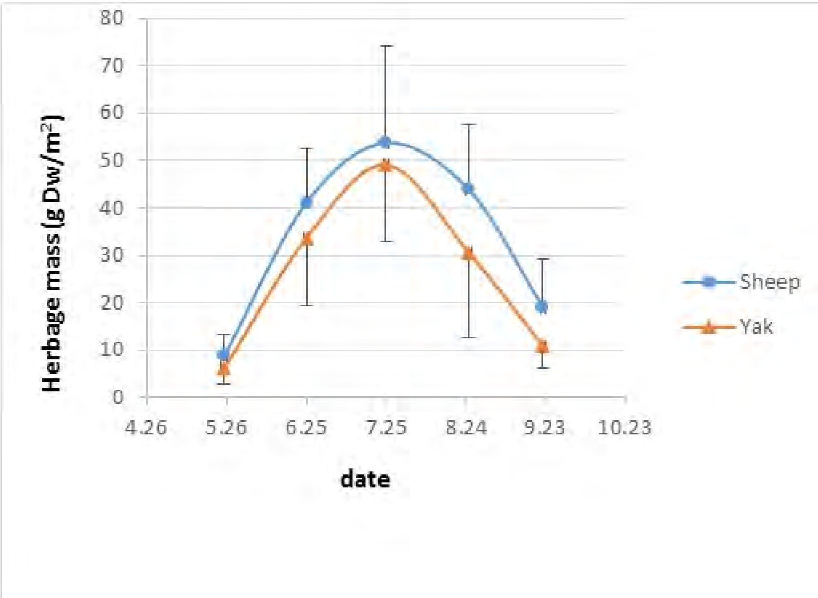

Figure 1. Changes of herbage mass in each pasture (error bars show standard deviations).

Table 1. The ANPP of each pasture.

Year	Animal	ANPP (gDW/m^2)	s.d.
2014	Yak	82.7	49.2
	Sheep	76.4	30.0
2015	Yak	59.2	36.7
	Sheep	63.6	25.1

Conclusion

In this high altitude pasture, to develop a feasible grazing plan for this region, it is important to consider low ANPP and very short growing season of herbage.

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Dynamics of Plant Community Succession on Plateau Zokor Mound in a Sub-alpine Meadow on the Tibetan Plateau

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Key words: Qinghai-Tibetan Plateau; Disturbance; Deterministic; stochastic

Introduction

Plateau zokor (*Eospalax baileyi* syn. *Myospalax baileyi*) is a dominant rodent species in the sub-alpine meadow ecosystem in Qinghai-Tibetan Plateau. This species pushes out bare mound mosaics at different times. In this study, we aimed to track the development pattern of plant community during mound restoration.in a sub-alpine meadow.

Material and Methods

Study sites and experimental design

A field experiment was conducted at the Research Station of Alpine Meadow and Wetland Ecosystems of Lanzhou University (34°55′N, 102°53′E; altitude: 2950 a.s.l.) in Hezuo, the northeast of Qinghai-Tibet Plateau. The soil is brown calcic and the climate is cold and humid, with an average annual temperature of 2.4°C and an annual average precipitation of 545 mm. The experiment area was light grazing in winter. The vegetation in the experiment area is a sub-alpine meadow dominated by grasses (*Elymus nutans*) and forbs (*Artemisia tangutica*).

Ten fresh and natural mounds (1 week to 3 months old, the diameter approximately 40 cm) were selected during May to August in each year from 2009 to 2013. To 2013, a total of fifty mounds in successional stages (1 week to 3 months old, and 1, 2, 3, 4-year-old) were established and labeled as 1-5, respectively. Additionally, ten round quadrats (diameter: 40cm) of the reference matrix community (not disturbed by zokor in recent years) were set as stage 6.

Sampling

Vegetation investigation was carried out in August 2013. The identification of each species was determined, species numbers were counted and the percentage of cover of each species in each quadrat was estimated visually.

Analysis methods

Bray-Curtis dissimilarity index was evaluated the divergence/convergence degree over all possible pairs of mound communities which belong to the identical stage. Linear-regression analysis displayed relationship of succession stages with species richness, total coverage and community dissimilarity, respectively. All statistical analyses were performed in SPSS17.0.

Results and Discussion

Species richness and relative coverage of plant community on zokor mound significantly increased along succession stages (Figure 1; P < 0.001), indicating mound environment gradually improved the community developed under light-grazing condition. Community dissimilarity significantly declined through succession stage (P < 0.001). This result was not in line with the historical contingency theory, but provides powerful evidence of a deterministic environmental-sorting process (Fukami, 2015). Newly-form mound communities exhibit a highest dissimilarity in species composition as stochastic factors and dispersal limitations.

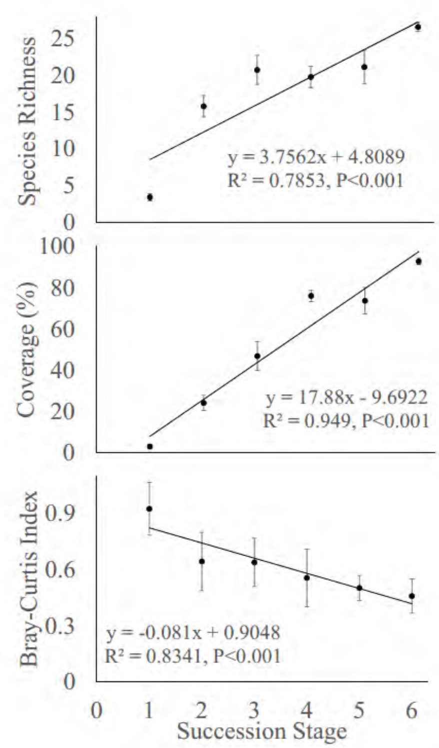

Figure 1. Variations of species richness, coverage and community dissimilarity in plant communities on zokor mound along succession stage.

Conclusions and Implications

In post-disturbance mound succession, species richness and vegetation coverage community gradually increased, but community dissimilarity gradually declined, species composition at early stage of succession was stochastic, while co-occurring species were primarily a product of deterministic environmental-sorting processes at later stages.

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Indicator Species of Different Managements in Natural Grasslands of Pampa Biome

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Key words: grazing; Southern Campos.

Introduction

The Pampa biome in Rio Grande do Sul state is a natural ecosystem with a large biodiversity (Bilenca & Miñarro, 2004 and Boldrini, 2002).To maintain the *equilibrium* between biodiversity and forage production to herds, it requires a sustainable land-use that preserves the natural diversity and produce forage to the herds (OVERBECK, 2007). It can be accomplished through the adjustment of stocking rates after understanding the plant's responses to grazing. However, a study considering all areas of the Pampa biome and its present species would be complex, given the high number of plant species. In this context, selecting species that represent determined grazing managements could be an alternatively method of analysis.

The aim of this study was to identify indicator species of different grazing managements in the natural grasslands of Pampa biome.

Material and Methods

The experiment was conducted in a natural grassland of Pampa biome located at Bagé city (31° 18' S, 53° 57' W) in Rio Grande do Sul state. The area is located in a transition zone between the Southern Campaign and Southeast Hills and the climate is Cfb, temperate humid, according to Köpen classification with the historical average rainfall, of last 30 years, of 1446.2 mm and average temperatures of 18.7 ºC (INMET, 2015). The area has no history of agricultural mechanization and, during the last 40 years, it was managed extensively with cattle and sheep herds at low stocking rates of < 0.5 animal unit ha^{-1}.

In June 2012, the experimental area was completely excluded from grazing of large herbivores and it was subdivided in three managements: two grazing methods (continuous stocking (CONT) and rotational stocking (ROT)) and an excluded area (EXCL). The animal entrance in CONT and ROT occurred in February 2013.

The vegetation was preferentially sampled transects with 1.25 m² of area were delineated (20 in CONT, 20 in ROT and 10 in EXCL). We used a modified Londo-scale (LONDO, 1976) to estimate the cover class of each vascular plant species. The vegetation survey was conducted from December 2014 to February 2015.

Aiming to characterize management practices, Indicator Species Analysis (Dufrêne and Legendre, 1997) was conducted using the 'indicspecies' package (De Cáceres and Jansen, 2012; R Development Core Team 2015). It was selected as candidates those species occurring in at least 10 % of the final reference sites. It also allowed combinations of up to five species. The *indicators* function was used to calculate indicator *specificities* and *sensitivities*. Finally, to reduce the possible indicators, *pruneindicators* function was used (De Cáceres et al. 2012).

Results and Discussion

The result of analysis showed two indicator species for each management and all of them, except one, were grasses (Table 1).

Table 1. Indicator value analysis, where A is specificity, B is sensitivity, sqrtIV is square root of the indicator value and Cover is pooled coverage (%).

Management	Final indicators*	A	B	sqrtIV	Cover
CONT	Erpl	0.7912	0.95	0.8670	100
	Asmo	0.5311	0.75	0.6311	
ROT	Axaf	0.7568	0.90	0.8253	100
	Pano	0.5660	0.95	0.7333	
EXCL	Saan	0.7385	0.70	0.7190	90
	Anlan	0.5347	0.60	0.5664	

*Anlan: *Anthaenantia lanata* (Kunth) Benth.; Asmo: *Aspilia montevidensis* (Spreng.) Kuntze; Axaf: *Axonopus affinis* Chase; Erpl: *Eragrostis plana* Nees; Pano: *Paspalum notatum* Flügge; Saan: *Saccharum angustifolium* (Nees) Trin.

The CONT management is characterized by two species frequently associated with overgrazing disturbance effects (e.g. excessive defoliation and trampling). Both are not palatable species. Exotic grass, *Eragrostis plana* is also associated with invasive processes in native grasslands areas and nowadays can be considered as a huge problem to native diversity of plant species of Pampa biome. In EXCL management, both species are unpalatable tussock grasses with tall size. The latter attribute can be the determinant success factor over other species in light capture. Two palatable native grasses were the indicator species of ROT management. It can be associate with the grazing tolerance with this species and with the rotational criteria applied in area: time to thermal accumulative of 375 degree-day (degree Celsius *per* day; DD) which allowed the elongation of 2.5 leaves *per* tiller of grasses of functional groups A (e.g. *Axonopus affinis*) and B (e.g. *Paspalum notatum*) (Cruz et al, 2010).

Conclusions and Implications

Indicator species analysis characterized accurately our grazing managements. This approach can be used to provide a simple (but accurate) vegetation data analysis.

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Soil Characteristics on the Hulunbeier Meadow Steppe under Different Grazing Intensities: A Case from the Steppe around a Herdsmen's Settlement

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Keywords: Hulunbeier, meadow steppe, grazing intensity, soil characteristics.

Introduction

Meadow steppe has the highest productivity in Inner Mongolia grassland, China, which plays an important role in the production of animal husbandry. Hulunbeier is the core area of the distribution of Inner Mongolia meadow steppe. Long term uneven grazing use, which often happened on the areas close to the herdsmen's settlements, had caused serious degradation of the steppe (Yu L et al., 2015). In most case, the water resources generally located in the settlement, so livestock mainly graze around the settlement in the warm season. The frequency of grazing and trampling is often heavy around the water source but decreases with distance, forming a grazing intensity (GI) gradient. The heavy GI area will show degradation characteristics, including productivity lose, biodiversity reduction, soil erosion etc. It was difficult to accurately measure the vegetation change in the grazing commons, so several indexes of soil were chosen to monitor and judge the steppe's condition under different GI. These soil indices will help evaluate utilization levels and designing more sustainable grazing patterns.

Materials and Methods

The research sites were selected in a steppe around a fixed herdsman's settlement in central Ewenki autonomous Banner of Hulunbeier region, where the summer average T is 19.7º C with a frost-free period of 115 days. Annual average rainfall is 340 mm, of which, 70% is concentrated in July and August. The soil type is dark chestnut. *Stipa baicalensis*, *Leymus chinensis*, and forbs are the dominant species, and legumes occupy a certain proportion. According to the preliminary investigation, based on the distance starting in central settlement from near to far the steppe was zoned into four different GI treatments including heavy grazing (HG, 0-1.5km), moderate grazing (MG, 1.5-3.0km), light grazing (LG, 3.0-5.2km) and no grazing (CK, far from 5.2km, only used in winter). Estimated stocking rates were 0.67, 1.06 and 1.67 SU • ha^{-1} (no animal in CK; SU=sheep unit) of grazing lands for each sheep unit. Three transects were set in three directions to act as the replicates. Each sampling point was processed in different intensity's middle area along the line, and the sampling was repeated 4-5 times. Soil moisture content (SMC), moisture loss rate, soil organic matter content and soil total nitrogen (TN) content were determined.

To determine moisture loss rate, self made metal cylinders (30cm high, 20cm diameter and 9420cm^3 volume) were constructed. The same volume of the undisturbed soil and vegetation were placed into the cylinders. Only the top of the cylinder was open to allow the plants free growth, and the remaining part was sealed for control of any water exchange. All metal cylinders with the samples were embedded into steppe to facilitate the observation of the location, and the rain water is not allowed to enter. The samples were weighed every day at a fixed time with electronic balance until the sample plants completely dead. Other soil indicators were measured using laboratory routine methods. Analyses of variance (SAS) was used to test for differences due to stocking rate.

Results and Discussion

Changes of SMC under different GI

Almost all of the soil moisture is from the natural precipitation because of the deep water table. During the warm season, the average SMC of 0-30cm soil layer was measured after 5 days and 9 days after a rainfall of 31mm. The different GI showed different moisture differences. In "5 days" in CK, LG, MG and HG it was 11.04%, 9.00%, 8.32% and 7.55% respectively, in which, CK and others showed significant difference (p<0.05). But between LG, MG and HG there was no significant difference. In "9 days" it was 6.19%, 5.21%, 4.25% and 3.15% respectively and all means were significantly different (p<0.05). That means that soils subjected different GI's had different soil moisture holding capacity, which would directly affect the productivity of the steppe.

In order to understand the mechanism of the difference of SMC, the moisture loss rate was determined. Moisture loss includes plant transpiration and soil evaporation. No significant difference in SMC (p>0.05) at the beginning of the observation. Observed duration of HG was for 26 days, MG and LG for 27 days, CK for 28 days. The overall trend was that the amount of moisture lost per day was gradually reduced, with CK to maintain the highest (p<0.05), and the least of loss was HG. It is assumed that the evaporation rate of soil surface was the same (all litters were removed), which indicates that the better the vegetation condition was, the greater the moisture consumed. This result was contrary to the SMC under grazing. The possible reason is the effect of litter residues. In the natural state, there were different litter covers on the soil surface in different GI, that were 85%, 66%, 47% and 12% respectively. There was a positive correlation between litter cover and SMC. So the soil surface evaporation was the key way for moisture loss.

Changes in soil organic matter and nitrogen content

Soil organic matter. The average organic matter content of 0-30cm soil layer was 5.88%, 5.68%, 5.52% and 4.84% respectively in CK, LG, MG and HG. Among them, CK and HG were significantly different (p<0.01). Soil organic matter decline in HG indicates the loss of productive potential.

Soil nitrogen content. Grazing had a significant effect on the TN content of 0-20cm soil layer. In the 0-10cm layer, CK was significantly higher than LG (p<0.05), and LG was significantly greater than MG and HG (p<0.05); in the 10-20cm layer, CK was significantly greater than LG and MG (p<0.05), LG and MG were significantly higher than HG (p<0.05). No significant differences were found among treatments at 20-30cm (Fig. 1). Zhang et al. (2010) obtained similar results.

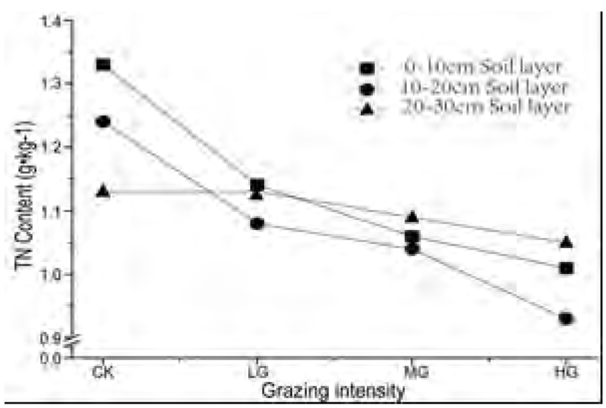

Figure 1. The relationship between grazing intensity and soil TN content in 0-30cm soil layer.

Conclusions and Implications

HG is mainly caused by the long term uneven use because of shortage of watering sources. Soil characteristics reflected that HG areas had been severely degraded. Additional water sources should be developed further from settlements and HG areas could be protected for some time to promote recovery.

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Climate Change in Rangelands

6.1 PLANT ADAPTATIONS TO CLIMATE CHANGE

Biomass Productivity and Browse Species Adaptation to Climate Change Based on Natural Rangeland Management at Kordofan Region, Sudan

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Key words: Browse, fodder trees and shrubs, Relative frequency, pastoral source, Semi-Arid

Introduction

Browse is obviously important for animals, especially in the arid and semi-arid zones where about 52% of cattle, 57% of sheep, 65% of goats and 100% of camels in tropical Africa are found (Von Kaufmann, 1986)]. Pasture grows poorly or only seasonally, the leaves, pods or young shoots provide the main browse for animals. Browse should represent at least 20% of livestock diets during the dry season (Houerou, 1980). The current study aims to estimate biomass from fodder trees and shrubs of pastoral source in Kordofan area at semi-desert, arid and semi-arid). The secondary objective to identify the common browse species, as well as fodder trees and shrubs adaptation to climate change based on natural rangeland management.

Materials and Methods

This study was conducted in North and West Kordofan states, Sudan. Preliminary data was collected with a ground survey for 31 sites (2.25 ha for each site) were selected with systematic random sampling. Within each site, four samples were recorded by point quarterly Centre method (Baltzer, 2007). In each sample three branches of tree and shrub were collected, dried and weighed to calculate the fodder production value (kg/ha).

Results and Discussion

Results of the study found that the highest production of the browse from trees and shrubs were (530.8 kg/ha) recorded in semi-Arid zone. Additionally, eight tree and shrub species used as fodder were reported in the study area, where highest relative frequency value (59.3%) was recorded by *Faidherbia albida* and (225%) for *Leptadenia pyrotechnica*. The results showed presence of five classes of vegetation cover, which are; bare land, trees/grass, trees/agriculture, trees and shrubs. The tree fodder biomass in the study area was found 1.99 million tonnes in season 2012 and 1.29 million tonnes in season 2013.

Table 1 shows browsing productivity and rainfall in ecological zones. Therefore, assessment of biomass production from trees becomes essential for proper management of livestock, range and forests. Despite the importance of browsing, research and development efforts regarding to the potential biomass available for browsing of the woody plants are often omitted because of the lack of methodology and difficulty to calculate or application method in some cases, which results in underestimation of the forage potential. The results found that the highest production of the browse trees and shrubs at semi –arid may be due to increase average rainfall. Also the lowest browse productivity at semi-desert to decrease of rainfall. The relationship between browse production twig diameter-length may vary with site, years, browsing pressure, over story canopy, plant species and size, presence of leaves, phonological stage of growth, and twig location on the plant (FAO, 1992).

Table 1. Browse productivity and average rainfall in three ecological zones in North and Western Kordofan states, Sudan.

Ecological zones	Average browse productivity (kg/ha)	Average rainfall (mm/year)
Arid	525.5	309.2
*Semi- Arid	530.8	322.8
Semi- desert	346.7	134.55

The result in Table 2 shows frequency of common trees and shrubs fodder in 2012 and 2013. Highest frequency recorded in 2012 were for *Faidherbia albida* (59%) and *Leptadenia pyrotechia* (225%) in 2013).

Table 2. Frequency of common trees and shrubs fodder in ecological zones at North and Western Kordofan states, Sudan.

Species	Season 2012 (%)	Season 2013 (%)
Balanites agyptiaca	37.5	18
Boscia senegalensis	30.3	117
Faidherbia albida	59.3	15.7
Guiera senegalensis	25.3	0
Leptadenia pyrotechia	0	225
Acacia senegal	16	19
Acacia tortilis	24.5	30
Maerua crassifolia	0	10

Conclusion and Implications

The study concludes that browsing characteristics of the common fodder trees and shrubs and their adaptation to climate change should be considered for rangeland management. High frequency of trees and shrubs proved browse availability in the area. The study recommends the use of remote sensing technology in estimation of fodder biomass of trees and shrubs with emphasis on fodder tree, due to its significant contribution in animal nutrition in the drought periods.

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Effect of Litter on the Vegetation of the Desert Steppe in Inner Mongolia

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Key words: Grassland, functional group, season, *Salsola collina*

Introduction

The dead herbage in grasslands has been referred to as litter. It ameliorates the soil temperature and interacts with the hydrological cycle, thereby affecting available soil water for plant growth Willms and Chanasyk, 2006. Therefore, the existence of litter can maintain and stabilize the aboveground net primary production (ANPP) on grassland ecosystem. We tested the hypothesis that litter removal reduced ANPP while litter addition increased ANPP on the Desert Steppe in Inner Mongolia and that their effects were influenced by the season of treatment.

Materials and Methods

The study was conducted at the Inner Mongolia Academy of Agriculture and Animal Husbandry Science (41°47'17"N, 111°53'46"E) located in a Desert Steppe. Mean annual precipitation was 250 mm and the dominant plant species *were Stipa breviflora*, *Artemisia frigida* and *Cleistogenes songorica*.

Litter removal and addition experiments were conducted on two neighboring sites. The removal experiment was conducted in a livestock exclosure that had been erected in 1996 while the addition experiment was conducted on an adjacent grazed site with heavy grazing (stocking rate = 2.71 sheep unit/ha/year). Each experiment consisted of a split plot design with litter removal or addition treatments (heavy, moderate and control) as the main plot (2×6m) and season (fall, spring) as the sub-plot (2×3m). The litter treatments were applied a single time in consecutive treatment-years from fall, 2006 to 2010 and spring, 2007 to 2011. The treatments were replicated 5 times in each treatment-year. The ANPP of species and their ground cover was measured at peak standing crop in the growing year after treatment. Heavy litter removal consisted of raking the fallen (fragmented) and standing (attached to the crown) litter after cutting the latter to near ground level. In the moderate treatment, only the fallen litter was removed by raking.

The effect of litter removal and addition on ANPP was tested on selected functional groups and their totals. The functional groups were grass (rhizomatous and bunch) and forb (annual and perennial). Litter removal and addition were analyzed separately. The MIXED model procedure was used for analysis of variance with litter treatment as the main factor and season as the sub-factor. The residuals were checked for normality using the UNIVARIATE procedure (SAS, Version 9.1.3, SAS Institute Inc., Cary, NC, US). Means were separated with the LSD test ($p < 0.05$).

Results and Discussion

In this study we examined the effects of a single episode of litter removal or addition on the short-term effects on vegetation expressed by production and canopy cover. Litter removal or addition were both expected to affect the microclimate of the soil, which we assessed by measuring the plant response. We anticipated that the effect that season would be expressed through litter mass, whether left *in situ* or added, on snow capture over winter (Willms and Chanasyk, 2006), or by its influence on the loss of soil moisture in either winter or spring. In the first year after treatment, neither litter removal nor addition had any effect on total ANPP and that of grass, forbs or *Salsola collina*. Growing season precipitation, as defined by categorical values of high ($\overline{x}$ = 203 mm) or low ($\overline{x}$ = 130 mm) annual totals, had the most significant and consistent effect on the variables measured in both the removal and addition experiments, and its effect across litter treatments was similar ($P > 0.05$). In the litter removal experiment, total ANPP in high precipitation years was about 40% greater than in low precipitation years, with most biomass contributed by a greater yield of *Salsola collina*. In the litter addition experiment, the differences were smaller but also contributed mostly by the response of *Salsola collina*. The season of litter addition modified ($P < 0.05$) the effects of precipitation on the ANPP of *Salsola collina*. The season of litter addition had no effect ($P > 0.05$) when precipitation was low but in years of high precipitation the effect was greater ($P > 0.05$) with litter addition in fall rather than spring.

The opportunity for litter to modify the soil environment is dependent on its mass and the occurrence of soil moisture. In the present study, the mass of litter present was very small (14.6 g · m^{-2}) compared with the Typical Steppe in Inner Mongolia (140 g · m^{-2}; Wang et al. 2011) or the Mixed Prairie in Canada (1171 g · m^{-2}; Willms et al. 1993). In the latter study, litter had no effect ($P > 0.05$) on ANPP in a year with above average precipitation and had a reduced effect in a year with below average precipitation, while in both studies by Willms et al (1993) and Wang et al. (2011) soil heat units where greatest where litter had been removed.

Therefore, the primary factor that may have mitigated the treatment differences in the present study was a small litter mass whose effect was below a threshold that could be detected. Another factor might be that most (85%) annual precipitation occurs during the growing season (May to September) when it would be quickly utilize by plants thus making water conservation on the Desert Steppe irrelevant.

The short-term relationship between litter mass and production as examined in this study relates to its ability to conserve water while evidence (Facelli and Pickett, 1991) suggests that over a longer period where litter is removed that species composition may also be affected. In our study we found few effects in the first growing season after imposing the litter treatments and no effects that persisted beyond that, which is indicative of the high degree of resilience of the plant community and the individual species that dominate it. Repeated litter treatment might have produced a detectable shift in species composition by allowing plants to adapt to a new soil moisture regime but that possibility is hypothetical. Evidence from a grazing study in the Desert Steppe suggests this might occur but it assumes that grazing and litter removal produce similar effects in a xeric environment.

The greatest response occurred from the annual forb, *Salsola collina*, which was primarily responsible for exploiting increased precipitation and accounts for fluctuations in total biomass. Therefore, litter management as a strategy for enhancing production on the Desert Steppe. This study did not address other factors that might be influenced by the presence of litter or by the indirect effect of grazing by sheep. The fact that ANPP in the litter addition site was only about 60% of that in the removal site suggests other factors, such as a smaller proportion of *Salsola collina*, might be responsible for the difference. Nevertheless, the community response to the litter treatments was similar at both sites even though the effects were unremarkable.

Acknowledgments

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Climate Warming and Long-Term Trends in Saskatchewan Hay Yield

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Key words: Climate change, precipitation use efficiency, adaptation

Introduction

Analysis of long-term decline in Saskatchewan average hay yield has been associated with rising fertilizer prices (Jefferson and Selles, 2007) or to changing crop rotations that reduced stored soil water for deep-rooted perennial forage crops (Jefferson and Larson, 2014). As both reports noted, the problem of long-term trend analysis is that of collinearity of other unknown factors that are also changing over time. Jefferson and Selles (2007) reported no long-term temperature trend in Saskatchewan spring (April, May and June) temperatures. However, climate change research has reported long-term global temperatures increasing over time (Hadley Centre, 2016). The objective of this analysis was determine if global temperature change was associated with long-term change in Saskatchewan hay yield.

Materials and Methods

The data base for this project was reported previously (Jefferson and Selles, 2007; Jefferson and Larson, 2014). In short, provincial average hay yield was obtained from a Saskatchewan Ministry of Agriculture database. Weather data from 16 weather stations representing the agricultural regions of Saskatchewan was obtained from the Environment Canada Historical Weather Database (Environment Canada, 2015). April, May and June (AMJ) precipitation, maximum temperature, mean temperature and minimum temperature by month was summed or averaged as appropriate to represent the growing conditions for the hay crop. Producers in Saskatchewan typically harvest one hay cutting per year and summer regrowth is either grazed or left to ensure good winter survival of the legume species. Data from 1967 to 2011 were included in this analysis.

Analysis was done with JMP Software (SAS Inc. Cary NC USA). Probability for significance in regression analysis was set at 0.10.

Global temperature difference data was obtained from the United Kingdom Meteorological Centre, Hadley England (Hadley Centre 2016). The data used global temperature data based on the change from the 1960 to 1990 baseline average global temperatures. The values in the global temperature difference data range from -0.212 °C in 1974 to +0.509°C in 2005. There is a significant time-trend in the data (R^2=0.82, $P<0.001$) over the period of this analysis (1967 to 2011).

Results and Discussion

As previously reported (Jefferson and Selles, 2007), there was a relationship between AMJ precipitation and Saskatchewan hay yield (Figure 1a). While the previous report suggested a linear relationship, this analysis indicated a reciprocal of precipitation equation was the best fit to the larger database. An examination of the data points suggested that years earlier in the data base (1967 to 1990) tended to appear above the regression and later years (1990 to 2011) tended to appear below the regression line. The residuals from the regression equation were saved and then regressed on the Global Temperature Difference variable (Figure 1b). The linear regression was significant (R^2= 0.29, $P<0.001$) indicating that as global warming has occurred the residuals about the precipitation/hay yield equation tend to become more negative. In other words, the same precipitation early in the study period tended to produce more hay than later in the period. For example 89 mm of AMJ precipitation in 1969 was associated with 3113 kg ha^{-1} hay yield, but 89 mm in 2001 was associated with 1724 kg ha^{-1}. In another example, 100 mm was associated with 3136 kg ha^{-1} in 1987 but 99 mm was associated with 2016 kg ha^{-1} in 2009. A stepwise regression analysis indicated that AMJ precipitation and Global temperature difference explained 54% of the variation in Saskatchewan hay yield (P=0.10). As the global temperatures warm, less hay is produced per mm of precipitation in Saskatchewan. This supports the earlier report that precipitation use efficiency for Saskatchewan's hay crop has declined (Jefferson and Larson 2014) although that report also linked the decline to changing crop rotations. Cannell et al. (2003) reported declining summer hay yields in the UK due to increasing temperatures.

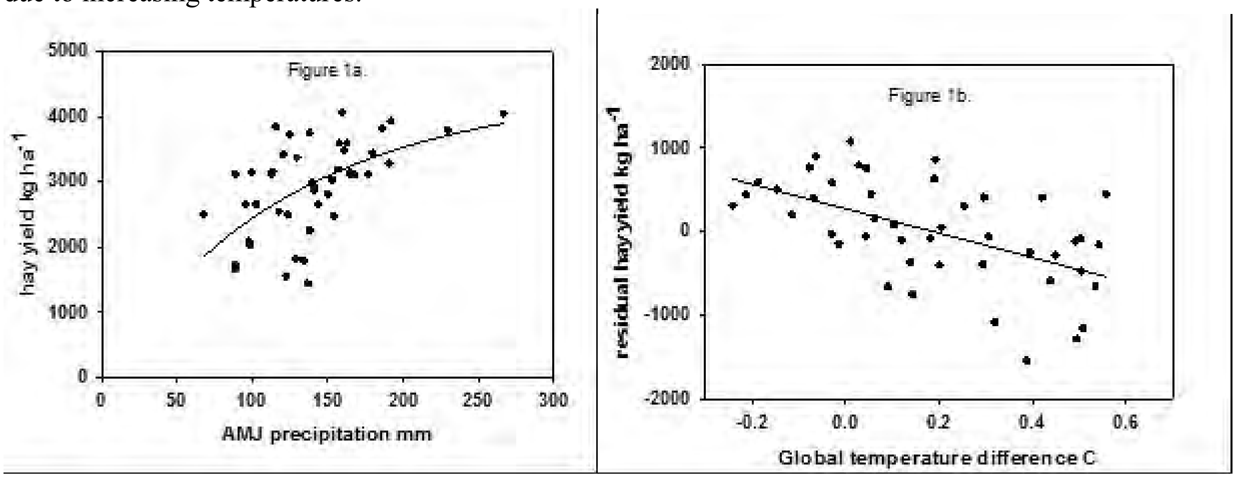

Figure 1. Saskatchewan hay yield from 1967 to 2011 as affected by annual spring precipitation with fitted reciprocal regression (R2 =0.24, P<0.001) and residuals from that regression fitted to Global temperature difference with linear regression (R2=0.29, P<0.001).

This new observation can be explained by the physiology of photosynthesis. Gas exchange with the atmosphere occurs through the leaf stomata with CO_2 entering the leaf to be absorbed by photosynthetic reactions and H_2O vapour exiting the leaf. Water lost in this manner contributes to latent heat loss (cooling) of the leaf tissue. As air temperature increases, the amount of water lost to latent heat per g of carbon fixed increases. In water limited or semiarid environments, such as Saskatchewan, perennial forage precipitation use efficiency will be reduced by higher temperatures.

Other crops, such as wheat, barley and canola, have reported yield increases during the same period of time (Jefferson and Larson, 2014). In other words, these crops have demonstrated adaptation to increasing global temperatures while the hay crop has not. One difference between these crops is the rate of technology adoption. In wheat, for example, new cultivars are released from plant breeding programs continuously but are replaced by newer higher yielding cultivars within a decade. In contrast, hay producers in Saskatchewan continue to use cultivars that were developed in the 1960s (Beaver and Algonquin alfalfas for example) because the cost of seed of new cultivars is higher and the perceived advantages are not apparent to producers. Is it possible that slow technology adoption has resulted in maladaptation to increasing global temperatures? Older forage crops (10 years or more since establishment are common in Saskatchewan and may also contribute to poor precipitation use efficiency.

Conclusions and Implications

Hay yield and precipitation use efficiency of hay is declining in Saskatchewan. The responsiveness of the hay crop to spring precipitation is declining and this appears to be associated with global temperature increases. This suggests that the Saskatchewan livestock industries will experience more hay shortages in the future as the global temperatures are predicted to continue to rise. Further research on precipitation use efficiency and high temperature adaptation in the breeding of new hay cultivars should be undertaken.

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Strategies of Maintenance and Production of Megathermal Species in the Pampas Central

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Key words: *Chlorisgayana*, Rhodesgrass

Introduction

Livestock production of the center- north of the Pampa Argentina is mostly extensive in nature utilizing natural grasslands, and perennial and annual cultivated pastures (INTA EEA Rafaela, 2013). In recent years has shifted to regions considered marginal, most soil constraints (salinity and flooding). All this is necessary for evaluating the potential and conditions of rangeland management and forage implemented with sustainability production systems criteria (Morlacco, 2014).*Chlorisgayana* is a forage grass that adapts and produces in saline - alkali soil and plastic in different weather conditions, from subtropical to temperate. In diploid genetic form, it is being cultivated as forage in large areas and has a 5.25% crude protein content and 43% digestibility.

Objectives

To describe three cultivars of *C. gayana*based on the number of plants m^{-2}, runners per plant, basal cover, seed production, and quality variables.

Materials and Methods

Three *C. gayana* cultivars (Santana, Recleimer, and Finecut) were seeded (4.5 kg ha^{-1}) in the experimental field of the Faculty of Agricultural Sciences, National University of Rosario, Santa Fe (33ºS, 61ºW) on an Argiudolvertic soil (35 ppm P, 3% organic matter), on 11/14/2013.The plots were 5 x 5 m, using a completely randomized design with 3 blocks. Degree days were calculated considering 12ºC as base temperature

The degree of development of stolons was evaluated on 10/28/2014, using a 0,1m^2grid with 10 cm x 10 cm internal divisions, and measuring the number of runners and soil cover. The same grid was used for determining the number of inflorescences m^{-2}, considering two measurements per plot. Dry biomass per sampling date was de established by cutting above ground material leaving a 10 cm stubble, registering fresh and oven dry weight (65 ° C until constant weight). Data was expressed as total biomass (oven dry matter) accumulated per ha. Crude protein was determined by semi-micro Kjeldahl (Bateman, 1970), ADF and NDF according to Van Soest & Robertson, 1985.To assess the production of seeds, two fully expanded inflorescences were harvested for each sample (grids 0.1 m^2), on 12/22/2014, 15/01/2015 and 02/27/2015 and placed in paper bags. Weight of one thousand seeds of each of the inflorescence was determined using a precision balance (0,001g). Results were analyzed by ANOVA and Tukey test means comparison ($p < 0.05$) was used to determine significant differences between cultivars and different harvest dates.

Results and Discussion

No differences in number of plants (134 ± 4.94 $m^{-2)}$ were detected among cultivars 60 days after sowing. Recleimer had the highest values of dry matter accumulation and quality at both sampling dates, though differences were significate only with respect to Finecut. There were no significant differences in protein, in any of the dates (Table 1), the height of plants differs significantly between different dates, but not between cultivars.

Table 1. Dry matter per plant, protein, NDF (neutral detergent fiber), and ADF (acid detergent fiber). Means with the same letter are not significantly different; $p > 0.05$.

Degree Days	cv	Dry matter ($g\ plant^{-1}$)	protein (%)	NDF (%)	ADF (%)
598	Recleimer	4.50 ab	7.06 a	48.03 a	38.17 a
598	Finecut	2.83 b	8.31 a	42.77 b	32.81 bc
598	Santana	6.17 ab	8.94 a	44.70 ab	33.33 bc
1026	Recleimer	10.17 a	8.46 a	46.47 ab	36.12 ab
1026	Finecut	8.83 ab	8.54 a	46.57 ab	32.16 c
1026	Santana	5.83 ab	8.31 a	45.79 ab	33.83 bc

Table 2. Mean number of plants m^{-2}; number of stolons m^{-2}, and % soil cover.

Cultivar	n	number of plants m^{-2}	number of stolons m^{-2}	% soil cover
FINECUT	6	95.00 a	0.83 a	55.00 b
SANTANA	6	88.33 a	0,77 a	36.67 a
RECLEIMER	6	76.67 a	0 79 a	35.83 a

Means with the same letter are not significantly different; $p > 0.05$.

Only differences between cultivars for land cover were observed after a year of implanted pasture. This increased soil cover may have been due to the combined effect of the high absolute values of plants m^{-2} and stolons $plant^{-1}$.

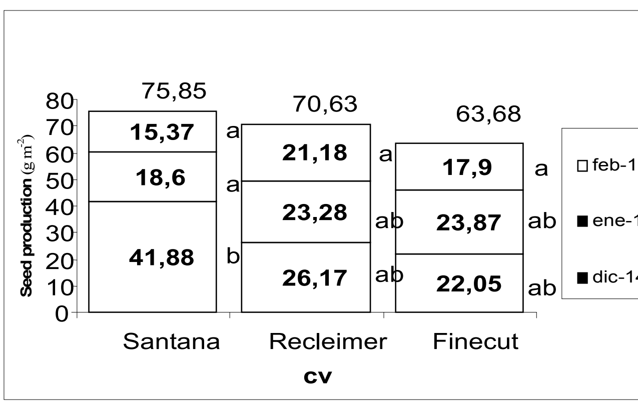

Figure 1. Seed production ($g\ m^{-2}$). No major differences of total seed production was detected among cultivars, but Santana concentrated seed production in the first harvest date. Means with the same letter are not significantly different; $p > 0.05$.

Conclusions

Higher ground cover, achieved by cultivar Finecut, may be due to the combined effect of the high absolute values of plants m^{-2} and stolons $plant^{-1}$. If our goal is to harvest seeds, it appears that the first date would be the most convenient, especially for Santana harvest (it represents 55% of total production). These would allow different management schedules according to different objectives: forage or seeds.

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Diversity for C3 and C4 Plant Types in Guinea Grass Reveals Its High Potential as Climate Resilient Species

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Key words: Leaf anatomy, germplasm, guinea grass, photosynthetic pathway

Introduction

Panicum maximum (Guinea grass) is an important multi-cut forage grass. It is widely adapted because of its ease of propagation, fast growth and high nutrient quality during the rainy season yielding 40-60 t/ha dry matter with crude protein content up to 14% and 41-72% dry matter digestibility (Bogdan, 1977; Sukhchain & Sidhu, 1992). It is highly suitable for rangelands receiving 900 to 1500 mm rainfall, although it can survive under less than 400 mm rainfall. Additionally, availability of annual as well as perennial types (Malaviya, 1996) makes the crop suitable for irrigated as well as rainfed conditions. Genus *Panicum* is reported to have species with either C3 or C4 photosynthetic pathways. C3 grasses of temperate region have better quality where as C4 tropical grasses are adapted to warmer climate with high biomass production and comparatively poor nutritional quality. Guinea grass germplasm collected and evaluated at Indian Grassland & Fodder Research Institute shows high degree of variation for various traits including biomass yield. The present work was undertaken to anatomically screen the global germplasm collection of *P. maximum* in order to know the existing intra-species variation for photosynthetic pathways which will further allow identifying the individual germplasm lines to be used in different/changing environmental conditions.

Material and Methods

170 germplasm accession of *P. maximum* were grown in paired rows of 3 m each accommodating six tussucks in each row at 60 cm apart. We cut sections from young leaves of each plant to enable screening for photosynthetic pathway; each section was stored in distilled water to keep them moist. Five leaves were taken from each germplasm accession and the single best section of each leaf was taken for observation on one middle vascular bundle (MSV) and one side vascular bundle (SVB) which was 3rd from middle in most cases. Sections were observed under compound light microscope (Nikon). Observations regarding presence and the extent of area occupied by chloroplast in the large cells surrounding vascular bundles were recorded on MVB and SVB. The area occupied by the chloroplast in a cell was recorded only on the basis of visual estimation under microscope. Further, averaging was done on five sections observation.

Results and Discussion

On average, 10 cells were found surrounding the middle vascular bundle (MVB) whereas the side vascular bundles were surrounded with 4.4 cells. Most of these cells surrounding MVB in most of the accessions were seen with chloroplast except six accession wherein the number of cells surrounding MSV with chloroplast were <70% of total cells. The cells surrounding SVB mostly showed the presence of chloroplast among all accessions. However, the percent area covered with chloroplast was highly variable. The bundle sheath (BS) cells of MVS on an average showed 69.3 percent area occupied by chloroplast although variation was observed from 3 to 100% (Table 1). Similarly the mesophyll cells around MVS showed 52.1 area occupied by green pigment. Mesophyll cells also showed variation from 4.2 to 91%. A similar trend was also observed with BS of SVB. Pigmentation of BS cells reflects the C4 nature of the plant. Variation for pigmentation in BS cells and mesophyll cells of both MVB and SVB shows that the accessions are both C3 and C4 (i.e. intermediate type). Further, there appears to be continuous variation from C3 to C4 type. This variation reveals that the species has high adaptation potential to varied climate. The typical C4 types are likely to perform much better under intense light and elevated CO_2. The wide diversity in the genepool for various agronomic and morphological traits such as leaf length/width, leaf position (erect/drooping/semidrooping), stem thickness, leaf hairiness, flowering behaviour (flowering throughout year/once in year) has been reported earlier (Malaviya, 1996, 1998; Kaushal et al., 2000). This variation coupled with information on C3/C4 offers ample opportunities for identification of high yielding genotypes under abiotic stress conditions. Plants with C4 photosynthesis have a specialized leaf anatomy which is requisite for their CO_2 metabolism and which effectively eliminates photorespiration and increases the capacity for CO_2 assimilation. It is generally agreed that plants performing C4 photosynthesis are particularly well-adapted to high radiation intensity, high temperatures and to dry habitat conditions because of their better water-use efficiency.

Table 1. The chloroplast pigmentation in bundle sheath cells in accessions of *Panicum maximum* leaves.

	MVB				SVB			
	No of cells	Cells with chloroplast	Area with Chloroplast (%)		No of cells	Cells with chloroplast	Area with Chloroplast (%)	
			BSC	MC			BSC	MC
Average	10.0	9.2	69.3	52.1	4.4	4.2	65.8	49.3
Min	7.2	5.0	3.0	4.2	4.0	2.8	3.2	13.8
Max	13.4	12.8	100.0	91.0	6.0	6.0	100.0	84.0

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Potassium and Sodium Simultaneously Play a Positive Role in Responding to Drought Stress in *Apocynum venetum*

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Key words: Drought stress, osmotic adjustment, photosynthesis, *Apocynum venetum*

Introduction

Drought stress is one of the major environmental factors limiting growth and productivity of crops worldwide. Plants have developed multiple protective mechanisms at morphological, physiological and molecular levels to adapt to drought stress. Potassium (K^+) and sodium (Na^+) (at certain levels of supply) play important roles in stress resistance in plants (Subbarao et al. 2003; Szczerba et al. 2009). However, the synergistic effect of K^+ and Na^+ on drought-resistance of plants has remained an elusive topic.

Apocynum venetum is a perennial semi-shrub widely distributed in the temperate desert-steppe of Eurasia and northwestern China. We are interested in understanding the physiological mechanisms underlying the adaptation to drought environment, and whether mild-salt can alleviate the deleterious impact of osmotic stress on growth of *A. venetum* seedlings.

Materials and Methods

Five-week-old seedlings irrigated with Hoagland solution were firstly subjected to 0.01 mM K^+ for 7 d, and then were randomly divided into two groups: low K^+ (0.01 mM K^+) and normal K^+ (2.5 mM K^+). In each group, there were three treatments: control (C, neither sorbitol nor salt), osmotic stress (D, seedlings were irrigated by Hoagland solution containing sorbitol with the final osmotic potential of -0.2 MPa) and drought stress together with salt (D+S, seedlings were irrigated by Hoagland solution containing 25 mM NaCl and a certain amount of sorbitol with the final osmotic potential of -0.2 MPa). After 5 days, plants were harvested for further physiological analysis. Parameters related to growth, photosynthesis, water status, leaf osmotic potential (Ψ_s) and ion concentrations were measured.

Results and Discussion

K^+ deficiency had no effects on growth of *A. venetum* seedlings under control condition. No significant difference on plant height, biomass and water status was observed between low K^+ and normal K^+ treatments (Table 1). These results indicate that *A. venetum* is noticeably tolerant to K^+ deficiency. Moreover, an abundant accumulation of K^+ in leaves was found, regardless of external K^+ supply in medium (Table 2). Therefore, we propose that *A. venetum* should be considered as a K^+-efficient species.

Table 1. Plant growth, photosynthetic parameters and water status in leaf of *A. venetum* under different treatments.

Treatments		Fresh weight (g plant^{-1})		Height (cm)	Pn (ìmol CO_2 $m^{-2}s^{-1}$)	Gs (mmol $m^{-2}s^{-1}$)	Tr (mmol H_2O $m^{-2}s^{-1}$)	RWC (%)	WUE$_i$ (ìmol CO_2 mmol H_2O^{-1})
		Shoot	Root						
Low K^+	C	0.966 a	0.171 b	34.3 a	3.40 b	21.95 a	0.74 c	90.4 a	144.4 d
	D	0.742 b	0.159 b	30.0 b	1.99 d	13.48 c	0.45 e	85.2 b	147.7 d
	D+S	0.855 a	0.215 a	33.1 ab	2.42 c	15.79 b	0.60 d	92.3 a	155.5 c
Normal K^+	C	0.970 a	0.169 b	36.4 a	3.82 a	23.14 a	0.86 a	94.1 a	173.4 ab
	D	0.701 b	0.159 b	29.6 b	2.13 d	12.41 c	0.45 e	91.7 a	172.2 b
	D+S	0.900 a	0.197 a	35.4 a	3.86 a	21.89 a	0.79 b	94.7 a	178.2 a

Values are means (n = 6). Columns with different letters indicate significant difference at $P < 0.05$ (Duncan test). The same as below.

Osmotic stress (D) significantly inhibited plant growth with significant reduction in shoot fresh weight (FW), plant height, net photosynthesis rate (Pn), stomatal conductance (Gs) and transpiration rate (Tr), compared to the control (C) (Table 1). However, under the D+S treatment, the biomass and plant height significantly increased compared to that under D treatment, and achieved or even surpassed the control level. A significant increase in parameters related to photosynthesis and water status such as Pn, Gs, Tr, relative water content (RWC) and intrinsic water use efficiency (WUE_i) was observed in seedlings grown under D+S compared to D treatment (Table 1). This demonstrated that moderate concentration of NaCl can alleviate the deleterious impact of drought stress on the growth of *A. venetum*.

The leaf Ψ_s declined consistently in plants exposed to osmotic stress in the presence or absence of 25 mM NaCl, but the reduction was lesser in plants subjected to D+S than D treatment (Table 2). The decreased Ψ_s are generally considered to be an indicator of osmotic adjustment through the production and/or accumulation of osmotically active molecules/ions (Martínez et al. 2004). In the present study, we found that K^+ concentrations in leaves remained stable or even were significantly higher under D or D+S treatment than that in control, regardless of whether K^+ in medium was sufficient or not (Table 2). Correspondingly, the contribution of K^+ to leaf Ψ_s exceeded 37 % under any growing conditions (Table 2), suggesting that K^+ is the uppermost osmolyte playing an essential role in osmoregulation for drought tolerance in *A. venetum*. Moreover, compared with C and D, Na^+ concentrations in leaves dramatically increased under D+S (Table 2). The contribution of Na^+ to leaf Ψ_s in plants exposed to D+S treatment was 5.7 and 2.8 times higher than that in plants exposed to D treatment under low K^+ and normal K^+ conditions, respectively (Table 2). These results demonstrated that the addition of 25 mM NaCl enhanced osmotic adjustment capacity of *A. venetum* under drought environment.

Table 2. Leaf osmotic potential (Ψ_s), ion concentrations, and the contributions of cations to Ψ_s.

Treatments		Ψ_s (MPa)	Concentration (mmol g^{-1} DW)		Contribution of cations to Ψ_s (%)	
			K^+	Na^+	K^+	Na^+
Low K^+	C	-1.124 a	1.337 c	0.036 b	48.51 a	1.32 b
	D	-1.672 c	1.366 bc	0.024 c	37.20 d	0.53 d
	D+S	-1.418 b	1.416 b	0.105 a	41.18 c	3.04 a
Normal K^+	C	-1.162 a	1.368 bc	0.037 b	44.56 b	1.17 bc
	D	-1.459 b	1.475 a	0.036 b	42.58 bc	1.02 c
	D+S	-1.388 b	1.431 ab	0.102 a	39.72 cd	2.84 a

Conclusions and Implications

Three key conclusions were drawn from our study: 1) *A. venetum* is a typical K^+-efficient species that possesses prominent efficiency of K^+-uptake and utilization under K^+ deficiency. 2) Accumulation of high concentration of K^+ in leaves for osmoregulation is an effective strategy for *A. venetum* to cope with drought environment. 3) Moderate concentration of NaCl alleviates the adverse impact of osmotic stress on growth of *A. venetum* by improving osmotic adjustment capacity. That is why this species could successfully grow in K^+-deficient soils and is able to survive under drought and saline environments. These findings provide important implications for the utilization and management of barren and saline land, which is potentially valuable for ecological improvement of rangeland in arid and semi-arid area.

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Abiotic Stress Responses in *Stipa sibirica* (L)

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Key words: Fv/Fm, PS II, drought, cold, salt

Introduction

Stipa sibirica (L) is one of the economically important perennial grass species that belongs to the family of Poaceae. It grows naturally in mountain steppe rangelands in the west and north of Mongolia and is being used for grazing and hay production and consumed by livestock. *Stipa* is the most important genus in grasslands of the cool temperate semi-arid zones (Nakamura et al.,1998). It has early growth in spring, good quality for animal productivity and good adaptability to severe conditions in Mongolia.

The objective of this study was to identify physiological and morphological responses of *Stipa sibirica* (L) species to cold, drought and salinity stress in laboratory conditions.

Materials and Methods

Plant material and growth conditions

The *Stipa sibirica* (L.) plants, used in this study were grown at 24/20°C (70% humidity) in continuous fluorescent illumination (100–150 µmol photons m^{-2} s^{-1}) in soil irrigated with water. After 6 weeks the seedlings were transferred to different experimental growth conditions.

For cold stress, 6 week old plants were transferred to low (4°C) temperature under constant light during 21 days. Control plants remained at 24°C under constant light.

For the salt treatment, seeds were dehusked, surface-sterilized and germinated on an MS medium (Murashige et al.,1962) containing 50, 100 mM NaCl and KCl. Plants were then grown in plant chamber 16/8 h light/dark photoperiod (100-150 µmol photons m^{-2} s^{-1}) and a day/night temperature of 24/20°C. For the sorbital treatment, sterilized seeds of plants were plated on MS media containing 200 and 400 mM sorbital according to Kadota et al (2001). The final germination percentages (GF) and the rate of germination were determined by a formula in Timson et al (1965).

Measurement of Photochemical efficiency

Photochemical efficiency was measured using a portable Plant Efficiency Analyzer (Hansatech Instruments, Norfolk, UK) according to the method of Tovuu et al., (2012).

Results

The photochemical efficiency (Fv/Fm) under normal growing conditions was 0.8 ± 0.01 for *Stipa sibirica* (L) plants. However, after the low temperature treatment at 4°C for 5 days, Fv/Fm dropped to 0.67 ± 0.02 and Fv/Fm decreased to 0.62 ± 0.03 after 7 days and it was maintained until 15 days (Fig.1A). Drought stress is characterized by stopping irrigation (severe drought). Exposure of plants to a drought stress for 10 days significantly decreased the photochemical efficiency of PSII and the Fv/Fm values were almost 50% lower (0.41±0.01) compared with the control plants (0.81±0.01) (Fig.1B). Thein vitro experiment also shows that *Stipa sibirica* (L) has no resistance to the drought conditions. With sorbitol treatments the germination rate was only 15-20% compared with control plants.

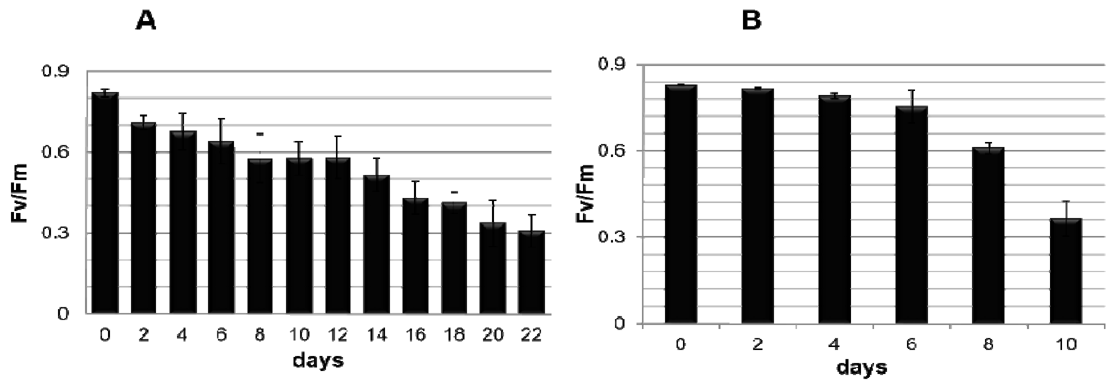

Figure 1. The photochemical efficiency of PSII (Fv/Fm) in plants acclimated to cold (A) and drought (B) stress. Values are means ± SD (n=5).

Discussion and Conclusions

The Chl fluorescence parameter Fv/Fm represents the maximum activity of PSII and can be used to monitor PSII photoinhibition. This parameter describes the efficiency of electron transport inside PSII and has been shown to be linearly correlated with the quantum yield of light-limited O_2 evolution and with the proportion of functional PSII reaction centers (Genty et al., 1989).

The results of this study demonstrated that Stipa sibirica (L) plants were better adapted to cold conditions than the drought conditions as they showed less visible symptoms, and highest Fv/Fm levels at the long time chilling stress. The combined cold and drought stresses caused more dramatic reductions in Fv/Fm than either cold or drought alone, starting at 14 and 7 days after treatment, respectively.

An increase in drought resulted in the reduction of the root length and plants retained their radicle length compared with the control plants. The in vitro experiment results also showed that, treatment with sorbitol plants was significantly different from control plant.

Stipa sibirica (L) plants growth is retarded under salt stress. Plant height, root length and dry matter weight of plant decreased when compared to control plants. According to our result of this experiment *Stipa sibirica (L)* was negatively affected by increasing salinity.

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Leaf Epidermal Features of Some Rangeland Species of Kovilpatti

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Key words: Stomatal index, trichomes, Kovilpatti grasslands, South India

Introduction

Epidermal features of the selected rangeland plants have been documented by Metcalfe and Chalk (1950); Thakur and Patil (2011). This paper reports the epidermal features on some unstudied species, which occur across the Rangeland biome of Kovilpatti, Southern part of India, with focus on stomatal characteristics and stomatal pattern.

Materials and Methods

The plants were collected from rangelands of Kovilpatti, Southern India for the present study. For the stomatal and epidermal tissues, the fresh, preserved and herbarium materials were used. The stomatal measurements were conducted using the Optika Bionocular Microscope (Model B-353). For each imprint/epidermis, five random views were selected and photographed under a microscope. Up to seven stomata were randomly chosen in each view, and the following measurements were made: Stomatal index (SI, %), Stomatal density (SD, in mm−2).

Results and Discussion

The present study was restricted mainly to stomatal complex, trichomes and its types, epidermal cell shape and cystoliths. The results of stomatal complex were depicted in the Table 1. Different types of trichomes are found in these species ranging from unicellular, peltate non-glandular to multicellular shaggy and glandular long hairs. The leaf epidermal anatomy of different species of rangeland has proved to be of much importance in the identification (Davis and Heywood, 1963).

The overarching goal of the current study is to document anatomical and morphological features of *range land plants* to permit our testing of the following hypotheses: that anatomy and morphology of all 12 range land species should reflect adaptation to the xeric environments in which plants occur. Like higher number of stomata in lower side and less number of upper side prevent more water evaporation (Salilsbury, 1932). Guard cell of *Balanatis* have thick wall, it helps to prevent water evaporation. Tricomes in *Capparis* and *Andrographis* are also helps to tolerate drought condition. Other than this these plants have some morphological modifications like spines (*Capparis, Carissa & Ziziphus*), thorns (*Azima, Balanites & Prosopis*) and wax layer (*Calotropis*). Four species (*Boerhavia, Cissus, Coccinia & Hybanthus*) didn't have any special adaptations to a xeric environment. Anatomically the 4 species share same character of larger epidermal cells (high stomatal index).

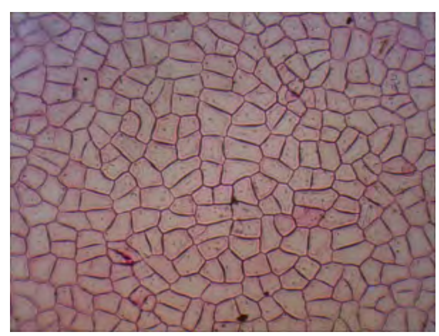

Figure 1. ***Azima tetracantha*** **Lam. upper epidermis stomata.**

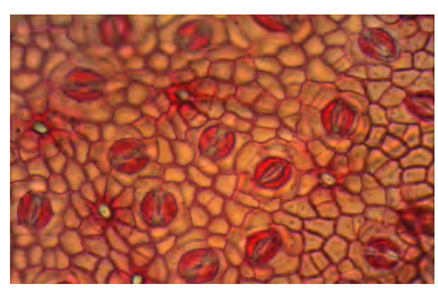

Figure 2. ***Balanites aegyptiaca*** **lower epidermis stomata.**

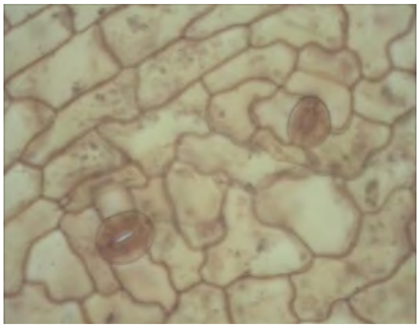

Figure 3. ***Cissus quadrangularis*** **lower epidermis stomata.**

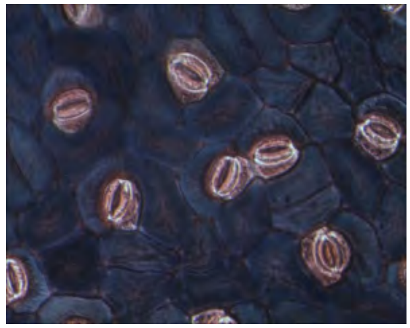

Figure 4. ***Prosopis juliflora*** **lower epidermis stomata.**

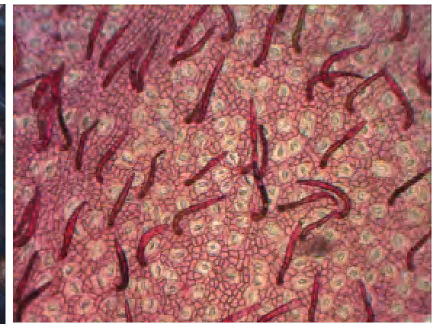

Figure 5. ***Capparis diversifolia*** **Trichomes**

Table 1: Characters of the Stomata of studied Rangeland species.

Botanical name	Stomatal Type	Nature	Stomatal frequency		Stomatal Index	
			U	L	U	L
Andrographis paniculata (Burm.f.) Nees	Diacytic both sides	Amphi Stomata	150	120	23.07	37.97
Azima tetracantha Lam.	Paracytic	Hypo Stomata	----	46	----	11.76
Balanites aegyptiaca (L.) Delile	Paracytic both sides	Amphi Stomata	97	86	3.7	7.2
Boerhavia diffusa L.	Upper- Anomocytic & Lower Anosocytic	Hypo Stomata	---	56	-----	16.6
Calotropis gigantea (L.) Dryand.	Paracytic both sides	Amphi Stomata	134	89	41.2	9.3
Capparis diversifolia Wight & Arn.	Paracytic	Hypo Stomata	---	110	----	6.8
Carissa spinarum L.	Paracytic both sides	Amphi Stomata	76	69	2.4	6.8
Cissus quadrangularis L.	Anomotetracytic in upper & Anisocytic in lower	Amphi Stomata	120	131	9.09	6.25
Coccinia grandis (L.) Voigt	Anomocytic both sides	Amphi Stomata	---	102	----	19.04
Hybanthus enneaspermus (L.) F.Muell.	Anisocytic both sides	Amphi Stomata	127	168	12.5	32.2
Prosopis juliflora (Sw.) DC.	Paracytic both sides	Amphi Stomata	203	226	40.7	42.85
Ziziphus xylopyrus (Retz.) Willd	Sunken	Amphi Stomata	30	27	5.2	3.8

U – Upper epidermis ; L – Lower epidermis

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Forage Production of Some Native Species in Dry and Wet Years in the Semi-Arid Prairie Ecoregion, Saskatchewan, Canada

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Key words: Western Wheatgrass, Little Bluestem, seeded pastures, Great Plains, native forages.

Introduction

About 5.7 million hectares of the Canadian Prairie is covered by seeded pastures (Statistics Canada, 2010). The climate in the Canadian prairie is very variable and drought has always been a potential threat to forage production, with approximately eight major drought periods in the last 400 years (Bailey et al, 2010). It is very important for rangeland and pasture managers to be prepared for the next drought cycle. Locally adapted forage species may better withstand drought stresses than non-native species. The objective of this research was to evaluate the forage production potential of seven native forage species under dry and wet conditions in the semi-arid ecoregion of Saskatchewan, Canada.

Material and Methods

This experiment was conducted at Agriculture and Agri-Food Canada (AAFC), Swift Current Research and Development Centre (SCRDC) near Swift Current, Saskatchewan, Canada. This area is located in the dry mixed grass prairie ecoregion which is the driest part of the province (Bailey et al, 2010). Weather data was collected from AAFC Swift Current for 2014, 2015 and an average of the past 120 years (Fig 1). Precipitation in 2014 was close to average; whereas 2015 was one the driest years on record.

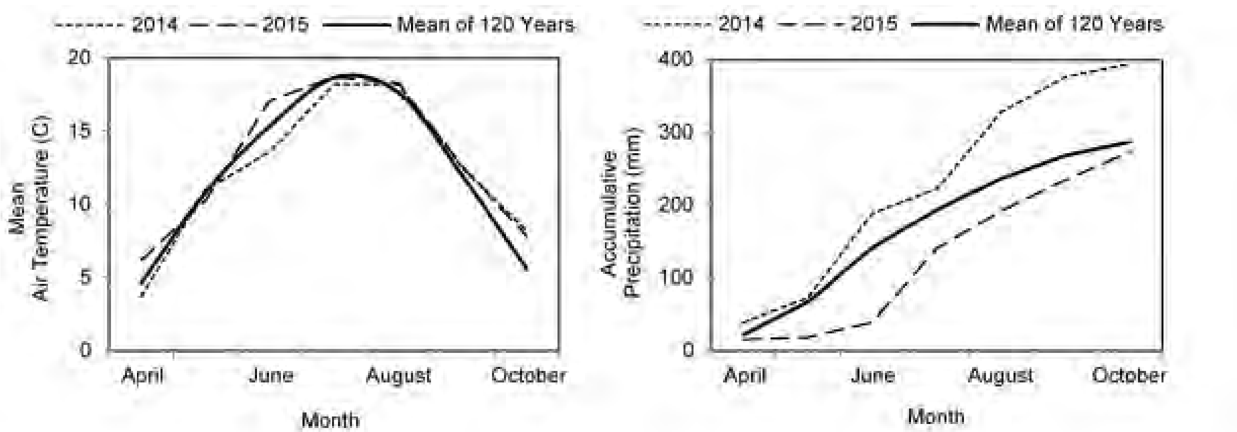

Figure 17. Mean Air Temperature (C) (Left graph) and Accumulative Precipitation (mm) (Right Graph) in 2014, 2015 and Average of 120 Years at Swift Current SK, Canada.

Seven native perennial forage species from three functional groups were selected for this experiment (Table 1). A split-plot block design was seeded with four replicates in 2010 (Mischkolz et al 2013). Forage production was measured in the first week of July (mid-season) and the last week of August (late-season) in 2014 and 2015 by clipping, to a height of 2 cm above soil surface. The aboveground biomass of the species within two square-meter quadrats was randomly selected. The biomass was dried at 60 °C to constant mass and weighed.

Table 1. Common name, Latin name, abbreviation and functional group of selected species.

Common Name and Latin Name	Abbreviation	Functional Group
Bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve)	BBW	C_3
Nodding brome (*Bromus porteri* (J.M. Coult.) Nash)	NOB	C_3
Western wheatgrass (*Pascopyrum smithii* (Rydb.) Barkworth & D.R. Dewey)	WWG	C_3
Little blue stem (*Schizachyrium scoparium* (Michx.) Nash)	LBS	C_4
Side-oats grama (*Bouteloua curtipendula* (Michx.) Torr.)	SOG	C_4
Purple prairie clover (*Dalea purpurea* Vent.)	PPC	Legume
White prairie clover (*Dalea candida* Willd.)	WPC	Legume

Results and Discussion

Forage production varied among the different forage swards (Fig 2). In all treatments, forage yield was higher in August compare to July for both 2014 and 2015. There was a large increase in forage production of LBS in August compared to July harvest. One of the driest years on record was 2015, however, the forage production of WWG, BBG and LBS were not affected significantly by the severe drought conditions. On the other hand, forage production of SOG, NOB, PPC and WPC were significantly reduced in 2015. Among C3 grasses, WWG followed by BBW produced the highest forage yield. LBS as a C4 grass performed better than SOG in regards to productivity and moreover, SOG showed reduction in 2015. In conclusion, the results showed that the forage production of WWG was higher in both July and August compared to the other forage species, and the drought year did not significantly affect WWG productivity. WWG can likely tolerate drought conditions thanks to deep and dense rhizomatous root systems (Ogle et al 2009), whether differences in rooting depth of the other species can explain differences in drought sensitivity remains to be explored.

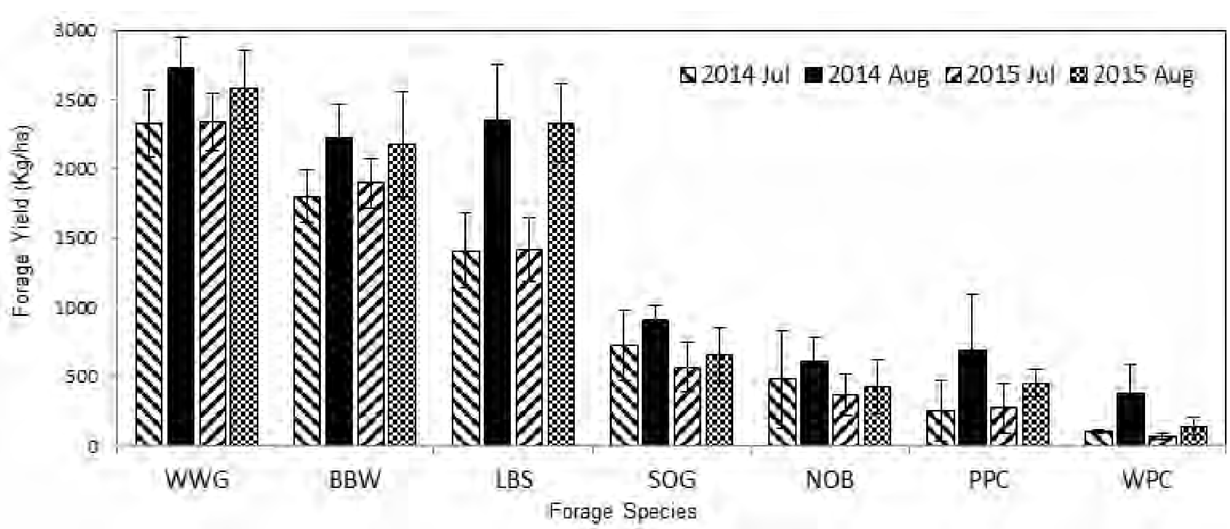

Figure 18. Forage production of seven native forage species in July and August of 2014 and 2015.

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The Effects of Climatic Fluctuations on Vegetative Cover and Production Case Study: The Rangeland of Taleghan Research Station (Iran)

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Key words: Climate change, life form, production, Taleghan, Iran

Introduction

Global warming is affecting aquatic and terrestrial ecosystems; particularly, plant biomass production (De Boeck et al., 2008) and plant community composition (Kardol et al., 2010) as a result of changes in precipitation and temperatures (Aerts et al., 2006). However, increased temperature stress on plants could lead to reduced plant productivity (White et al., 2000). We conducted an 8 year study to examine the effects of climate fluctuations on vegetation production and composition at the Teleghan experimental range in the Alborz Mountains, Iran.

Material and Methods

This study was done at a ten-year exclosure area in the rangelands of Teleghan (Shahrak weather station) which is located on the southern aspect of the Alborz Mt. The average altitude of the area is 2100 m. asl. It has semi-cold and dry climate with annual average rainfall about 471 mm over eight years. Average temperature of the eight years was also about 12.63 ^{o}C. The dominant soil texture of the area was a sandy-silty-clay formation. Dominant plant species of the area were grasses such as *Stipa barbata* Desf. *Agropyrum trichophorum* (Link.) Richter, and *Bromus tomentellus* Boiss. along with cushion like shrubs such an *Astragalus adscendens* Boiss. & Hausskn. The vegetation percent cover for each life-form (grasses, forbs, and shrubs), was separately recorded over 8 years in the exclosure area and the species production was also weighed individually in the monitoring period. The clipping of species in 4 square meters plots was done from 1 cm to the ground on end of spring and first of summer. In order to determine the climate fluctuation on vegetation cover and species production, standard model of multi-regression was employed as it can get at the truth without any prejudice and foretelling. As a matter of fact, the model can clarify the proportion of each independent factor on dependent factor. Moreover, the correlation of coefficient for each relationship was obtained as well. The statistical analysis was done by SPSS v.22 software.

Results

Temperature and precipitation varied from year-to-year, but 2009 was the coldest year, and 2008 the driest (Figs. 1 and 2) Grasses were the dominant lifeform every year, followed by forbs and shrubs (Fig. 1 and 2). Grass production was greatest in 2008 which corresponded to a year of high temperature and low precipitation. Shrubs maintained consistent cover over time. The shrub species had the least cover and production in the study period.

Grass cover and production were most strongly predicted by temperature and rainfall (Table 1).Forbs were least correlated with environmental factors. The growth of all life forms was negatively correlated with precipitation.

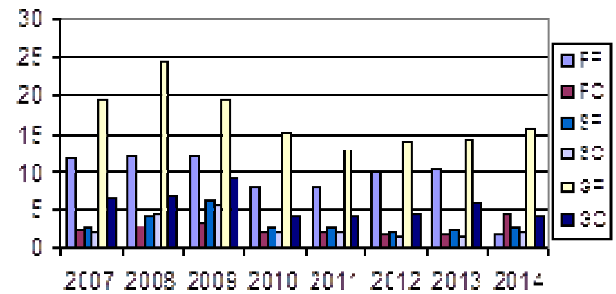

Figure 1. Pursuit of vegetation form cover (%) and production (gr/m^2) along with climate changes.

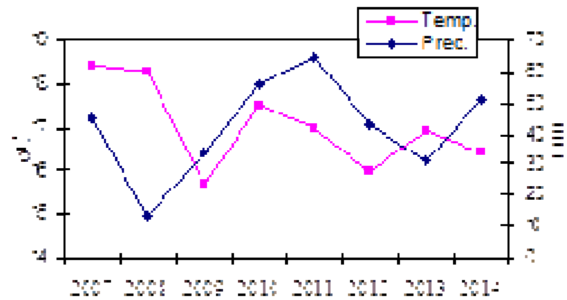

Figure 2. Pursuit rainfall (mm) and temperature (^{o}C) in the studied period.

Table 1: The standard models of depended and independent variables of the area.

Depended Variable	Standard Equation	R[a]
Grass cover	Y= -0.69P[b] – 0.21T[c]	0.68
Forb cover	Y= -0.203P – 0.379T	0.43
Shrub cover	Y= -0.603P – 0.222T	0.60
Grass production	Y= -0.707P + 0.332T	0.84
Forb production	Y= -0.527P + 0.171T	0.58
Shrub production	Y= -0.558P – 0.326T	0.59

a: correlation coefficient, b: Precipitation, c: Temperature

Discussion and Conclusion

We found that temperature and precipitation are relatively strong predictors of vegetation cover and biomass. The production of all life forms was negatively correlated with precipitation, which is surprising, but is likely because of soil texture. The soils are very sandy and rain easily so excess precipitation cannot be retained. Grasses, in particular, have a fibrous root system, that allows them to capture precipitation and survive low soil moisture (Davidson, 1969b). Grass production was negatively correlated with temperature so that because of increasing of temperature, moisture of soil will quickly loss and the species hence cannot use sufficient humidity to grow. Shrub species in contrast have deep taproots where allowing them to access deeper reservoirs of water and grow steadily over the survey period. As other researchers have claimed that climate fluctuation can effect on vegetation structure and biomass (De Boeck et al., 2008), in this study, it has also been emphasised.

Our study demonstrates that different life forms respond to variation in temperature and moisture differently. Future changes in the climate will likely have impacts on the structure and production of the plant community.

Acknowledgement

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Effect of Soil Moisture on Grass Yield in Typical Steppe of China

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Key words: Soil moisture, grass yield, grey relational analysis, lag effect

Introduction

Inner Mongolian typical steppe is an important natural pasture and rangeland with good soil texture and rich plant species. Its productivity is mainly governed by the distribution of seasonal precipitation that affects the whole grassland ecosystem by changing soil moisture (He Feng et al., 2008). Hence grassland yields are closely correlated with soil moisture content. In this study, the relationships between aboveground biomass and soil moisture at various soil depths were analyzed with mathematical models. This will provide a feasible method for predicting the productivity of typical steppe in Inner Mongolia. The objective of the study was to build mathematical model of grass yield based on soil moisture from different soil layers and compare correlation between grass yield and soil moisture.

Materials and Methods

Experiment site

Test plots were located at the natural grassland of Xiwuzhumuqin County, Inner Mongolia (44.36 Lat., 117.43 Long., 1090 m Elev.) with average annual temperature of 1~2 °C and annual precipitation of about 350 mm.

Data collection and analysis

The experiments were conducted by establishing 4 randomized replicated sample plots (1 m^2), and sampling occurred every 15 days from May 15^{th} to August 15^{th} over three years (1993-1995). The plant samples were collected by mowing to 5 cm above ground. The dry weights of plant and soil samples were measured. The dynamic changes of aboveground biomass were examined by combinations of exponential and linear models with soil moisture as an auxiliary variable. Data were analyzed using R3.2.3 software.

Results and Discussion

Soil moisture

Soil moisture content was different for soil depths with greater fluctuations in top layers (0~10 cm, 10~20 cm, 20~30 cm) than deeper layers (30~40 cm and 40~50 cm) (Fig. 1). The study results for soil moisture content were similar to that of Meadow Steppe (Liu Qingquan et al., 2005).

Aboveground biomass

Lag effect of soil moisture content on net productivity of grass occurred on every sampling date range during 1993-1995.

Relationship between soil moisture and aboveground biomass

According to $Matrix_{GRD}$ gained by grey relational analysis method (Liu Sifeng et al., 2013), the GRD between soil moisture content of 30-40 cm depth and grass yield was the largest among five soil depths in every year. It shows that deep soil moisture was more related to grass yield than shallow soil moisture during 1993-1995 in typical steppe.

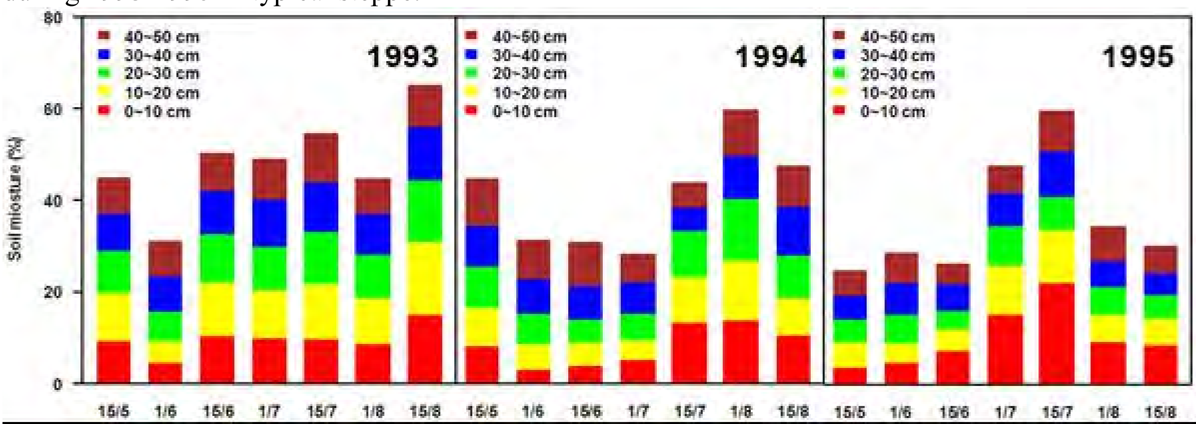

Figure 1. Trends of soil moisture content in different soil layers from different sampling dates.

$$\begin{array}{c} \quad\quad\quad\; 0\sim10cm \;\; 10\sim20cm \;\; 20\sim30cm \;\; 30\sim40cm \;\; 40\sim50cm \;\; Moisture \\ Matrix_{GRD} = \begin{bmatrix} 0.6405 & 0.6425 & 0.6507 & 0.6755 & 0.6668 \\ 0.8565 & 0.8536 & 0.7933 & 0.8645 & 0.8062 \\ 0.8400 & 0.8351 & 0.8335 & 0.8548 & 0.8144 \end{bmatrix} \begin{array}{l} Yield_{1993} \\ Yield_{1994} \\ Yield_{1995} \end{array} \end{array}$$

Model of aboveground biomass

According to Table 1, fitting accuracy of yield model were more than 90% during 1993-1995. It shows that the exponential-linear models of grass yield with soil moisture (Equation 1) that produced the largest GRD in various soil depths are valid and feasible in predicting production of typical steppe in Inner Mongolia.

$$\hat{Y}ield_{year}(t) = k_1 \exp[k_2(t-1)] + k_3 \sum_{i=1}^{t} Soil\,moisture_{30\sim40cm}(t) \;\; (t = 1, 2, \cdots, 7) \quad \text{.........(1)}$$

Table 1: The parameters and fitting accuracy of yield model during 1993-1995

Year	k_1	k_2	k_3	*Fitting accuracy*
1993	−187.1237	−1.1991	2.9600	90.70%
1994	−210.1784	−0.7762	4.2548	93.88%
1995	−185.1001	−1.3370	4.4592	93.22%

Conclusion and Implications

The moisture contents of top soil layer had a greater fluctuation than the deeper soil layer. The net productivity of grass had a lag due to the change of soil moisture. Most of the time, the GRD between grass yield and soil moisture was relatively larger at lower soil depths. It is feasible to use an exponential-linear model to predict grass productivity of typical steppe in China.

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Diversity of Soil Microfauna Communities in Different Salinity Habitats of the Songnen Grasslands

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Key words: Soil fauna, diversity, salinity habitat, Songnen grasslands

Introduction

Saline-alkali lands differ in their biotic and abiotic environments (Agnieszka et al, 2013; Xin et al, 2012). The effects of soil salinization on the compositions and diversities of soil microfauna in different salinity habitats contribute to the diversity (Cole et al., 2006). We investigated the compositions of soil microfauna in different salinity habitats of the Songnen grasslands and the spatial-temporal variations of the structure, diversity of the soil microfauna, the relationships between soil microfauna, and environmental factors.

Materials and Methods

The study site was located at the Changling Site in Jilin Province (123°44′-123°47′E，44°40′-44°44′N), northeastern China. The area has a sub-humid continental monsoon climate. The main soils in the study area include light chernozemic soil: saline meadow, alkaline meadow, alkaline saline and chernozemic sand. The saline communities are mainly distributed in the salinized meadow. According to the extent of the salinization, the respectful dominant species, the main plant communities were composed of *Chloris virgata*, *Suaeda corniculata*, *Puccirrellia tenuiflora* and *Artemisia anethifolia* habitats.

In July, five habitats were sampled: *Chloris virgata* (a), *Suaeda corniculata* (b), *Puccirrellia tenuiflora* (c), *Artemisia anethifolia* (d), and the alkali spot habitat (e). Four quadrats were randomly selected. The sampling of soil microfauna occurred within a 10 cm × 10 cm space. Soil microfauna were collected from the litter layer, and the 0-10 cm, 10-20 cm and 20-30 cm soil layers. The soil microfauna were identified with the aid of a microscope.

The determination of soil microfauna community diversity indexes were applied to these data: Shannon-Wiener index: $H'=\sum_{i=1}^{s} P_i \ln P_i$, Margalef richness index: $D=S\text{-}1/\ln N$, Pielou evenness index: $e=H'/\ln S$, Simpson dominance index: $c=\sum(N_i/N)^2$.

Results

We collected 1,341 individuals belonging to one phylum, four classes, and twelve orders or suborders in the five salinity habitats during six sampling periods. The mean density of the soil microfauna was 6,705 individuals/m^2, ranging from 2,350 individuals/m^2 in the alkali spot to 9,400 individuals/m^2 in the Artemisia anethifolia habitat. The communities were dominated by Actinedida, Oribatida, Gamasida and Isotomidae. The common groups were Entomobryidae, Diptera larvae and Sminthuridae.

The soil microfauna diversities differed among the different habitats, with the greatest for 21 classes in the *Artemisia anethifolia* habitat, followed by 19 classes in the *Chloris virgata* habitat, 15 classes in the

Suaeda corniculata habitat, 14 classes in the *Puccirrellia tenuiflora* habitat, and 12 classes in the alkali spot habitat (Fig 1). The group number has a digressive tendency with the abundance of the 0-10 cm soil layer significantly greater than the other two layers.

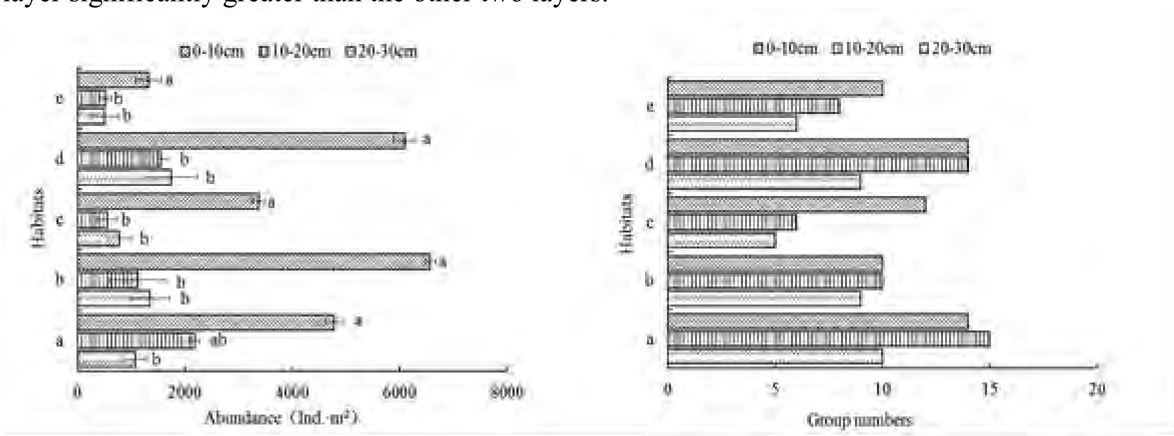

Figure 1. Vertical distribution of soil fauna in different salinity habitats (mean ±SE). Different letters indicate spatial differences within seasons at the $p<0.05$ level

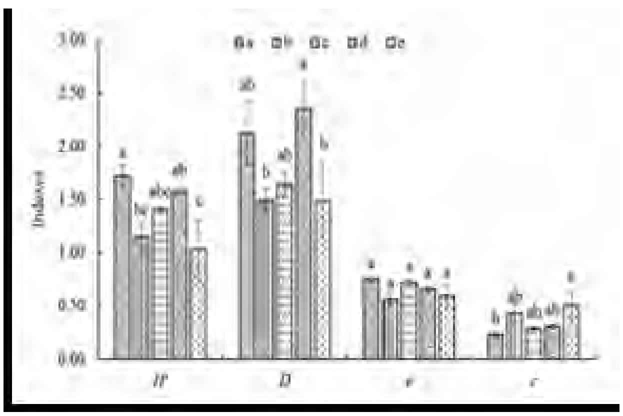

Figure 2. Diversity indexes of soil fauna in different salinity habitats (mean ±SE). Capital letters indicate temporal differences within habitats at the $p<0.05$ level

The Shannon-Wiener and richness indexes of the alkali spot habitat are significantly lower than those of the other habitats (Fig. 2). The temporal variations of each diversity index varied among the habitats.

Conclusions

As the soil salinity increased, group numbers of the dominant and rare groups gradually reduced. Soil salinity decreased the density and diversity of soil microfauna. Consequently, soil salinity has an important effect on the soil microfaunal community composition and structure.

Acknowledgments

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Resilience of Steppe Vegetation after a Dryness Cycle in Algeria: Example of Hadj Mechri Commune in the Laghouat Wilaya

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Key words: Rangeland, functional strategy, resilience, dryness, Algeria

Introduction

The Algerian steppe covers 20 million hectares and it is one of the largest livestock production zones in North Africa. The steppe has been impacted by climatic changes, land use changes, increasing in demography, and overgrazing over the last 40 years.

It is generally agreed that productivity of the Algerian steppe has declined and this has been confirmed by studies (Nedjraoui and Bedrani, 2008; Salamani *et al*, 2013). This decrease in vegetation is generally explained by the increase of dryness events and by overgrazing. Understanding how vegetation recovers after dryness events will help to devise management practices that avoid overgrazing. The last six years were marked by a severe dryness in 2007 and 2008, followed by a very wet year in 2009, and normal rainfall patterns from 2010 to 2013. The goal of our study was to understand the dynamic of the rangeland vegetation after a dryness event.

Material and Methods

Our study site was the agro-pastoral commune of Hadj Mechri (65.270 ha) in the Laghouat, Wilaya (Algeria). The region is considered semiarid (P= 315mm year, CV=31%). This commune is representative of the degradation of steppe vegetation over the climatic cycle (2007-2013). It has been registered a low rainfall in 2007 and 2008 (196 mm), a very wet year in 2009 (501 mm) and medium years from 2010 to 2013 (320 mm).

We made 275 phyto-ecological surveys using the method of "points quadras" (Daget et Godron, 1995) between 2007 and 2013. These surveys were used to characterize the vegetal formation and their ecological characteristics (specific contribution, vegetal cover, pastoral value and potential stocking rate). To assess the differences in botanical composition, we projected the Bray Curtis dissimilarities using Nonmetric Multi-Dimensional Scaling (NMDS). We used the two axes of the NMDS as indicators of botanical change and to identify the different vegetal formations. We also used the Raunkiaer classification (1934) and Grime strategies (1977) to describe the vegetation. We also assessed vegetation cover, the cover of sand, the pastoral value and the potential stocking rate. We compared these different variables between the different years using ANOVA followed by a Tukey HSD test.

Results and Discussion

The analysis of the botanical composition confirm that the surveys were made in three different vegetal formations: *Stipa tenacissima L.*, *Lygeum spartum L.* and *Stipagrostis pungens Desf.*. We observe a change in botanical composition during the different years of the surveys with a shift between 2011 and 2012. We have interpreted that these changes were due to a decrease of sable cover and an increase of organic matter. This modification is also correlated with an increase in biodiversity and a change in

Raunkier groups from geophyte to therophyte. Regarding the Grime strategies, the cover of competitor species is higher in the first years of the monitoring at the opposite the cover of ruderal species increase. It is interesting to notice the time-lap between rainfall and vegetation dynamics. The year 2009 had the highest rainfall (501 mm) over the cycle but the vegetation variables were not different from the dry years. The shift in vegetation was the most important in 2010 when there was an increase of the number of species, vegetal cover and pastoral value, and annual species and a decrease of sand cover (decrease of 91% of the sable cover between 2009 and 2013 in the *Lygeum spartum* formation). The trends remained similar for the three years after 2010 characterized by an average rainfall. Since 2013, the pastoral value is decreasing. It could be due to the increase of ruderals that could be an indication of the increase of anthropic pressure on the vegetation. The dynamics of the different variables of vegetation are represented in the Figure 1.

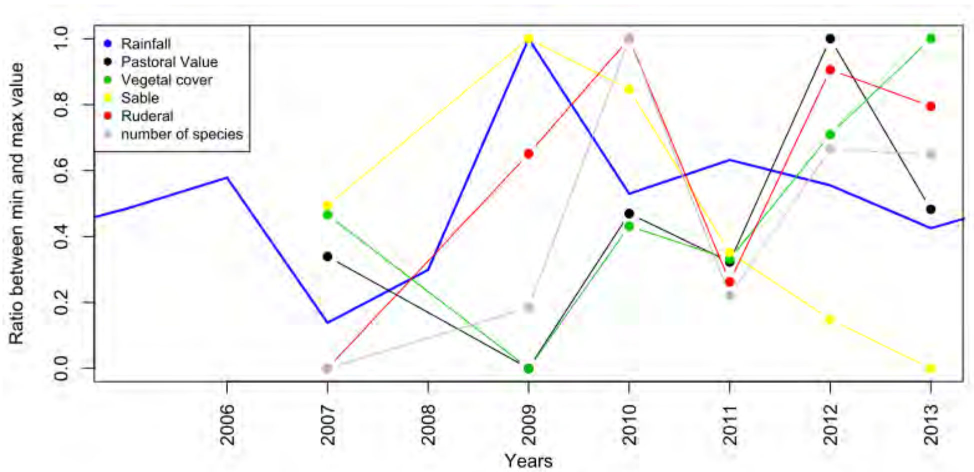

Figure 19. Dynamic of the variables of the vegetation and the rainfall per year. The x axis represents the years; the Y axis corresponds to the value of the normalized variable (0 for the minimal value of the yearly mean value of the variables and 1 for the maximal value).

The vegetation in our studied site was subject to large rainfall variability, high level of anthropic disturbance with high stationary stocking rate. These factors favored ruderal species and therophytes species. The therophytes species are able to survive the climatic events and grazing due to their quick growth and high seed production (Jauffret and Lavorel, 2003).This overgrazing is also confirmed by the diminution of the pastoral value of 28% between 2012 and 2013 and the diminution of pastoral production.

Conclusion

In this work, we have showed the resilience of the steppe vegetation to a dryness event. We observe an ecological succession of the vegetation. Competitor species were more present during the dry years. A very wet year can stimulate the functioning of the ecosystem. The competitors' species are progressively replaced by ruderal species maybe due to the impact of grazing.

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Effect of Litter on the Vegetation of the Desert Steppe in Inner Mongolia

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Key words: Grassland, functional group, season, *Salsola collina*

Introduction

The dead herbage in grasslands has been referred to as litter. It ameliorates the soil temperature and interacts with the hydrological cycle, thereby affecting available soil water for plant growth Willms and Chanasyk, 2006. Therefore, the existence of litter can maintain and stabilize the aboveground net primary production (ANPP) on grassland ecosystem. We tested the hypothesis that litter removal reduced ANPP while litter addition increased ANPP on the Desert Steppe in Inner Mongolia and that their effects were influenced by the season of treatment.

Materials and Methods

The study was conducted at the Inner Mongolia Academy of Agriculture and Animal Husbandry Science (41°47'17"N, 111°53'46"E) located in a Desert Steppe. Mean annual precipitation was 250 mm and the dominant plant species *were Stipa breviflora*, *Artemisia frigida* and *Cleistogenes songorica*.

Litter removal and addition experiments were conducted on two neighboring sites. The removal experiment was conducted in a livestock exclosure that had been erected in 1996 while the addition experiment was conducted on an adjacent grazed site with heavy grazing (stocking rate = 2.71 sheep unit/ha/year). Each experiment consisted of a split plot design with litter removal or addition treatments (heavy, moderate and control) as the main plot (2×6m) and season (fall, spring) as the sub-plot (2×3m). The litter treatments were applied a single time in consecutive treatment-years from fall, 2006 to 2010 and spring, 2007 to 2011. The treatments were replicated 5 times in each treatment-year. The ANPP of species and their ground cover was measured at peak standing crop in the growing year after treatment. Heavy litter removal consisted of raking the fallen (fragmented) and standing (attached to the crown) litter after cutting the latter to near ground level. In the moderate treatment, only the fallen litter was removed by raking.

The effect of litter removal and addition on ANPP was tested on selected functional groups and their totals. The functional groups were grass (rhizomatous and bunch) and forb (annual and perennial). Litter removal and addition were analyzed separately. The MIXED model procedure was used for analysis of variance with litter treatment as the main factor and season as the sub-factor. The residuals were checked for normality using the UNIVARIATE procedure (SAS, Version 9.1.3, SAS Institute Inc., Cary, NC, US). Means were separated with the LSD test ($p< 0.05$).

Results and Discussion

In this study we examined the effects of a single episode of litter removal or addition on the short-term effects on vegetation expressed by production and canopy cover. Litter removal or addition were both expected to affect the microclimate of the soil, which we assessed by measuring the plant response. We anticipated that the effect that season would be expressed through litter mass, whether left *in situ* or added, on snow capture over winter (Willms and Chanasyk, 2006), or by its influence on the loss of soil moisture in either winter or spring.

In the first year after treatment, neither litter removal nor addition had any effect on total ANPP and that of grass, forbs or *Salsola collina*. Growing season precipitation, as defined by categorical values of high ($\overline{x}$ = 203 mm) or low ($\overline{x}$ = 130 mm) annual totals, had the most significant and consistent effect on the variables measured in both the removal and addition experiments, and its effect across litter treatments was similar ($P > 0.05$). In the litter removal experiment, total ANPP in high precipitation years was about 40% greater than in low precipitation years, with most biomass contributed by a greater yield of *Salsola collina*. In the litter addition experiment, the differences were smaller but also contributed mostly by the response of *Salsola collina*. The season of litter addition modified ($P < 0.05$) the effects of precipitation on the ANPP of *Salsola collina*. The season of litter addition had no effect ($P > 0.05$) when precipitation was low but in years of high precipitation the effect was greater ($P > 0.05$) with litter addition in fall rather than spring.

The opportunity for litter to modify the soil environment is dependent on its mass and the occurrence of soil moisture. In the present study, the mass of litter present was very small (14.6 $g \cdot m^{-2}$) compared with the Typical Steppe in Inner Mongolia (140 $g \cdot m^{-2}$; Wang et al. 2011) or the Mixed Prairie in Canada (1171 $g \cdot m^{-2}$; Willms et al. 1993). In the latter study, litter had no effect ($P > 0.05$) on ANPP in a year with above average precipitation and had a reduced effect in a year with below average precipitation, while in both studies by Willms et al (1993) and Wang et al. (2011) soil heat units where greatest where litter had been removed.

Therefore, the primary factor that may have mitigated the treatment differences in the present study was a small litter mass whose effect was below a threshold that could be detected. Another factor might be that most (85%) annual precipitation occurs during the growing season (May to September) when it would be quickly utilize by plants thus making water conservation on the Desert Steppe irrelevant.

The short-term relationship between litter mass and production, as examined in this study, relates to its ability to conserve water while evidence (Facelli and Pickett, 1991) suggests that over a longer period where litter is removed that species composition may also be affected. In our study we found few effects in the first growing season after imposing the litter treatments and no effects that persisted beyond that, which is indicative of the high degree of resilience of the plant community and the individual species that dominate it. Repeated litter treatment might have produced a detectable shift in species composition by allowing plants to adapt to a new soil moisture regime but that possibility is hypothetical. Evidence from a grazing study in the Desert Steppe suggests this might occur but it assumes that grazing and litter removal produce similar effects in a xeric environment.

The greatest response occurred from the annual forb, *Salsola collina*, which was primarily responsible for exploiting increased precipitation and accounts for fluctuations in total biomass. Therefore, litter management as a strategy for enhancing production on the Desert Steppe. This study did not address other factors that might be influenced by the presence of litter or by the indirect effect of grazing by sheep. The fact that ANPP in the litter addition site was only about 60% of that in the removal site suggests other factors, such as a smaller proportion of *Salsola collina*, might be responsible for the difference. Nevertheless, the community response to the litter treatments was similar at both sites even though the effects were unremarkable.

Acknowledgments

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Interactions between Microorganisms and Plant Genotype Affect Soil Carbon under Drought Conditions

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Key words: drought, endophyte, *P.indioca*, *P.polymyxa*, soil carbon

Introduction

Soil is a major terrestrial pool for carbon that contains 2.5×10^{18} g of carbon in the first 100 cm depth (Abu-hashim 2016). Small changes to soil carbon storage may have major implications for climate regulation through atmospheric CO_2. Many factors affect carbon content in the soil including temperature, water content, land use, human manipulation, soil texture, soil structure and also plant species. This experiment was designed to determine whether plant-associated microorganisms and plant genotypes interact to modulate rhizospheric carbon. For this purpose we used *Paenibacillus polymyxa* (Pp) as a plant growth promoting bacteria (PGPB), *Piriformospora indica* (Pi) as a mycorrhizal-associated plant growth promoting fungi (PGPF); and *Neotyphodium coenophialum* (Nc) as an endophyte fungi in two genotypes of *Festuca arundinacea*.

Materials and Methods

Two genotypes (75B and 75C) of tall fescue (*Festuca arundinacea* Schreb) were planted in 24 pots each or six pots per each treatment (control, Pp. Pi and Nc). Six pots were inoculated with *N.coenophialum* (Nc). All *F. arundinacea* were transplanted at the beginning of October 2013 in 48 pots (3 Kg) and buried in the field (32˚ 42' 48.6″ N and 51˚ 32' 6.10″ E, 1625 masl). After 50 days, 6 pots were injected with 30 ml of *P.polymyxa* inoculum prepared in a nutrient broth (4.6×10^8 cfu cm^{-3}). A control group was injected with sterile bacterial culture media and another 6 pots were injected with 30 ml culture of *P.indica* with 2.8×10^8 cell cm^{-3} that was prepared in Kaefer medium (Kumar et al., 2014) and 6 control pots were inoculated with sterile inoculum. The plants were overwintered. Beginning of March, a drought stress treatment was applied. Soil water content was maintained at 14 ± 5% of volumetric water measured by TDR (8 bars of matric potential). The whole plant growth period was 210 days with 120 days effective growth. The final 60 days included the drought stress, after-which plants were harvested and rhizosperic soil was collected for carbon analysis (Kalra, 1998).

The original culture of *P.polymyxa* PTCC 1021 (ATCC 21830) was obtained from the Iranian Research Organization for Science and Technology (IROST). Bacterial inocula were prepared in nutrient broth solution, following supplier protocols, and incubated at 30°C while shaking at 120 rpm for 48 hours. Soil organic carbon (SOC) and total soil carbon (TC) were determined by K2Cr2O7 titration and ICE-440 elemental analyzer respectively. Statistical analyses were conducted based on completely randomized factorial design using SAS 9.1 for Windows (SAS Inc., USA). Differences at $P<0.05$ were considered statistically significant.

Results and Discussion

Table 1 shows the effect of plant-associated microorganisms on SOC and TC. Inoculation with *N.coenophialum* (Nc) elicited increases in SOC and TC for both the 75C (1.13% and 8.37%) and 75B (12.14% and 2.29%) genotypes. Similar positive effects were elicited by inoculation with *P. polymyxa* and *P. indica* for both genotypes (Table 1).

Table 1. Effect of associated microorganisms on total and organic soil carbon (g. kg $^{-1}$ ± SE) in two genotypes of *F. arundinacea.* Different letters within columns are significantly different (*P* < 0.05).

	Total soil carbon (TC)		Soil organic carbon (SOC)	
	75C	75B	75C	75B
Control	44.94 (± 0.01)^{b}	44.89 (± 0.04)^{b}	16.95 (± 0.08)^{b}	14.83 (± 0.06)^{c}
Nc	45.45 (± 0.06)^{a}	45.92 (±0.01)^{a}	18.37 (± 0.06)^{a}	16.63 (± 0.03)^{b}
Pp	44.85 (± 0.03)^{b}	46.21 (±0.02)^{a}	17.10 (± 0.11)^{b}	17.22 (± 0.11)^{ab}
Pi	45.20 (± 0.01)^{b}	45.95 (±0.05)^{a}	17.60 (± 0.11)^{b}	18.60 (± 0.05)^{a}

Rhizosphere-associated microorganisms appear to facilitate soil carbon accumulation, a process that is mediated by plant genotype. Tan et al. (2004a,b) reported that SOC is generally affected by land use, soil texture, and drainage. However, this study showed that SOC is also affected by biological interactions with plant genotype. Unfortunately, human activities (*e.g.* fertilization, plowing) tend to reduce the abundance and activity of beneficial soil microorganisms and, based on the evidence produced here, these activities may also reduce the capacity for biologically-mediated soil C accumulation.

Conclusions and Implications

Our findings emphasized the importance of soil microorganisms in soil C accumulation and show that plant-associated microorganisms can increase in amount of C stored within the rhizosphere, a process that was mediated by plant genotype. These processes need to be understood in order to predict and manage shifts in soil C pools in response to changes in land use and climate. In conclusion, with the aim of understanding SOC dynamics and mechanisms of stabilization, it is important to consider the effects of biological interactions and plant genotype.

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Heat Waves Reduce Ecosystem Carbon Sink Strength in a Eurasian Meadow Steppe

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Key words: extreme climate, global change, Eddy covariance, grassland, carbon flux

Introduction

An increasing number of studies have shown that human activities and climate change have regulated ecosystems simultaneously, with human disturbances producing much stronger impacts than climate change. The fifth report of Intergovernmental Panel on Climate Change (IPCC 2013) confirmed human activities contribute to extreme climate, such as heat waves (HW). Compared to global warming, HWs have always done more damage to human societies and natural ecosystems, counteracting the global ecosystem and leading to more drastic climate changes. Therefore, HWs can be treated as a beginning of an ecosystem's vicious cycle. When we study this cycle, it is important to determine the impact of HWs on ecosystems. The intensity and frequency of extreme climatic events such as HWs are increasing worldwide. HWs are characterized by rapid heating for several days, having a much stronger influence on plants than gradual warming. Unlike chronic warming, HWs may place plants beyond their acclimated range, requiring emergency physiological responses in order to avoid sudden death.

Materials and Methods

The study was conducted at the Songnen Grassland Ecology Field Station of the Northeast Normal University (NENU), in Changling (CL), Jilin Province, China (123° 30′ E, 44° 35′ N, 171 m a.s.l). The Songnen meadow steppe is located in transitional zone. An open-path eddy covariance (EC) flux measurement tower was deployed in 2007 for a long term monitoring project to measure CO2, water vapor, energy, and meteorological variables. The climatic data were obtained from the China meteorological data-sharing service system (http://cdc.cma.gov.cn/). We selected the data of Qianguo'erluosi (QG), which is the site nearest to the flux tower (Station number: 50949, 124° 52′ E, 45° 05′ N, 135.9 m a.s.l.); both sites are situated in the southern Songnen Plain. This area has a temperate, semi-arid continental climate; characterized as cold with dry springs and warm, wet summers.

We defined HWs following De Boeck et al. (2010) with a few modifications. First, we used the daily maximum air temperature (Tmax), instead of mean air temperature. Then, we calculated the top 10% of the growing season daily Tmax and defined these days as "hot days." A period with at least five consecutive hot days was defined as a HW. However, if a "non-hot day" fell within a six-day or longer period of otherwise hot days, this period was also considered as a single HW. For example, 12 hot days could contain up to two non-hot days and still be considered a single HW.

Results and Discussion

We detected 918 days of "hot days" and 27 HW events. HWs occurred primarily in June, July, and August. Overall, the most HWs occurred in July. During the last 60 years, most HWs occurred in July, however, during the last decade, more than 80% of HWs (5 out of 7) occurred in June. The longest duration of a HW was 15 days, occurring in August 1982 and July 2000. Furthermore, 14 of the 27 HWs occurred within the last 20 years, accounting for 50% of all HWs of the past 60 years. This equals to approximately one HW occurring every 2 years. Although the exact timing of HW events is unpredictable, the study still showed an increase in the number of HWs during the last 20 years (1993–2012), with half of all HWs occurring within these two decades.

Table 6 Statistics of 60-year heat waves (HW) characters of Qianguo (QG) in a Eurasian meadow steppe from 1954 to 2013 (step by 10-years).

	Hot day (day/10yr)	Heat wave (times/10yr)	Mean HW length (day)	Max HW length (day)	Times per month		
					June	July	August
1954-1963	141	1	11.0	11	-	1	-
1964-1973	142	2	6.0	6	-	2	-
1974-1983	184	7	9.6	15	1	5	1
1984-1993	95	3	6.3	11	-	1	2
1994-2003	195	7	9.0	15	2	5	-
2004-2013	166	7	7.1	9	5	-	2
total	923	27	8.2	15	8	14	5

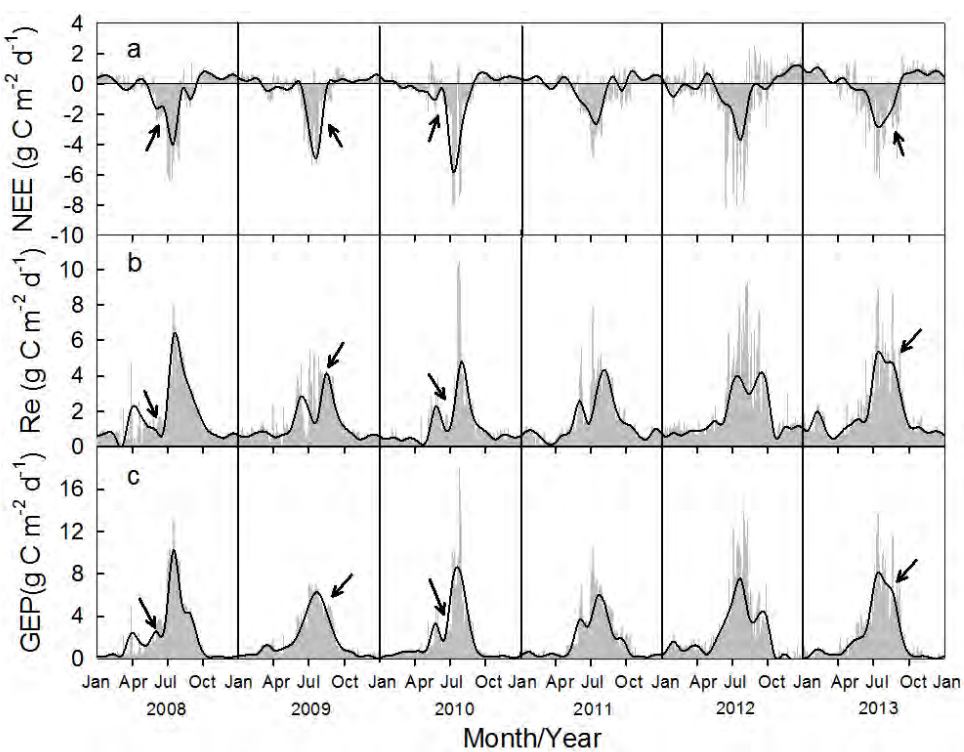

Figure1. Songnen meadow steppe carbon exchange from 2008 through 2013. a: NEE (Net Ecosystem Carbon Exchange); b: Re (Ecosystem Respiration); c: GEP (Gross Ecosystem Production). The grey bars indicate the daily number, the lines indicate 10 days running average, the arrow point the heat wave (HW) time.

The meadow steppe's capacity is lower than that of forest, but higher than those of typical grassland. The annual mean NEE between 2008 and 2013 was -114.0 g C m^{-2}, with a mean of -157.5 g C m^{-2} for the growing season. The decrease of NEE caused by the HW did not occur at the first day, it occurred as two fluctuations, one small then one large. The first fluctuation happened on the second day after the HW occurred, then after a temporary restoration, the next peak appeared. The second peak appeared at h4, and we considered this peak to be the tolerance limit of this meadow steppe. The time when this large fluctuation appearance was associated with the initial vegetation growth state and the ecosystem water condition before, but the large fluctuation will happen before h6 concluding that 2 or 3 days of high temperatures will not cause severe impact on carbon exchange. However, when HWs last for a long time (at least 4 days), the natural ecosystem will be influenced. This influence is caused by both high temperature and drought. Most studies consider that droughts are the main HW effects on ecosystem plant species. Our study supports this opinion, and we obtained a further corollary by analyzing the two peaks of NEE decrease, which was caused by HWs. The mean ET decrease of 28% from h2 to d4 as 2.51 mm indicates that the decrease of NEE at h2 may reflect the stand-alone influence of heat, whereas the second peak at h4 may be due to the joint action of heat and drought. Considering the NEE of h1, the initial small decrease (h2 or h3) and the second peak on d4 or d5, we estimated that heat alone would cause a 15%–25% decrease in NEE, whereas the joint action of heat and drought would cause NEE to decrease by 50%–75%.

Conclusions and Implications

As a consequence of global change, intensity and frequency of extreme events such as heat waves (HW) have been increasing worldwide. By using a combination of continuous 60-year meteorological and 6-year tower-based carbon dioxide (CO_2) flux measurements, we constructed a clear picture of a HWs effect on the dynamics of carbon, water, and vegetation on the Eurasian Songnen meadow steppe. The number of HWs in the Songnen meadow steppe began increasing since the 1980s and the rate of occurrence has advanced since the 2010s to higher than ever before. HWs can reduce the grassland carbon flux, while NEE (net ecosystem carbon exchange) will regularly fluctuate for 4–5 days during the HW before decreasing. However, Re (ecosystem respiration) and GEP (gross ecosystem production) decline from the beginning of the HW until the end, where Re and GEP will decrease 30% and 50%, respectively. When HWs last five days, WUE (water-use efficiency) will decrease by 26%, SWC (soil water content) by 30% and SWP (soil water potential) will increase by 38%. In addition, the soil temperature will still remain high after the HW although the air temperature will recover to its previous state.

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6.2 Livestock and Grazing system adaptations to climate change

Climate-Clever Beef: Extension Strategies to Support Beef Business Profitability in a Changing Climate

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Key words: Climate change, extension, productivity, profitability, beef business

Introduction

Beef businesses in northern Australia are finding it difficult to remain productive and profitable in the face of challenges such as climate variability and increasing input costs. A recent industry report suggests that the majority of northern Australian beef businesses are currently not economically sustainable (McLean et al., 2014). In addition, adverse terms of trade, limited recent gains in on-farm productivity and low profit margins under current management systems and climatic conditions will leave little capacity for businesses to absorb any climate induced losses (Stokes et al., 2012). To support their carbon trading scheme (Emissions Reduction Fund), the Australian government invested in research which would enhance landholders' ability to minimise greenhouse gas emissions, sequester carbon in soil, engage in the carbon farming economy and increase the agriculture sector's resilience to climate change. Grazing businesses in the Maranoa-Balonne region, in sub-coastal eastern Australia, are typically well-developed, diverse, small to moderate scale enterprises. These businesses provided an ideal environment to evaluate practices/technologies that may achieve the end result of reduced emissions or increased soil carbon, whilst maintaining productivity and profitability. This study aimed to achieve these outcomes through the use of different extension strategies, including on-farm trials, focus groups, and one-on-one support. This paper discusses the effectiveness of these various extension strategies used during the project.

Materials and Methods

The Climate Clever Beef initiative in northern Australia was undertaken by industry, natural resource management groups and two state departments, over six years from 2010-2015. In the Maranoa-Balonne region we worked with 12 farms, trialling management practices and sharing results with the wider industry. We formed a farm business group to facilitate peer learning and assist with improved knowledge transfer amongst group members. To best achieve project outcomes, three extension approaches were used within the project: the 'group facilitation/empowerment model', the 'individual consultant/mentor model' and the 'technology development model' (Coutts et al., 2005). Activities focussed on improving financial literacy skills and generating a better understanding of the key performance indicators of the business. The opportunity to undertake a full business analysis over five financial years, 2009-14, was offered to all group members, with nine businesses opting to undertake this activity. Reports detailed annual key performance indicators of the business, including: kilogram of beef produced per adult equivalent, cost of production, operating margin and labour efficiency.

On-farm trials were established on each property. Scenario modelling was undertaken when trials were beyond the project's resources or timeframe. Practices to be trialled were selected based on business strengths and weaknesses identified through business analysis, alignment with current management practices, long-term goals and those that would enhance the productivity and profitability of the business. Trials and practices focussed on a number of key areas: improving animal performance; changing the enterprise mix, and; improving pasture and soil carbon (Bray et al., 2015).

Results and Discussion

Utilising a range of extension approaches throughout the project proved to be a successful way to achieve project outcomes. Group meetings and discussion were useful in building rapport among group members. The business analysis reports and group discussion assisted individual producers to redefine their management goals and more accurately identify where to make modifications and changes in the business. In a survey taken towards the end of the project all of the responding (n=6) businesses that participated in the business analysis activity indicated that they found it a useful part of the project. Reasons given for this rating included: an increased knowledge of their business and profit drivers, being able to see the impacts of management decisions on the business and where to focus attention to improve future performance. Interestingly, while many changes were prompted or directed by the business analysis activity, all participants in the survey indicated that they did not make any changes to the business solely as a result of business analysis. Practice change required the business analysis to be coupled with other extension and advisory approaches (e.g. one-on-one property visits).

Research suggests that the use of trials can increase the adoption of a new technology, mostly due to the landholder learning the skills needed to apply innovations, avoiding any large financial risks and increasing the probability of the landholder making a correct decision (Pannell et al., 2006). Within the group there was a high adoption rate, with eight of the twelve businesses adopting new practices. This was likely due to most of the landholders having taken steps already towards considering the new practices prior to the project. The on-farm trials served to justify their considerations through positive affirmation with the results received. Options modelling, provided a similar outcome. Where changes led to a direct production or profit outcome, producers were more likely to implement this practice in full following the completion of the trial. Practice changes that generally led to an improvement in the business were increased animal performance and grazing land management. According to Stokes et al. (2012), business performance under changed climatic conditions is likely to be most affected through reduced carrying capacity, due to declines in land and pasture condition, and subsequent reductions in animal productivity. Therefore, increases in productivity in these areas will assist with mitigating the impacts of climate change and potentially improve business profitability.

Conclusions and Implications

The use of multiple extension approaches, especially in conjunction with business analysis activities, successfully encouraged and supported adoption of practices to improve financial performance, productivity of the grazing business and adaptation to a variable climate.

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Flexible Stocking Strategies for Adapting to Climatic Variability

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Key words: Precipitation variation, forage availability, enterprise flexibility, seasonal precipitation patterns, climate change

Introduction

As a result of precipitation-induced variability on forage production, ranchers have difficulty matching animal demand with forage availability in their operations. Flexible stocking strategies could more effectively use extra forage in highly productive years and limit risk of overgrazing during dry and drought years. Flexible stocking strategies can blend science-based information with experiential knowledge from ranchers to influence stocking rates. Incorporating flexible stocking strategies can be difficult due to maintenance of cow herd genetics, but flexible stocking using yearlings could substantially increase economic returns to ranchers compared to conservative stocking (Torell et al. 2010). The objective of this paper is to showcase the process of effectively incorporating flexible stocking strategies into a ranch enterprise.

Materials and Methods

Using long-term (1982-2014) data from a northern mixed-grass prairie at the USDA-Agricultural Research Service High Plains Grasslands Research Station near Cheyenne, Wyoming, USA, the relationship between spring (April + May + June) precipitation and forage production was determined.

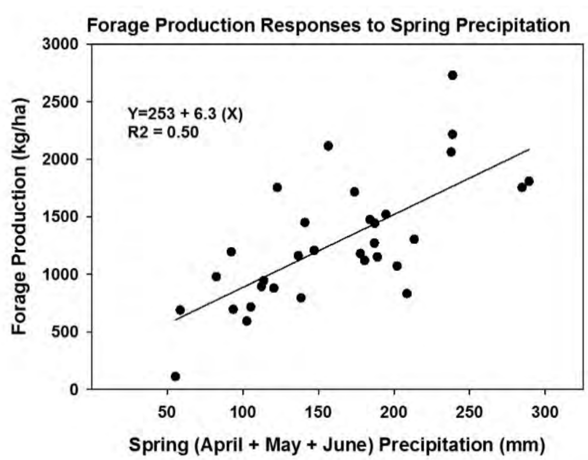

Figure 1. Relationship between spring precipitation (April-June, mm) and forage production (kg/ha) for the northern mixed-grass prairie near Cheyenne, Wyoming, USA. Updated from Derner and Hart (2007).

This science-based information was used in early spring 2015 for a first approximation of estimated forage production with amount of precipitation determined from seasonal forecasts by the Climate Prediction Center (http://www.cpc.ncep.noaa.gov/). This first approximation was adjusted using experiential knowledge from Mark Eisele and his daughter Kendall Roberts of the King Ranch related to prior end of growing season soil moisture, remaining plant residual biomass, drought status, livestock market economics and risk tolerance (Table 1). Thus, this process blended science-based information with local knowledge to inform adaptive range management.

Table 1. Experiential knowledge to adjust stocking estimate derived from science-based information.

Variable	Decrease stocking estimate	Increase stocking estimate
Plentiful end of prior growing season soil moisture		X
Inadequate end of prior growing season soil moisture	X	
Excess plant residual biomass		X
Marginal plant residual biomass	X	
Not in drought, nor predicted to be		X
In drought or predicted to be, or recovering from drought	X	
Livestock economics: Bull market		X
Livestock economics: Bear market	X	
Risk tolerance: High		X
Risk tolerance: Low	X	

Additional adjustments in the estimated forage production amount occurred as the spring progressed with actual precipitation received and updates to seasonal precipitation forecasts. On June 1, actual April and May precipitation values and estimated June precipitation values from the Climate Prediction Center (http://www.cpc.ncep.noaa.gov/) were used to make a final determination of forage production. This final forage production estimate was multiplied by 25% to determine amount of forage available for livestock intake, which was then multiplied by the land area and divided by 360 kg to determine animal unit months (AUMs). The total number of AUMs was divided by a four month grazing season (June-September) and then by 0.7 as the animal unit equivalent (AUE) for yearling heifers which grazed the study area.

Results and Discussion

Exceptional spring precipitation in 2015 resulted in high predicted forage production, and experiential knowledge suggested additional increases in the stocking rate due to plentiful end of prior growing season moisture, excess plant residual biomass, and lack of drought or predicted drought. No change in stocking rate occurred due to livestock economics or risk tolerance. Collectively, with the science-based information and the experiential knowledge, stocking rates were increased 45% (1.35 AUM/ha) above the recommended moderate rate (0.93 AUM/ha). The flexible stocking rate was 9% greater than the heavy rate (1.24 AUM/ha). Stock density in the flexible stocking strategy was 0.48 steers/ha compared to 0.33 steers/ha for the recommended stocking rate. Livestock gains in the flexible stocking strategy were 33% greater (51.7 vs 39.0 kg/ha) compared to moderate stocking. This 12.7 kg/ha difference in livestock production for the flexible stocking strategy would result in about $11.55/ha more economic return over the moderate stocking rate with selling price of $0.90/kg.

Conclusion and Implications

Flexible stocking strategies provide opportunities to more effectively match animal demand with forage availability across years which could potentially substantially increase net economic returns. Currently, accuracy of seasonal precipitation predictions is not sufficient for most ranchers to use for determining forage production for flexible stocking strategies, though forecasts are improving. Current low adoption rates for flexible stocking strategies are related to weather forecasting uncertainty, the low risk mentality of most ranchers, and inherent constraints in enterprise structure.

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Mongolian Rangeland Changes with a Changing Climate

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Key words: Climate change, biomass, vulnerable, dzud, drought

Introduction

As the largest ecosystem in Mongolia, rangeland not only provides abundant natural resources for economic development, but also safeguards the environment of the country as it acts as an ecological protective screen. However, because of the arid and semi-arid regions, most rangelands are seriously limited by climate as changes in precipitation and temperature can affect the pasture biomass in grassland ecosystems. The results of climate change estimation over whole Mongolia showed that, air temperature increased by 2.14 degrees and precipitation decreased by 7% in last several decades (Natsagdorj et al, 2007). The biomass changes were different site to site, ranging from -0.244 g/m^2 to +0.479g/m^2 over whole Mongolia and generally in most of natural zones occurred decrease of biomass in each month during vegetation period (Bolortsetseg and Erdenetuya, 2004).

Pastureland is degraded, and desertification is increasing as traditional pasture management practices have been abandoned and pastures are overused without allowing adequate resting times.

As of May 2010, *dzuds* (summer drought followed by severe winter) have resulted in a total of 8,711 households losing all of their livestock and 32,756 households losing more than 50 percent of their total livestock (Statistical Book, 2011). More than 1,400 households who lost all their livestock moved to aimag and soum centers. Furthermore, this dzud caused the herders to have deteriorated health, mental stress, and be more prone to illnesses.

Materials and Methods

Natural green vegetation has become the main source for keeping and managing the sustainability of an ecosystem and for producing a healthy environment of feeding human society through hay and pasture based livestock husbandry. For pasture biomass estimation we have used both of EVI (Enhanced Vegetation Index) derived from MODIS satellite data (NASA Pathfinder source, 2000-2010) and ground pasture biomass measurements of 323 sites and air temperature and precipitation data from 1960s to 2010 of 69 meteorological stations and several of ground measurements from other sources. The biomass, air temperature and precipitation changes have been determined by linear regression analysis and for their spatial distribution used Co-kriging interpolation method with GDEM data using ArcMAP software.

Results

The climatic data analysis of 50 years showed that annual mean air temperature has been increased by 2.14 degree Celsius and annual precipitation has decreased by 7 percent (Natsagdorj, 2007). According to the meteorological site measurement data the air temperature has been increased at all sites between 0.4-2.9 degree Celsius and the annual precipitation has changed between -123.0 mm/year and +40.3 mm/year. As results of spatial distribution map showed that in northwestern part of Mongolia, the precipitation has been increased over 10 mm a year, but air temperature has increased over 2 degree Celsius. In most eastern part of Mongolia the precipitation has been decreased over 20 mm a year and up to 123 mm a year, which corresponded to areas with increasing air temperature.

Many herder families are still trying to increase their livestock numbers, even though the pasture is degraded and yields are decreasing each year. As *dzud* and *drought* become more frequent, the risk of losing livestock rises. So, with no insurance, a large herd may seem the best strategy to ensure survival. However, this is a faulty strategy, as although it may provide short-term benefits, it has long-term costs. Rangelands are already degraded, and expanding herd sizes further degrades the pasture resulting in (i) less food being available for livestock; (ii) poorer livestock health; (iii) higher death rates among livestock; (iv) less milk, meat, and wool production per head; and (v) reduced incomes for herders.

The measurement site based biomass changes were different site to site, ranging from -0.244 g/m^2 to +0.479g/m^2 over whole Mongolia (first map of Figure 1). In the central part of Mongolia, some areas with strong decrease of pasture biomass have been overlapped with precipitation decreasing areas, but not everywhere, especially in western Mongolia biomass decreased with increase of precipitation. The number of livestock of Mongolia has reached up to 51.97 million in 2014, which increased in 45.7 per cent from 1980.

As result of long term remote sensing data analysis (Erdenetuya, 2004), in high mountain regions or 31% of the country NOAA/NDVI values have increased (green color) and in all other 69% parts NDVI values have decreased (yellow color) and/or had almost no change (white color) within last 25 years (second map of Figure 1).

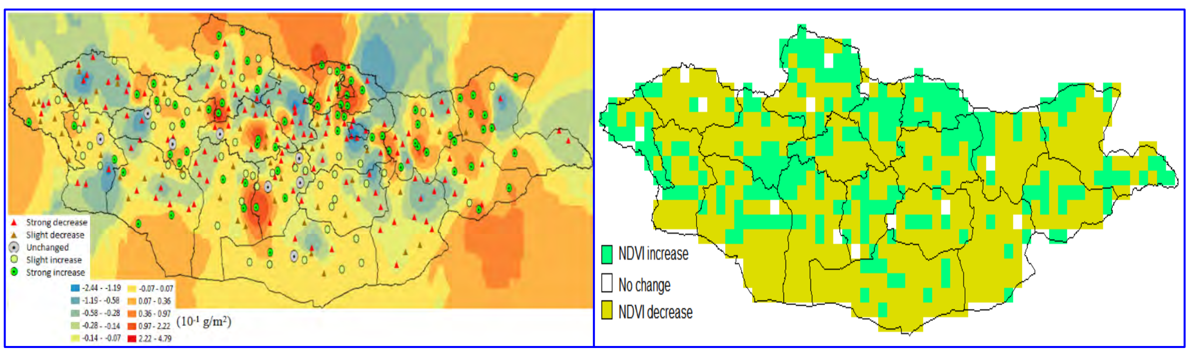

Figure 1. Biomass and NOAA/NDVI change map of Mongolia

Conclusions

During this study period in Mongolia, the air temperature rises fluctuated and warmed up by 2.14 degree Celsius, which is illustrating global change, annual precipitation varies widely and it is not obvious regularity. Researching the response of grassland community to climate change not only pays attention to common meteorological factors, such as mean air temperature, annual precipitation, but also understands extreme climate factors, such as drought, desertification. Compared to 1980s, grassland areas have dropped by 6.1 percent and mean productivity has reduced 14.7 percent and number of livestock has been increased by 45.7 percent.

Mongolian nomadic herder's living environments, health and safety are suffering unprecedented threats by the temperature increment, distribution of rain and extreme events of weather endless emergence.

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Modelling Adaptation and Mitigation Strategies for Māori Livestock Farms in Aotearoa New Zealand

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Key words: Integrated GHG modelling, collective land tenure, cultural values, Farmax Pro™, Overseer®

Introduction

This paper outlines the first stage of a research programme that investigates modelling a range of voluntary greenhouse gas (GHG) mitigation options on four case study pastoral farms that are collectively-owned by Māori groups. These four case studies are part of a network of 29 farming entities located in different regions of the country. Strategies include investment into enhanced production system technologies and land utilisation diversification with lower environmental impacts. Many of the mitigation options are adaptations of nutrient reduction strategies that New Zealand farmers are adopting in response to regulations requiring reduced nitrate leaching into freshwater water bodies. A key element of this research programme is understanding the influence of the collective land ownership system and cultural values on the choices of mitigation options as well as assessing the influence of these factors on decision-making.

Methods

A case study group of 29 Māori pastoral farming entities located in different regions of New Zealand was established in 2014 at the start of the research programme. These entities were selected on a typology matrix made up of several criteria including organisational type, farm type, size, geographic location etc. (see Kingi et al., 2016 for a more detailed description). Data from each of the 29 farms were entered into Overseer® (2014) to provide a nutrient profile including nutrient leaching (N and P) and GHG emissions (N_2O, CH_4 and CO_2). Four case study farms were selected based primarily on farm type and geographic location. To protect the identity of the farms they are labelled: Northland sheep and beef (S&B), Bay of Plenty dairy, East Coast S&B and Taranaki dairy. Emission strategies reflected a balancing of multiple objectives including impact on farm profitability (economic farm surplus - EFS) but also balanced against cultural priorities such as *kaitiakitanga* (inter-generational stewardship) and *whanaungatanga* (intra/inter tribal relationships) through *whakapapa* (genealogical links or affiliations) (Kingi et al. 2013; Kingi 2013). The four farms were modelled in Farmax Pro ™ (2010) a farm system and economic simulation model that indicates the biological feasibility of a livestock system. Carbon sequestration modelling was calculated using the Scion Radiata Calculator Pro Version 4.0. An emissions matrix or integrated model will combine the results of Overseer, Farmax and the Radiata Calculator into MyLand, a GIS spatial model. The results of the integrated model will be reported in subsequent publications.

Results and Discussion

Brief descriptions of the 4 case study farms include: 1. Northland S&B: 1,079 hectare (ha) beef finishing farm on podzols, allophanic, and ultic soils with 765 ha effective, 38 ha in production forestry, 140 ha in native bush and 136 ha in wetlands; 2. Bay of Plenty dairy: 153 ha effective on peat and pumice soils producing 135,052 kg MS (883 kgMS/ha); 3. East Coast S&B: 3,999 ha property with a mixture of sandy clay loams and silt loams with 1,941 ha effective. The farm supports 7,229 sheep stock units and 10,216 cattle stock units; 4. Taranaki dairy: 170 ha effective area on allophanic soils supporting 506 milking cows at peak producing 185,871 kg MS/ha (1,093 kg MS/ha). The results of the initial round of mitigation modelling are shown in Table 1 below.

Table 1. Scenario Modelling Results.

Scenario	% Change in GHG Emissions (from base)	% Change in Profit (from base)
Bay of Plenty (Dairy)		
Remove summer/autumn crops and replace with supplements	-3%	5%
Partial wintering facilities	-10%	1%
In-shed feeding with increased cow numbers	11%	11%
Plant 3 ha forest	-3%	-1%
Taranaki (Dairy)		
Eliminate N Fertiliser	-25%	-19%
Remove Crops	1%	7%
Plant 2ha into Trees	-3%	-1%
Zero Carbon Footprint	-100%	-28%
East Coast S&B		
Eliminate Nitrogen Fertiliser	-1.9%	-3.2%
50:50 Sheep:Beef	-2.4%	7.7%
60:40 Sheep:Beef	-3.4%	18.0%
Plant 50ha Forest	-21.3%	7.4%
Northland S&B		
Intensive Beef System	3%	20%
Plant 30 ha Forest	-66%	2%
Winter Lambs	1%	-3%
Increase Lambing %	-2%	2%

The modelling shows a general trend where a system change that resulted in a decrease in GHG emissions also decreased profitability, and similarly, a system change that resulted increased profitability resulted in an increase in GHG emissions. However, several exception were noted (shaded rows in Table) including: Removal of summer crops and replacement with supplements on the Bay of Plenty dairy; Partial wintering facilities on the Bay of Plenty dairy; Increasing the sheep:beef ratio on East Coast S&B to 50:50 and an even greater effect with a shift to 60:40; Planting of 50 ha of marginal land on East Coast S&B; Increased lambing percentage on Northland S&B; and Planting of 30 ha of marginal land in Northland S&B.

Planting marginal land into trees as a carbon sequestration strategy was not economic for dairy farms depending on the carbon price. At $6-7/tonne dairy farms are better to pay a carbon charge. If carbon prices increase significantly, converting land to trees or buying land elsewhere and planting trees as an offset becomes a more viable option. The breakeven price for carbon was $51/tonne for the Bay of Plenty dairy farm and $102/tonne for Taranaki. The situation for the two S&B farms was different. Planting an additional area of 53 ha on the Northland S&B would result in it being carbon neutral and the East Coast S&B given its current areas of production and indigenous forestry is essentially a net carbon sink. For both farms the calculated returns from forestry is greater than their current profitability, meaning that the breakeven price for carbon is effectively zero.

Conclusions

Each of the farms selected mitigation scenarios that were consistent with their business objectives and owner expectations and direct comparisons between the four case study farms were not possible.

However, there were three general observations that emerged. First, the relatively high dairy product price and low carbon price reduced the attractiveness of forestry as a viable alternative. Changes in these prices (i.e. expected decrease in milk price and an increasing carbon price) will reverse this situation. Second, a low carbon price (and potential carbon tax) was offset by capital investment into systems that increased profitability while also increasing GHG emissions. The option to pay the tax where the increase in profit exceeded the tax was the logical decision. This however, was tempered with the cultural priorities of doing the right thing to protect the environment. And third, a shift in livestock policy toward higher sheep ratios while heavily dependent on lamb/sheep prices was also boosted with increased reproductive efficiencies. Increasing forestry plantings on the S&B Farms increased profitability and significantly reduced GHG emissions.

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Rangeland Database Development for a Livestock Early Warning System in the Puna region of Peru

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Keywords: Puna, rangelands condition, sheep, forage monitoring

Introduction

The Puna region, located over 3,800 meters above sea level, covers more than 25 million ha of mountainous ecosystems across the Peruvian territory that are used mainly for grazing by 80% of the cattle and sheep, and 100% of the alpacas and llamas bred in Peru. Climate change and overgrazing impacts have increased the vulnerability of Puna herders due to land degradation. Given the increased vulnerability of herders and the need for adaptive management strategies, the objective of this work is to build a database of vegetation, soil and grazing practices data to parametrize a forage production model that will be used in the development of a livestock early warning system to reduce Puna herders' vulnerability to climate change.

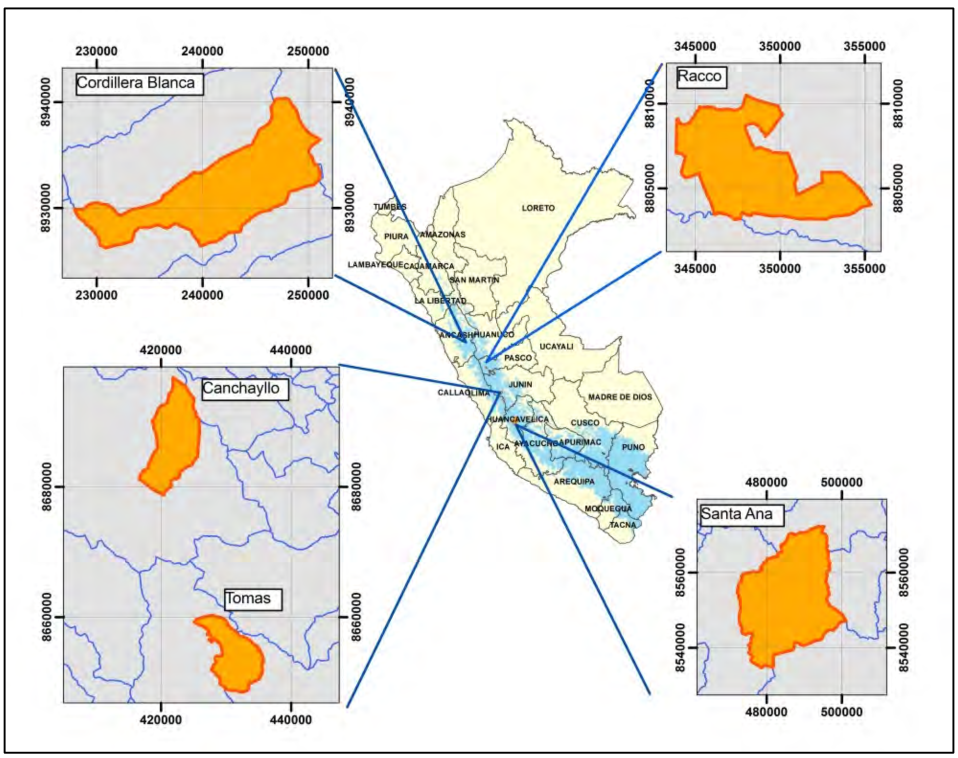

Figure 1. Monitoring sites location: Cordillera Blanca, Racco, Canchayllo, Tomas and Santa Ana

Materials and Methods

Since May 2014, 46 monitoring sites have been established in 5 provinces (18673.42 ha) in the Puna region (Figure 1). At each site, vegetation, soil, and data on grazing practices (e.g., season of use, stocking rates, and herd characteristics) were collected for input into the PHYGROW forage production model (Stuth et al. 2003). PHYGROW is unique among rangeland simulation models in that forage intake is driven by the preferences for plants for each grazer in the model, therefore allowing examination of plant species desirability by the livestock and plant community being simulated. Data were collected at monitoring sites within three vegetation types: tall grassland, short grassland and mountain wetlands (known as bofedales) and two rangeland conditions, fair and poor. Plant species were classified by functional group (grasses, pseudo grasses, forbs and short shrubs) and desirability (palatability for sheep).

Results and Discussions

A total of 149 plant species were identified and forbs were the dominant functional group (Figure 2). Short grasslands and bofedales (mountain wetlands) species composition are dominated by cushion plants and dwarf herbaceous forbs (Wilcox et al 1987). In addition, forbs in tall grassland increased as rangeland condition decreased. Biomass was higher in tall grassland and a linear relationship between biomass and rangeland condition were found in tall and short grasslands.

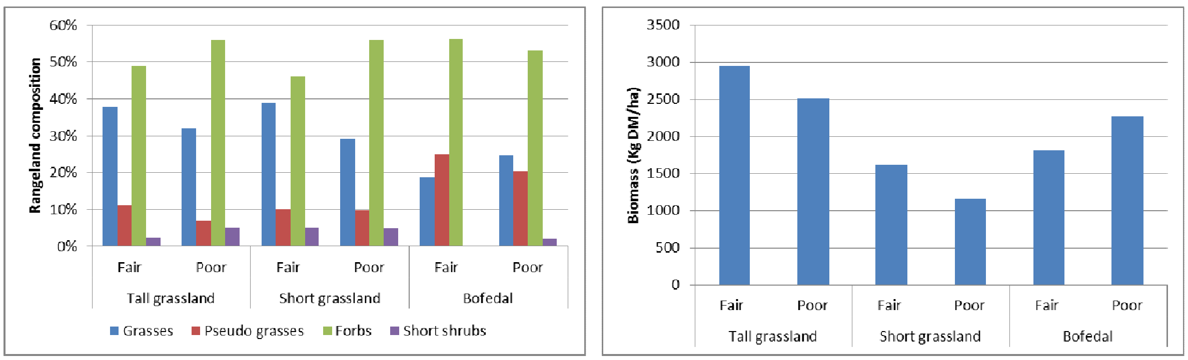

Figure 2. Rangeland composition and biomass in three vegetation types in different condition

Plant desirability for sheep grazing was higher in all vegetation types with fair rangeland condition compared to rangeland with poor condition (Table 1). Dominant forbs like *Alchemilla pinnata, Hypochoeris taraxacoides* and *Plantago tubulosa* were considered desirable for sheep in short grassland and bofedales. A mixture of grasses and forbs such as *Calamagrostis vicunarum* and *Trifolium amabile* were considered desirable for sheep in tall grasslands.

Table 1. Plant desirability (% cover of desirable and less desirable plants) for sheep grazing

Vegetation type	Rangeland condition	
	Fair	Poor
Tall grassland	47%	36%
Short grassland	40%	39%
Bofedal	47%	41%

Conclusions and Implications

Biomass and percentage of desirable species were higher in tall grasslands; therefore it is expected that the data collected will improve simulation results obtained with PHYGROW model for the Puna region by capturing the trends among different vegetation types and range conditions. This will allow more accurate forage predictions for early warning of impending drought or conditions that could lead to overgrazing.

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Does Holistic Planned Grazing Work in Rangelands? A Global Meta-Analysis

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Key words: Animal density, continuous grazing, forage utilization, Holistic Management®, ecosystem services, rotational grazing

Introduction

Holistic Management® is a framework for decision making and includes a livestock management approach now called Holistic Planned Grazing (HPG; Butterfield et al 2006). This approach advocates the moving of bunched livestock in a time-controlled manner to mimic natural herds. Claims that HPG can reverse climate change and improved forage production at double the stocking rate (Savory 2013) have been contradicted by some (e.g. Briske et al 2011; Carter et al 2014) and supported by others (Teague 2011, 2013). Considering this, and the disparity between scientific literature and practioners, a meta-analysis was conducted that compared the effects of HPG on production, soil and biodiversity with other grazing approaches on natural rangelands.

Materials and Methods

Relevant peer-reviewed literature between 1972 and 2015 that claimed a positive, neutral or negative effect of sHPG was counted and categorized according to vegetation, location, climate, and relevance to farm scale (e.g. camp size and animal density: Teague et al 2013). Means, standard deviations and derived quality indexes were extracted where possible and assessed using forest plots after analysis with the fixed- (FE), random- (RE) and quality effects (QE) models (MetaXL v. 2.2, Epigear International). Search terms comprised: *Savory grazing method OR holistic planned grazing OR holistic resource management OR short duration grazing OR multi-paddock OR cell grazing OR mob grazing* using natural language (Google Scholar, Academic Search Primer (EBSCO Host)) or Boolean operators. Several studies were obtained by 'snowballing'.

Results and Discussion

Most studies reported a neutral effect of HPG on plant production, animal production and profit compared to rotational or continuous grazing approaches. Most data sets extracted (n=103) compared HPG with continuous grazing: In agreement with other systematic reviews (Briske et al 2008; 2011; Carter et al 2014) the meta-analysis found no effect of HPG on plant basal cover or biomass (Fig. 1). At lower rainfall (Subgroup <500 mm p.a., Fig. 1) and camp sizes (<5 ha) HPG had a relatively negative effect (significant ES; $P<0.05$). Simulation models by Beukes et al (2002) have shown similar results regarding rainfall. Indeed, bunch grasses in arid areas benefit from sustained rest from livestock grazing (Carter et al 2014). The only positive agricultural effect of HPG relative to continuous grazing was an increased spatial utilization of forage (significant ES; $P<0.05$), presumably related to a reduced grazing selection when animals are bunched at relatively high densities. The latter data was based on few datasets (n = 14), most of which were simulated. Animal gain per hectare (animal gain) and gain per head (animal condition) were also neutrally affected by HPG compared to continuous grazing (non-significant ES; $P>0.05$) or negatively affected if animal densities were <5 animal units per hectare (significant ES, P<0.05). The three models were in agreement for all analyses except for animal gain where the QE model found that HPG had a neutral effect on animal production per hectare (non-significant ES; P>0.05), which is in agreement with the systematic reviews mentioned above, while the FE and RE models found a positive effect of HPG (significant ES; P<0.05).

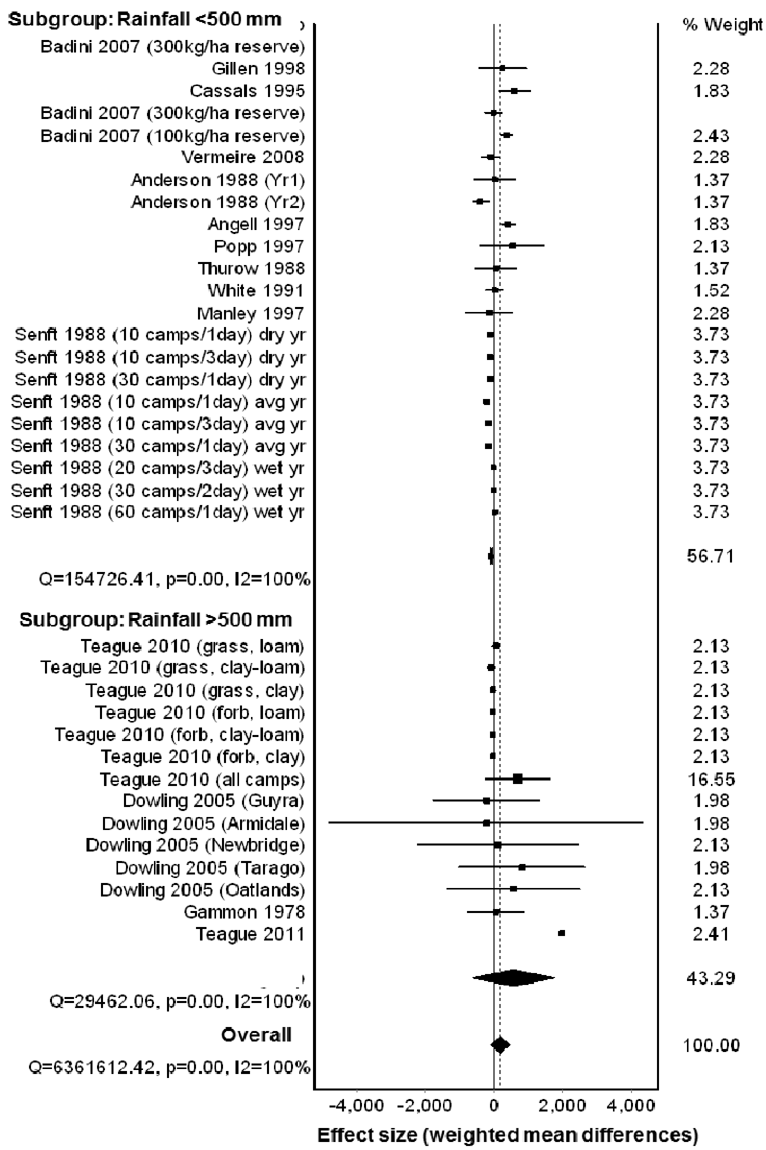

Figure 1. Forest plot of plant biomass (kg ha^{-1}) comparing Holistic Planed Grazing with continuous grazing using the Effect Size (ES) method and Quality Effects model.

Individual studies are indicated with means (■) and 95% confidence intervals (horizontal lines) while the overall effect size is indicated by a diamond (◆). The overall effect size is significant at P=0.05 where the width of the diamond (indicating 95% confidence intervals) does not cross the dashed vertical 'line of no effect'. P-values on the figures refer to the significance level of the heterogeneity index, where P<0.05 indicates significant heterogeneity (Cochrans Q and I^2) between studies.

Studies addressing the relative effect of HPG on soil characteristics, plant and animal biodiversity, soil and ecosystem services have reported both negative and positive effects but study numbers were too low to include in a meta-analysis.

Conclusions and Implications

The global literature indicates that Holistic Planned Grazing increases spatial utilization of forage, likely due to reduced selectivity by grazing animals, but that this does not appear to increase production. There is little evidence to date that HPG will increase climate resilience. Nevertheless, it is possible that HM® benefits production through increased opportunities for decision making. Very few studies take an ecosystem approach and none have considered rangeland food webs. The variability in climate and management between studies requires future studies to take a multi-factorial and predictive modelling approach to aid land user decision making.

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Foot and Mouth Disease Patterns in the Northeastern Rangelands of Kenya

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Introduction

Foot and mouth disease (FMD) is an extremely acute, highly contagious viral disease of both domesticated and wild cloven-hoofed animals characterised by fever and vesicular eruptions in the mouth, nares, muzzle, and feet and on the mammary glands. In domestic animals it is associated with productivity losses such as milk production, loss of weight and death of young stock. The disease is endemic in most countries in sub-Saharan Africa and the long term presence of the disease in the African buffalo (*Syncerus caffer*) which has been described, means that the disease cannot be eradicated in East and Southern Africa. It is an endemic disease in Kenya affecting animals such as cattle, sheep, goats, pigs, buffaloes, deer and antelopes with four serotypes currently in circulation i.e., O, A, SAT1 and SAT2. While the rest of Kenya maps show that FMD is prevalent, epidemiological maps indicate that North Eastern rangelands is free of the disease. This study was therefore carried out to determine if FMD is present in the Northern rangelands and the prevalent FMD serotypes found in the North-Eastern rangelands in Kenya.

Materials and Methods

The North Eastern rangelands in Kenya has an overall population of 2,385,572 (2009 Census), mostly of the Somali ethnic group and a land area of 126,902 km² characterized by porous borders, low rainfall (300-700mm per year) and livestock rearing in a nomadic lifestyle is the mainstay of the population. The districts surveyed from January to June 2008 in this study are shown in Fig 1. A questionnaire was administered to 47 Veterinary Officers and other service providers working in the northern rangelands Kenya to find out FMD occurrence, recognition and vaccination history. Herds with FMD outbreaks were selected and epithelial samples used to isolate the virus in tissue culture to perform ELISA testing antigen test and send to WRL, Pirbright for PCR tests. In order to detect carriers, 109 oesophageal-pharyngeal fluid samples were collected randomly in Garissa market from apparently healthy cattle of various ages using a probang. An Indirect Sandwich ELISA test was performed following standard procedures (Roeder *et. al.*, 1987).

Results and Discussion

During the study time, 3 outbreaks were encountered, one in Wajir (herd size 40) and 2 outbreaks in Mandera (170 and 90 herd sizes). All the outbreaks were in the dry seasons of the year. There were typical Foot and mouth clinical signs and signs ranged from inter-digital lesions (Fig 2), to tongue lesions (Fig 3). From these three outbreaks antigen detection by ELISA test was positive for serotype 'O' in all outbreaks and this was confirmed by the tissue culture and nucleic acid results. Characterisation revealed that the serotype was closely related to the vaccine strain produced in Kenya, K 'O' 77/78 by 99.06% on the VP1 protein responsible for infection and protection in vaccination. This means that vaccination with this strain would be effective. Currently no FMD vaccinations are carried out in the North eastern rangelands according to the questionnaires responses. Of the total animals that were sampled to check on carrier status in Garissa and Mandera, 5.5% were positive for serotype O on typing by ELISA and the same serotype O was detected from the same samples sent to WRL for confirmation by ELISA test. On PCR the carrier status was higher at 14.89%, which is expected since PCR is more sensitive. All the cattle positive cases for carrier status were adults over 3 years of age which agrees with other workers. Younger cattle eliminated the virus more efficiently than older cattle meaning that host factors (including maternal antibodies) and viral factors may be more important in establishment of persistence. In addition, lameness and vesicular lesions were observed in animals between 2-4 years old. All the outbreaks encountered occurred during the dry season of December 2008 to March 2009 which is similar to studies in Ethiopia where outbreaks were related to animal movement in search of pastures and water during the dry season (Gitao et al., 2014). In these traditional systems, goats and cattle are normally reared together thus complicating the disease epidemiology since goats are known to maintain the virus by getting infected without serious signs while cattle are the indicators of the disease. In these vast ranges, animal movement control is almost impossible and illegal movements of animals is rampant. Veterinary support services are scant and ill equipped to manage the situation which is made worse by conservative traditional cultures.

Four of the districts in the North Eastern rangelands including Mandera, Wajir, Garissa and Ijara border Somalia to the west and the border are porous with frequent border passage of people and livestock. There has been no surveillance of FMD in Somalia since 1991 due to state failure. However, in 2010 out of six epithelial samples submitted from different parts of the Afmadow district Lower Juba region in Somalia, three (50%) were positive for type O indicating the presence of type O across the border (Jabra and Hassan, 2010). Cattle movement from one place to another, sometimes involving the crossing of international borders, has been a long tradition and is considered as an indispensable activity in the daily life of people in the region. This is exacerbated by insecurity and lack of statehood in Somalia.

Figure 1. Districts surveyed (Labeled).

Figure 2. Inter-digital hoof lesions.

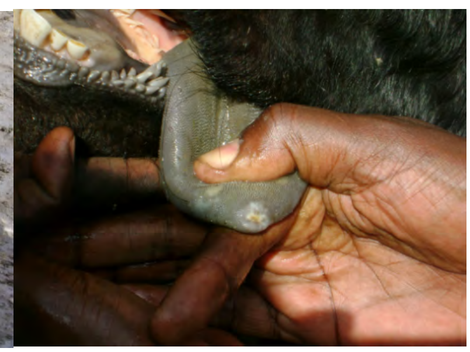

Figure 3. Tongue healed lesions.

Conclusions and Implications

Surveillance of trans-boundary diseases like FMD should be a priority matter when Somali is stabilized. An effective foot and mouth disease control strategy that may be developed for the region when security improves may therefore involve vaccination that will include type 'O'.

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Isotopic Signatures of Vegetation Change on Northern Mixed-Grass Prairie

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Key words: Long-term pastures, Kentucky bluegrass, invasive species, soil carbon, soil nitrogen

Introduction

National analyses have shown invasion of northern mixed-grass prairie by nonnative grasses such as Kentucky bluegrass (*Poa pratensis* L.). Invasion of native prairie by nonnative grasses may compromise ecosystem function and limit potential ecosystem services. Recent data from a long-term (100 year) grazing experiment near Mandan, ND have shown aggressive invasion of native prairie by bluegrass regardless of grazing intensity (Sanderson et al, 2015). We hypothesized that bluegrass invasion should have altered the ^{13}C and ^{15}N levels in the soil (less negative δ^{13}C in early years associated with greater native warm-season grass abundance) of the long-term pastures tracking the increased abundance of invasive cool-season grass aboveground. We analyzed archived soils from 1991 and new samples collected in 2014 for ^{13}C and ^{15}N to test the hypothesis.

Materials and Methods

Two pastures that have been grazed since 1916 at either a low [0.98 animal unit months (AUM) ha^{-1}] or a high stocking rate (2.4 AUM ha^{-1}) were sampled at the Northern Great Plains Research Laboratory near Mandan, ND (46°46’12’N, -100°55’59’W). Soils are a blend of Temvik and Wilton silt loams (Fine-silty, mixed, superactive, frigid Typic and Pachic Haplustolls). In 2014, soil samples were collected at 20 random sites per pasture and at six sites in an exclosure in the low stocking rate pasture. Four soil cores were collected at each site to depths of 0 to 7.6 and 7.6 to15.2 cm. Soil from each depth was composited across cores, dried at 35°C, hand sieved to pass a 2 mm sieve (to remove plant material), then ground on a roller mill to pass a 0.106 mm sieve. Subsamples were weighed into 5 x 9-mm tin capsules according to a calculated target weight. Samples were analyzed for total C and N and ^{13}C and ^{15}N isotopes with a continuous- flow stable isotope ratio mass spectrometer (Europa Scientific Integra) by the Stable Isotope Facility at the University of California-Davis. Carbon isotope ratios were expressed relative to the Pee Dee belemnite standard as a delta- value (δ) in parts per thousand (‰). Soils collected in 2014 were compared against archived samples taken at the same depths (and sampling regime) in 1991 (Frank et al., 1995).

Results and Discussion

During the 1990s, there was a major change from blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Griffiths; a C_4 grass) to dominance by the C_3 grass Kentucky bluegrass in the lightly stocked pasture (Table 1). In the heavily stocked pasture, dominance by bluegrass did not occur until the early 2000s (Sanderson et al., 2015). The change in vegetation was accompanied by a change in the isotopic composition of soil C. The soil δ^{13}C at both 0 to 7.6 and 7.6 to15.2 cm depths became more negative between 1991 and 2014 ($P< 0.05$, Table 2) as hypothesized. Soil δ^{13}C became less negative and δ^{15}N increased ($P< 0.05$) with increasing stocking rate at both soil depths. Soil C levels in the surface 7.6 cm increased ($P< 0.05$) an average of 35% (1.2 g C kg^{-1}) from 1991 to 2014; however, subsurface levels did not change ($P> 0.01$, Table 3). Similarly, soil N in the surface 7.6 cm increased ($P<0.05$) an average of 27% (0.09 g N kg^{-1}) from 1991 to 2014 and subsurface levels did not change ($P>0.01$).

Table 1. Changes in the relative foliar cover of blue grama and Kentucky bluegrass in two long-term pastures [stocking rates of 0.98 and 2.40 animal unit months (AUM) ha^{-1}] at Mandan, ND.

Stocking rate	Species	1964	1984	1994	2004	2014
AUM ha^{-1}		------Relative foliar cover (%)-----				
0.98	Blue grama	64	23	16	3	14
	Kentucky bluegrass	0	0	29	64	63
2.40	Blue grama	100	79	86	40	16
	Kentucky bluegrass	0	0	0	30	74

[1]Data for 1964, 1984, and 1994 are from Frank et al. (1995). Data for 2004 and 2014 are unpublished.

Table 2. Changes in soil $\delta^{13}C$ and $\delta^{15}N$ from 1991 to 2014 in two long-term pastures [stocking rates of 0.98 and 2.40 animal unit months (AUM) ha^{-1}] and an exclosure (no grazing) at Mandan, ND.

	$\delta^{13}C$				$\delta^{15}N$			
Grazing	0-7.6 cm depth		7.6-15.2 cm depth		0-7.6 cm		7.6-15.2 cm	
intensity	1991	2014	1991	2014	1991	2014	1991	2014
AUM ha^{-1}	------------------------------------‰------------------------------------							
No grazing	-22.83	-24.48*[1]	-20.86	-21.26*	4.25	2.88*	6.60	6.74
0.98	-21.08	-22.82*	-19.25	-20.47*	5.01	3.84*	7.30	6.71
2.40	-19.98	-21.64*	-19.22	-19.94*	5.12	4.40*	7.20	6.99
Standard error	0.25	0.25	0.26	0.26	0.16	0.16	0.15	0.15
Effect[2]	L	L	L	L	NS	L	Q	L

[1]*=indicates means differ (P<0.05) between years. [2]Grazing intensity effect, L=linear, Q=quadratic, NS=not significant (P>0.05)

Table 3. Changes in soil C and N from 1991 to 2014 in two long-term pastures [stocking rates of 0.98 and 2.40 animal unit months (AUM) ha^{-1}] and an exclosure (no grazing) at Mandan, ND.

	Soil C				Soil N			
Grazing	0-7.6 cm		7.6-15.2 cm		0-7.6 cm		7.6-15.2 cm	
intensity	1991	2014	1991	2014	1991	2014	1991	2014
AUM ha^{-1}	---------------------------------g kg^{-1}---------------------------------							
No grazing	35.0	46.7*[1]	23.0	22.5	3.2	4.2	2.2	2.2
0.98	33.2	43.6*	23.0	24.4	3.1	3.7	2.3	2.3
2.40	33.7	47.7*	24.5	28.0	3.1	4.1	2.4	2.6
Standard error	2.0	2.0	1.6	1.6	0.15	0.12	0.12	0.12
Effect[2]	Q	NS	NS	L	NS	NS	NS	L

[1]*=indicates means differ (P<0.05) between years. [2]Grazing intensity effect, L=linear, Q=quadratic, NS=not significant (P>0.05).

Conclusions and Implications

Vegetation in long-term (100 years) pastures changed dramatically during the last 25 years from predominantly C_4 grass to an introduced C_3 grass. Corresponding changes occurred in soil C and N that may have long-term effects on nutrient cycling.

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They Know — Let's Ask Them: Climate Change Variability and Household Adoption Strategies in Ghana's Rangeland

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Keywords: Climate change, Ghana, livelihood, pastoralism and rangeland

Introduction

Pastoralism is major source of livelihood for millions of people in rural Africa especially those in the savanna regions (Pye-Smith, 2012). The future of pastoralism and rangelands cannot be discussed without the mention of climate change. Global climate change, expressed in terms of increased temperature and shifts in patterns of precipitation, is a new challenge to the world of pastoralism. The consequences of climate changes such as increased temperature and intense drought conditions would likely lead to scarcity of pasture and water resources. The impact of climate change and variability on Ghana's pastoral rangelands can lead to drastic poverty as well as triggering severe resource competition and violent conflicts among pastoralist communities. Birch and Grahn (2007) indicated that pastoral adaptations and climate-induced innovative coping mechanisms are strategically embedded in the indigenous social structures and resource management value systems.

In Ghana, there is a critical gap of more systematic inquiry into the nature and economic impacts of adaptation practices and the challenges of local responses to climate change. Therefore, a critical and systematic appraisal of current individual adaptive behavior and public response in pastoral areas is essentially justifiable for policies to be designed and appropriate innovative practices promoted in those communities.

Objective of the study

The objective of the study was to analyze individual household adaptation behavior and impacts of embraced adaptation measures on pastoral production and rangelands in the Gushiegu District in the Northern Region of Ghana.

Methodology of the study

The adopted approach in this research included a review of related literature, field visit, data collection and analysis. A total of 200 households were randomly selected from five villages within the district for enumeration. A unique recall interview technique was used to acquire information on the adjustment mechanism to climate-induced changes, climate-induced shock survival in terms of experienced climatic risk exposure and sustained wealth losses.

This study used logistic regression model to analyze the data. The model was specified as:

$$Z_i = Log\{P_i/(1-P_i)\} = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + u \quad ………………… \quad \text{Equation 1}$$

Where: $i = 1, 2, 3 ...., k$ are the observations, α = constant. β = the regression parameter to be estimated. βX = linear combination of independent variables. Z_i = the log odds of choice for the *ith* observation. P_i = the probability of observing a specific outcome of the dependent variable (adoption). X_n = the nth explanatory observation. u= the error term.

Results

Results indicate, 98% of respondents perceived that the average temperature in the area had increased in the last decade. About 95% of the respondents interviewed further indicated that local rainfalls had decreased in the last decade. The study identified that the respondents have varying number of adaptive strategies and choices in traditional pastoralism, which includes increased mobility, more adoption of drought-tolerant livestock species, and resort to increase production and purchase of hay, and use of private rangelands. About 74% of respondents indicated that the growing strains of climate-induced difficulties have pressed them to increase their mobility in terms of distance and frequency. This suggests that increased mobility has significant food security implication. The estimated results generally indicate that the likelihood of pastoral household adoption of the selected major adaptation options is significantly influenced by age, gender, wealth status, degree of pastoral household shock resilience, and climatic variables. Increased mobility significantly decreases with age. That is younger pastoral households move around the rangelands in the event of climatic risks than the older generations. Male pastoral household heads are more likely to increase mobility as a survival strategy than females. There is positive relationship between mobility and annual rainfall conditions the study area. Institutional support mechanisms such as rural credit access and regular extension visits appear to have positive effect on pastoral household choice of the selected adaptation measures.

Conclusion and Implications

This study examines household climate adaptation strategies and their implied impacts on pastoral production in Ghana rangelands. Trends in climate variability in the last decade correspond with pastoralists' perception of climate change in the district. Government's policies on pastoral mobility must ensure sustainability in this naturally susceptible environment so as to achieve sustainable livelihoods for pastoralist in Ghana. Offering of commercially-oriented skill training and related rigorous capacity building assistance at the household level would go a long way to help pastoralists.

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Plant Species Composition Change in South Gobi Region of Mongolia

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Key words: Mongolian rangeland, monitoring, succession, similarity index, time series analysis

Introduction

A general consensus has developed among herders, government officials, donor institutions, and the public that Mongolian rangeland is degrading from a combination of overuse, especially livestock grazing, and weather events related to climate change. Although empirical evidence of the extent, degree, and nature of rangeland degradation is limited, there is growing evidence that it is occurring. Rangelands in the Dry Steppe ecozone are considered to be especially susceptible to climate change induced degradation because of highly variable annual precipitation. Three provinces comprise the South Gobi Region (**SGR**). Omnigov province and the southern two-thirds of Dornogov province are in the Desert ecozone. Dundgov province and the northern one-third of Dornogov province are in the Dry Steppe ecological zone (Sheehy et al., 2012). The SGR was selected for our study because: i) it is a zone of intersection between Desert and Grass Steppe ecosystems, ii) many national and international development projects are established in the region, especially mining and infrastructure development, iii) both the 2000/01 and 2009/10 severe winters severely affected the region, and iv) the region is reported as becoming increasingly arid as climate change occurs.

Materials and Methods

In 2011, we re-measured vegetation and soil attributes at 25 rangeland monitoring sites in the SGR along a north-south transect established in 2005 (Sheehy et al., 2012). Frequency, forage yield, and landscape attributes were used to describe above ground characteristics, and soil profiles were used to describe surface and below ground characteristics. Details of research techniques are described by Damiran et al. (2008) and Sheehy et al. (2012). In this paper, we use frequency and similarity index (**SI**) analysis (Morisita, 1959) to evaluate changes in plant species composition at monitoring sites as an indicator of change throughout the region.

Results and Discussions

Comparison of plant species found at monitoring sites in the SGR indicated a significant change in composition occurred between 2005 and 2011. In 2005, two-hundred and five plant species were encountered across monitoring sites. Graminoids, forbs and shrubs comprised 30, 40, and 30%, respectively, of plant species composition. Twenty-six of the plant species present in 2005 were not present in 2011. In 2011, one-hundred and eight plant species were encountered at monitoring sites. Graminoids, forbs, and shrubs comprised 27, 45, and 28%, respectively, of total plant species composition. Nineteen of the plant species present in 2011 were not present when sites were measured in 2005. Seventy-five percent of the sites in Dornogov province had high to moderately-high change in total species composition (SI = 0-0.3) (Data not shown). Sites in Dundgov province had a 57% change in species composition. The least affected by a change in species composition was Omnigov province where only 28.6% of sites were significantly affected by change in species composition.

Overall composition of vegetation (Table 1) at monitoring sites in Omnigov province had the highest Similarity Index (SI) of 0.51 while Dornogov province vegetation composition had the least SI (0.20). Dundgov province had intermediate similarity in vegetation composition (32%). Graminoid composition had least similarity (SI = 0.14 and 0.08, respectively) at monitoring sites in Omnigov and Dornogov provinces. Forb composition was least similar in Dornogov province (0.14 vs. 0.54 in Omnigov province and 0.38 in Dundgov province). Shrub composition was least similar in Dundgov province.

Table 1. Similarity index of plant species measured in 2005 and 2011 in the three South Gobi Region province of Mongolia.

	Province				
Item	**Omnigov**	**Dundgov**	**Dornogov**	**SEM**	***P*-value**
Graminoid	0.14	0.33	0.08	0.118	0.28
Forb	0.54	0.38	0.14	0.123	0.07
Shrub	0.34	0.14	0.27	0.128	0.58
Total Species	0.51	0.32	0.20	0.086	0.08

Sheehy et al. (2012) found that during the 12-yr interval between 1999 and 2010, the peak amount of annual cumulative rainfall occurring in the SGR increased between 1999 and 2003 in the Desert ecozone but declined in the Steppe zone. In the latter zone, cumulative rainfall decreased in 2001 and 2002, which corresponded with the drought and severe winters that occurred during that time. Between 2003 and 2005, cumulative rainfall in both Desert and Steppe ecological zones declined to a 12-year low, and remained low between 2005 and 2007. Beginning in 2007, cumulative rainfall again trended higher.

Our measurement of monitoring sites in 2005 and 2011 coincided with the beginning of extended drought during summer and with cold winters. Although the cold winter of 2009 killed millions of livestock in the SGR, high grazing pressure during the extended drought prior to livestock die-off severely affected resilience of plant species during this period. Although a one-year drought may not reduce the resilience of diverse ecological sites, a multi-year drought across ecozones that is not accompanied by reductions in large herbivore stocking rates will almost certainly have a negative impact on ecological condition of vegetation communities in the different ecozones.

Conclusion

Plant species throughout the South Gobi Region of Mongolia were severely stressed (or changed) by drought, severe winters, and overuse by livestock between 2005 and 2011.

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Climate Change Adaptation Strategies by Pastoralists along an Aridity Gradient in Southern Africa

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Key words. Climate change, adaptation, southern Africa, pastoralism

Introduction

Climate change has had negative consequences for farmers around the world over the last few decades (Mudombi, 2014). As a result, they have to provide external inputs to survive unfavorable climatic conditions and maintain their current levels of production. Pastoralists in southern Africa are resource poor and rely heavily on natural resources to provide sufficient water and forage for their livestock (Shackleton et al., 2000). In southern Africa, pastoralists receive little extension support and services and thus have to use their agro-ecological knowledge and limited resources to adapt to changing climatic conditions and increase their level of resilience (Mmbengwa, 2015). This paper assesses the challenges pastoralists encounter during climatic stresses and how they adapt in order to increase their level of resilience by using examples from South Africa and Namibia.

Materials and Methods

A qualitative research approach was adopted whereby focus group discussions were held with relevant stakeholders in seven pastoral areas to gain an understanding of livestock husbandry in the region and to develop leading questions for individual in-depth interviews with pastoralists. Arid and semi-arid pastoral systems along the aridity gradient from northern Namibia to South Africa that were studied are Sesfontein, Otjimbingwe, Ovitoto, Gibeon, Warmbad, Steinkopf and Leliefontein.

Results and Discussion

Pastoralists are experiencing a range of challenges during adverse climatic conditions and thus use several adaptation strategies. The largest threat to their livestock is a lack of forage especially during drought. They have thus developed 27 different adaptations to overcome their forage constraints. Pastoralists also experience challenges of extreme hot conditions and cold snaps following a drought, loss of income due to increased livestock mortality, uncertain environmental conditions and poor animal health.

To overcome the periodic lack of forage, pastoralists respond largely by adapting their grazing management during drought. Pastoralists in all study areas use herd mobility to either access key resources areas such as rivers, wetlands and mountains or outmigration onto private or other communal lands which they lease or are allowed to use free of charge. Night grazing due to high temperatures occurs only in cattle held areas in northern Namibia. Pastoralists also provide animals with supplementary fodder which they grow or purchase it using income from livestock sales or their social grants or salaries if they are employed in other sectors. They also collect leaves and pods from trees or grasses and shrubs which are inaccessible to livestock or allow their animals to graze in their home gardens during drought.

Due to the unfamiliar climatic and environmental conditions brought about by phenomena such as El Nino, pastoralists seek knowledge on how to mitigate drought impacts by attending workshops, engage in knowledge exchange between farmers, access media communications or engage with local agricultural extension services. Some also access drought relief schemes and agricultural loans when it is available to them.

Pastoralists also have long term adaptation strategies through diversifying their income streams in other agricultural activities such as pasture production or non-agricultural related activities such as tuck shops or save money for these bad times. They constantly change their herd composition, adapt their breeding seasons, and bring in new genetic materials that are more drought tolerant.

Pastoralists within similar climates use similar adaptation strategies because they will keep the same type of livestock and manage their animals based on their local agro-ecological conditions. Apart from climate, adopting a specific strategy could also be due to the cultural and political history of the area. Pastoralists in the South African sites were known to be and still are highly mobile although they practice mobility differently (Samuels et al. 2008) whereas due to colonial history, pastoralist in Namibia were confined to small grazing areas or farms with higher stocking densities, making it difficult to move with cattle that require larger areas.

Conclusions and Implications

Although pastoralists along the aridity gradient use largely different strategies across different temporal and spatial scales to adapt to changes in their rangeland, they are confronted with similar stressors. There is no indication that pastoralists have adopted new strategies as a result of climate change, thus we perceive that changes have not been too drastic to develop new strategies or it could be that the current strategies (of which mobility is a core factor) are flexible enough that it could be used under quite different and even harsher conditions. Thus policy development should be built on the foundation of their current adaptation strategies in order to build a climate resilient pastoral community.

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Economic Impacts of Increased Seasonal Precipitation Variation on Cow/Calf Producers

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Key words: Precipitation variation, cow/calf production, economics, forage, climate change

Introduction

The dependence of cattle production on forage production, which in turn, is dependent on amount and timing of precipitation, makes climate change a threat to the stability of the cattle industry. Changes in weather variability and the occurrence of extreme weather events coupled with cattle price cycle dynamics creates issues for cattle producers through positive and negative impacts on location, timing, and productivity of cattle production systems. Without proactive management during increased weather variation, cattle producers may be forced to destock herd numbers in order to accommodate lower levels of forage production in drought years. For cow/calf operations, it is optimal to destock during drought years and restock very slowly through heifer retention or purchase of breeding stock during favorable weather years. Increasing frequency and severity of drought will likely make managing for drought more difficult and could result in destocking decisions made during unfavorable price levels.

The objective of this paper is to determine how increasing variation in seasonal precipitation impacts cow/calf ranch viability.

Materials and Methods

A multi-period linear programming model is used to determine optimal management strategies for a representative cow/calf operation. The model was developed as part of a regional effort and has been widely used and adapted for federal land policy impact analysis, evaluation of management strategies, grazing management assessments, and wildfire impact analysis (Torell et al. 2013). The model has been parameterized to represent common cow/calf enterprises in southeast Wyoming. Using historical data from the USDA High Plains Grasslands Research Station near Cheyenne, WY, peak standing forage production and calf weight gain over the summer grazing season (approximately 125 days) are independently modeled as hyperbolic functions of total early growing season (April, May and June) precipitation. We simulate climate change by increasing the annual variation of this seasonal precipitation around the historic mean in 10% increments up to a 50% increase. The model is solved for actual historical (30 yr) precipitation patterns as well as the simulated altered precipitation patterns to determine the optimal managerial response and economic outcomes as inter-annual seasonal precipitation variation is increased. In order to account for cattle price cycle dynamics, the model is solved over 100 iterations that include varying annual cattle prices.

Results and Discussion

The hyperbolic relationship between both forage production and calf performance and growing season precipitation results in forage production and calf gain estimates that are negatively skewed with increasing precipitation variation. While mean forage production does not statistically significantly change, the minimum annual forage production over our planning horizon decreases by a larger amount than the maximum forage production increases. Likewise, mean weaning weights show no statistically significant change across simulated precipitation scenarios, while the minimum decreases by large amounts, and the maximum shows little to no change. Results show the optimal response to increasing annual precipitation variation is for cow/calf producers to reduce average herd numbers, by nearly 40% when the annual variation in early growing season precipitation is increased by 50%. Under this scenario, net discounted returns are reduced by 27% on average, and variability increases as shown by an increase in the coefficient of variation for discounted net returns. Further, the likelihood of any given year having a negative return increases from 14% under historical precipitation to over 31% when variation is increased by 50%. In order for the case operation to remain in business over the 35-year planning horizon, additional sources of revenue are required on an annual basis. The minimum amount of off-ranch income required is increased as seasonal precipitation variation is increased.

Conclusion and Implications

These results suggest that cow/calf producers are extremely vulnerable to any climatic changes that result in increased annual precipitation variation. Given the production lag from retaining heifers until the time she bears a calf, producers have a difficult time matching herd demand to changes in annual forage production. Our model suggests that an optimal strategy is to lower stocking in all years in order to forgo the costs of destocking and restocking in order to fully utilize forage production in every year. Even if mean precipitation stays constant as in our model, wider swings in wet and dry cycles makes carrying a large herd through the dry years extremely costly. This strategy of lowering stocking, however, requires additional sources of income in order to account for the decreased profitability of the cow/calf enterprise. There may be some opportunities for cow/calf producers to diversify and utilize yearlings as a flexible strategy to utilize forage production in favorable years, while holding a lower, more constant number of cows that are sustainable in the majority of years. Yearling enterprises are not constrained by the production lag facing cow/calf enterprises, and are therefore better suited to flexible stocking in response to annual forage production. For example, previous work by Ritten et al. (2010) has shown that optimal stocking rate and per-acre returns are reduced by only 20% when facing more drastic climate predictions for the same study area (an increase in seasonal precipitation variation of 100%). Therefore, adding a yearling enterprise may be a viable option to help cow/calf producers cope with any increase in growing season precipitation variation.

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Capturing Climate Change Knowledge of Pastoralists in Semi-Arid Rangelands of South Africa

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Key words: Livestock farmers, knowledge transfer, communal farming, adaptation

Introduction

Communal livestock farming is still globally regarded as one of the most ancient farming systems that are being practised by rural households in large parts of Africa. Regardless of South Africa being a dry country, approximately 70 % of South African farmers live in dry rangelands and rely on livestock farming as a means of livelihood (Mapiye *et al*., 2009). Despite facing various social, biological, economic, political and management challenges, these resource poor farmers have shown resilience. However, climate change is threating this resilience.With the projected increases in temperatures and rainfall variability, the climate change impacts that farmers in the dry regions of South Africa are experiencing are set to intensify. Thus there is a need to know how people understand and perceive the climate change in order to adapt to its impacts (Prokopy *et al*., 2015). The aim of this study was to assess the understanding of communal pastoralist's knowledge on climate change and to assess where this knowledge is derived from for adaptation purposes.

Methods and Materials

Two Nama-khoi descendent communities namely, Leliefontein and Steinkopf communal areas in Northern Cape, South Africa served as the study sites. A case study approach, with triangulation of focus group discussions and semi-structured interviews were used. The focus group discussion was aimed at drawing up a seasonal calendar, where 10 livestock farmers from Leliefontein participated and 14 from Steinkopf. The aim of the seasonal calendar was to obtain information on the farmers' perceived impacts of climate change during different seasons, and their use of local knowledge in making decisions for adaptation. Focus group discussions were followed by in-depth semi-structured interviews, where a set of theme related questions were used to stimulate the conversation with the farmers. Examples of questions asked were: *are you familiar with the term climate change? What does it mean to you? Where have you come to learn about climate change? How do shifts in seasons, and/or rainfall affect the environment and your livestock?* A total of 20 farmers from Leliefontein and 21 from Steinkopf were interviewed in Afrikaans. All interviews were translated to English and analysed using ATLAS.ti. The analysis included grouping respondents' answers according to pre-thought themes and new emerging themes.

Results and Discussion

Despite various other studies highlighting the lack of awareness and understanding of climate change among communal farmers, this study found that the majority of Leliefontein and Steinkopf farmers were aware of the term. 90 % of farmers in Steinkopf and 55 % of Leliefontein farmers had basic understanding of the term. Most of the farmers interviewed referred to climate change as "seasonal shifts" that they have been experiencing. One of the farmers stated that,

> "*Climate change is when there are weather changes, where the weather varies from the norm either in a day or during seasons. This variation is in temperature and rainfall.* "
>
> –Leliefontein farmer

The science community refers to climate change as long-term changes in the state of the climate, which is identified by changes in the means and variability, or changes in the frequencies or intensities of extreme events (IPCC, 2007). Both local farmers and the scientific explanations of climate change focus on climate variability over time. Scientists often prefer the term climate change for technical reasons, but should be aware that the term generates different interpretations among the general public and specific subgroups such as farmers.

Livestock farming is a tradition that is passed on from generation to generation for both communities. All respondents indicated that a large portion of their knowledge originates from intergenerational knowledge transfer. Oteros-Rozas *et al*. (2013) argues that the preservation of traditional ecological knowledge ensures the continuation of transhumance, which is a mobility strategy consisting of regular seasonal migration of livestock between summer and winter pastures for grazing productivity peaks. Due to both communities' long history of transhumance movement, their local knowledge is firmly embedded in the farmers experiences and observations (Ghorbani *et al*., 2013). Other sources of knowledge in the two study areas included media, workshops and meeting attendance. Media plays an important role in informing farmers about climate change as it increases potential for adaptation.

Conclusions and Implications

Despite the common narrative that communal farmers are not aware of the term climate change, this research highlights thatthe farmers' reference to 'seasonal shifts', captures the widely accepted definition on climate change. This knowledge has been preserved through the ancient pastoralist practice of transhumance. Apart from intergeneration knowledge transfer, media sources contributed to the farmers' understanding of climate change. This basic but, wealthy knowledge informs farmers of potential climate change impacts and informs adaptation strategies to be undertaken.

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A Resilience-Based Management System for Mongolian Rangelands

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Background

Although Mongolia's economy is expanding and diversifying, rangelands continue to be a dominant land use and source of livelihood. Rangeland management, however, changed dramatically with the transition from socialism to a free-market economy. Prior to 1990, both land and animals were publically owned. Management was closely controlled via cooperatives, including the number and type of animals, who herded them, and where they grazed throughout the year. After 1990, livestock were privatized but land continued to be owned by the state. Concurrently, the institutions responsible for livestock management and herder support dissolved and no new policies for rangeland management were established. Private ownership of livestock, economic incentives, and lack of regulation led to dramatic increases in livestock numbers at a national level. The lack of management of animal numbers and grazing periods underpins widespread reports of rangeland degradation across Mongolia, from both researchers and from herders themselves. The loss of rangeland productivity, in conjunction with regional aridification and loss of surface water sources associated with climate change portends the potential collapse of Mongolia's rangeland social-ecological systems.

A Resilience-Based Management System for Mongolian Rangelands

In response to these challenges, Mongolia sought to develop a RBM system for rangelands, with support from an international donor organization (the Green Gold Program) supported by the Swiss Agency for Development and Cooperation. The term "resilience" denotes the goal of managing and restoring rangeland vegetation, soils, and animal health such that herder livelihoods can persist in the face of environmental variability. The RBM strategy involves knowledge and information sharing, planning, and monitoring activities supported by herder's customary organizations and local and national governments (Fig. 1).

Assessment and management are centered on herder's collective rangeland management organizations that have been organized into Pasture User's Groups (PUGs). PUGs consist of the herders who have traditionally used a particular territory and who have been allocated the exclusive right to manage its rangeland. PUGs are nested within administrative units called *baghs* (municipal subdistricts) and *soums* (districts) that develop participatory plans with multiple PUGs. Representatives of national government agencies work at the soum level to provide PUGs and local governments with monitoring information, estimates of vegetation biomass as a basis for stocking rate adjustments, maps, and support of assessment and management strategies via state and transition models.

Twenty-five state and transition models were developed that are specific to distinct soil-landform units (ecological sites) within ecoregions, largely corresponding to pasture types recognized by herders. Each model describes alternative states, indicators of vegetation change processes, and management interpretations for specific ecological site classes. Relatively healthy rangeland conditions featuring high productivity and the presence of desirable plant species for the site class are used as a reference for rangeland assessment. Different states call for different management recommendations.

The primary policy tool for rangeland restoration is the "rangeland use agreement" between PUGs and local government. Via these agreements, herders are encouraged to reduce stocking rates by ca. 5-8% annually. Such gradual reductions are not expected to limit annual income when old and unproductive animals are removed. Family groups pay a small voluntary grazing fee, 300 Mongolian tugrik (0.15 USD) per sheep unit, into a common disaster risk fund. These contributions are matched by local government and invested in rangeland management or disaster relief which provides a strong incentive to herders for participation in agreements.

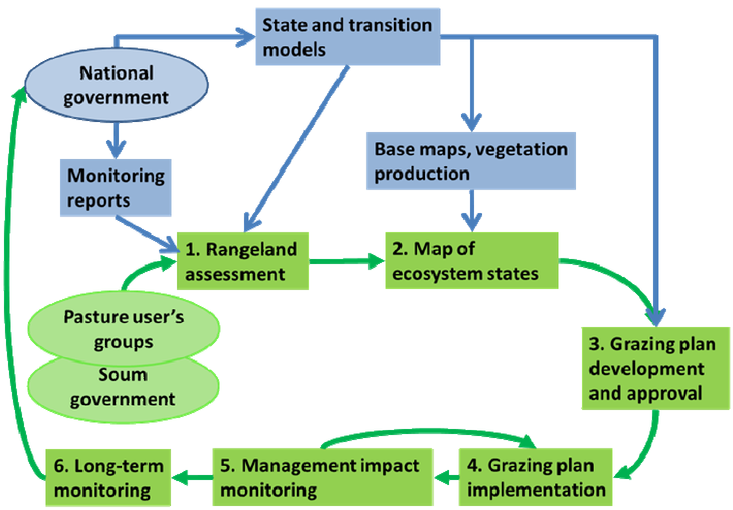

Figure 1. Steps in the resilience-based management approach. Green boxes and arrows indicate activities occurring at the local level (soum and pasture user's group, green ovals) and blue boxes/arrows indicate support from the national government.

Stocking rate and management recommendations developed as part of rangeland use agreements begin with rangeland quality assessments. National government technicians and PUGs use state and transition models to evaluate pasture areas within each PUG (step 1; Fig. 1). Longer-term monitoring trends are also considered in this step, via monitoring sites across the country that were established during the socialist era. Based on the assessment, government technicians work with PUGs to produce of a map of ecosystem states that provide a spatially-explicit representation of management needs (step 2). Using the map and state and transition models, yearly grazing plans can be developed by PUGs and local government, including stocking rates, seasonal use schedules for herder families, and other restoration actions (step 3). Plans are implemented over the subsequent grazing year (step 4). Short-term impacts of management (e.g., bare ground cover, forage utilization) are monitored using digital photographs and observations of pasture use by national government staff located in soums and used to adjust or enforce management plans adaptively (step 5 and loop). Long-term monitoring data are delivered to national offices and trends are reported to soum government and the national public (step 6). New information about ecosystem change can be used to update state and transition models periodically. Each of the steps described above addresses the general RBM principles.

The use of rangeland use agreements as tools for management change has only recently been implemented, so the long-term effectiveness of the RBM approach is unknown. Nonetheless, our success in establishing a nationwide RBM system highlights several strategies that may be useful in other settings.

We have found that collaboratively developed state and transition models are invaluable tools for the clear specification of environmental problems and their particular solutions at local to national levels. In addition, state and transition models will be used to identify environmental quality targets, including standards for branding of sustainable or "natural grassland based" livestock products, potentially commanding a 10-20 % price premium on the international market.

Alongside state and transition models, monitoring methods also facilitate a precise linkage between national-scale trends and local management responses.

Without significant donor support, it is unlikely that international scientific expertise, government agency workflows and policy, and herder's organizations would have been linked effectively.

Strategies for Genetic Improvement of Cattle in the North Patagonian Rangelands

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Key words: North Patagonian, cattle, genetic improvement

Introduction

Foot and mouth disease (FMD) has generated growing concerns to producers from the 1960s to the present because of the direct economic losses, as well as problems arising from international export trade. Since 1970, Argentina has been divided into zones with a different health status of FMD. Until 2013 a zone free of the disease with vaccination (North Patagonia A) acted as a protection area for the free zone without vaccination (the rest of Patagonia).

The zoophyte-sanitary barrier was moved to the Colorado river (Resolution 141/2013 of the Ministry of Agriculture, Livestock and Fisheries) and vaccination against the disease is no longer required in the valleys in Rio Negro province, part of Neuquén and the partido of Patagones in the southern tip of Buenos Aires province (North Patagonia Zone A).

Cattle ranching in the region began around 60-70 years ago replacing the sheep, but the first genetically improved cattle breeding came much later. Determining the impact of moving the health barrier to the Colorado River is a challenge for practitioners and livestock producers in the area. The new sanitary status of freedom from FMD without vaccination prevents the introduction of live animals to the buffer zone. This makes the challenge greater as it is necessary to produce meat products from different species to supply the population of Northern Patagonia reaching new markets FMD-free for better prices (Lascano and Boya, 2006, Pecker, 2007). Therefore, the objective of this study was to determine the strategies used by farmers to provide genetically improved animals. While the cattle in the region arises around 60-70 years replacing the sheep, the first genetically improved cattle come much later. To determine the impact of the shift of health barrier to the Colorado River is a challenge for practitioners and livestock producers in the area. The new sanitary status of free of FMD without vaccination prevents access of live animals to the buffer zone. This makes a greater challenge because it is necessary to produce meat products from different species to supply the population of Northern Patagonia reaching new FMD-free markets for better prices (Lascano and Boya, 2006, Pecker, 2007). Therefore, the objective of this study was to determine the strategies used by farmers to provide genetically improved animals to enhance cattle breeding in the grasslands of Northern Patagonia.

Materials and Methods

Interviews were carried out on all (sixteen) the regional farms dedicated to cattle genetic improvement to collect qualitative and quantitative data (Lhoste, 2001) in order to identify and understand the strategies and practices of used by cattle breeders for genetic improvement. The study area includes the plateau and valleys of Rio Negro province, in North Patagonia.

Results

The first cattle breeders settled in the area in the early 90s. Most of them started between 2000 and 2009, ranging from producers of a few bulls a year to those with large numbers of animals. The results of the interviews showed that most establishments produce bulls to be sold at regional shows or directly to livestock producers. In a few cases they also sell sperm or embryos. Very few cows are sold as they are used for replacement. The number of bulls sold per year ranges from 3-170 depending on the size of the stud farms. Aberdeen Angus is the most popular breed followed by Polled Hereford. Only one establishment is starting to breed Limangus.

Genetic improvement by artificial insemination is common in most establishments. Moreover, even though embryo transfer is a technique that is costly and requires trained professionals in the field, many breeders plan to use this method in the short or medium term.

Discussion

Given that the sanitary barrier banned the entry of live animals from the north of the country, it was thought that breeder sales would increase significantly. This did not happen because the cattle breeders bought new stock before the change in 2013, as well as a decrease resulting from the drought that hit during 2007-2009, in many cases reaching 50% fewer animals. Farmers are in a process of retaining cows, so delaying the genetic improvement process. An equally important factor is the existence of fattening to corral with a special category called young uncastrated male, of which some animals are selected for breeding because of their phenotypic characteristics. Finally, there is a percentage of producers who use their own replacement bulls leaving calves born in the field as future parents. Some improvements are displayed in the price and number of animals sold during the 2015 Rural Exhibitions.

Conclusions

The breeder producers have not yet perceived any changes in the demand for bulls and in some cases sales were difficult or only equal to the previous year. It is expected that an improvement in the breeder market will be seen three years after the change in the animal health status of this zone. Some improvements are displayed in the price and number of animals sold during the 2015 Rural Exhibitions.

The breeder producers use artificial insemination and embryo transfer as strategies to incorporate genetic material from other regions and thus provide the local market with high-quality reproductive animals well adapted to the environment.

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Drought and Animal Health Status Impacts on Cattle Rangeland Management in North Patagonia, Argentina

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Key words: Patagonia, drought, cattle rangeland management, animal health status

Introduction

In Argentina, two phenomena appear to have had an impact on livestock. Firstly, the expansion of agriculture (particularly soya) has pushed breeding activity from the humid Pampa to semi-arid areas like northern Patagonia. Secondly, a severe drought in North Patagonia between 2007 and 2012 required cattle breeders to seek new strategies to save animals from starving. Due to the decreased offer of forage, the number of cattle North Patagonia was reduced by half. In 2013, a change in the sanitary status of the area between the *Río Negro* and the *Río Colorado* absolved this livestock region from vaccinating their animals against foot and mouth disease (FMD). This area acts as a *buffer zone* against the transmission of the FMD virus to the rest of Patagonia that is free from FMD and, at present, has particular restrictions on the movement of animals from vaccinating regions.

However, this restrained entrance of animals and meat with bone created meat supply problems in this *buffer zone.* The aims are to become self-sufficient in beef but there is a lack of calves due to drought and the breeders are not accustomed to complete the growth cycle in the region. Prices of beef rose and this incentivized the search for new practices to increase efficiency. Calf producers in the plateau not only have to rebuild their livestock after the drought but they also have to supply sufficient calves for the calf feeding systems that arise in the area to provide meat for consumers.

Cattle grazing in North Patagonia is based almost entirely on natural vegetation. Continuous grazing and the periodic occurrence of severe droughts appear to modify the vegetation and induce the degradation of the spontaneous forage resources. It is normal to find very large paddocks continuously grazed by more animals than the feed capacity. However recently, some cattle ranchers are introducing some reproductive management changes and rotational grazing methods that are improving production standards.

Objective of the study

To analyze the adaptations implemented in cattle management in response to the drought and changes in the animal health status and to evaluate the results of the different strategies in a system approach.

Materials and Methods

Study site

The study area is located between the towns of Choele Choel and Rio Colorado and includes the plateau territory and the Rio Negro valley. The climate is cold temperate semi-arid to arid. The average temperature ranges from 6°C in July to 23°C in January. The average annual precipitation is 303 mm, falling mostly during spring (September) and autumn (March), but in 2002 and 2011, the rain deficit was 33% (INTA, 2000). Vegetation on the plateau is a xeric *Monte* characterized by a shrubby steppe with tussock grasses (Fernández *et al*., 1989).

Methodology

The farming system diagnosis was complemented by a zootechnical and economic analysis to evaluate performances (Landais *et al.*, 1987). Interviews were realized with 29 cattle farmers, using open inquests to collect qualitative and quantitative data, which represented 30% of the farmers in the plateau and about 50% of the surface area.

Results and Discussion

In the plateau area, there are two types of cattle breeding management, one "traditional" and one "technified". The "traditional" management consists of leaving the animals in a large field with a permanent stocking rate and only removing weaned calves for sale or for fattening in the valley zone. On the other hand, the "technified" management consists of seasonal breeding, with pregnancy diagnosis and venereal disease control, and divided grazing with animal rotation and a better water point distribution. In the "technified" management, early weaning was used during the drought, to liberate the cows earlier and thus try to save more of them.

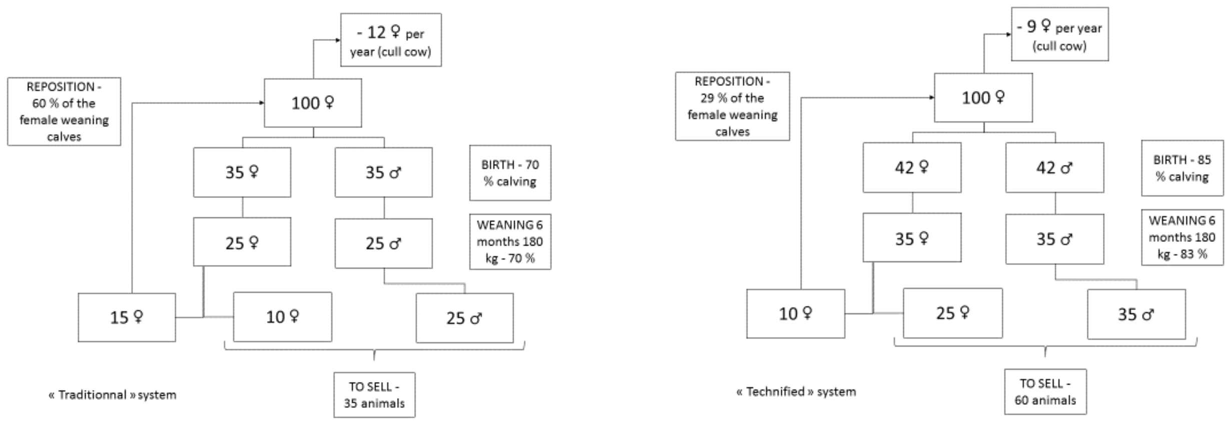

Figure 1. Productive performances of the "traditional" and "technified" managements (Leuret, 2015).

At the productive level (figure 1), the "technified" management, that lost less animals with the drought, allowed the farmer to achieve better production levels, and thus to sell a higher percentage of animals. Using the farmer equation (Le Masson A., 2003), we found that the "traditional" type has a herd increase of a 3% per year, whereas the "technified" type is about 1%. This is because the "traditional" type is still recovering from the drought and trying to reach the former number of animals, using a higher percentage of reposition. A large number of the farmers continue their system with a feed-lot in the valley area to complete the production chain.

Conclusions and Implications

More intensive management implies better production levels, and increased prices after the change in the animal health status allowing better incomes for the "technified" farmers.

The drought is a cyclic phenomenon in North Patagonia. Cattle rangeland management improvement, such as that being implemented by an increasing number of breeders, will surely enable them to face the next one better.

A rise in prices of animals in the region also resulted in expansion of the "technified" system and a tendency to complete the production cycle by the same farmers who produced weaned calves.

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Avoided Clearing of Vegetation: A New Business in Australia's Rangeland

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Key words: Carbon sequestration, semi-arid, woodlands, grazing, Australia

Introduction

Shrub management is essential for the sustainability of pastoral businesses in Australia's eastern semi-arid woodlands, and elsewhere in global rangelands. In the 1860's vegetation here was continuous grass and scattered trees and shrubs. Displacement of Aboriginal people and their "firestick farming", and overgrazing by recently introduced domestic livestock, rapidly changed the vegetation to annual forbs and shrub dominance. Peacock (1900), the first scientist in these lands, described this change as the "entire absence of grasses or herbage amongst the dense growth of injurious scrub upon the red lands, which fifteen years ago were open forest, well-grassed country". Research, much later, developed prescribed fire to reduce shrubs (Hodgkinson and Harrington, 1985) and aerial application of Glyphosate, which when applied in autumn after a fire the previous year, significantly increases the proportion of shrubs killed (Noble et al., 2005). Pastoralists incorporated shrub managements into their natural resource management property plans (sought by Government) but low commodity prices and limited access to capital commonly constrains implementation.

In 2015 the Australian Government introduced a scheme whereby pastoral businesses could "reverse-auction" the carbon in vegetation that would have been cleared for cropping or grazing (see http://www.environment.gov.au/climate-change/emissions-reduction-fund/methods/). The scheme contributes to meeting Australia's international obligation for C emission reduction but is in conflict with accepted range management for improving forage production. We discuss this conflict based on a grazing study and explore implications for long-term sustainability of businesses and natural values.

Materials and Methods

Ten sites bounded by latitudes 26 & 32°S and longitudes 143 & 147°E were selected in 1996 as representing shrub densities and managements in the region. Three treatments were established at each site; ungrazed (control), tactical (an experimental grazing management) and continuous (common practice) grazing. Treatments were adjacent and 3000 m^2 in area. Sheep, feral goats and kangaroos commonly grazed. Periodically, taut tapes were laid down slopes along three parallel 100 m transects 7.5 m apart in each treatment. Distances from 20 points 5m apart along each transect to the nearest shrub plant and the distance from each plant to its nearest neighbour were determined. Shrub densities were estimated from the distances using a technique that corrected for their wide distribution, i.e. for patchiness in the treatment areas.

Results and Discussion

Shrub density changed at all sites typified by the four sites shown in Figure 1. The greatest change took place at "Alice Downs" where shrubs were mechanically cleared in 1995. The other sites shown were not cleared, but showed similar responses. In all sites the continuous grazing treatment reduced shrub density and hence potential biomass.

Browsing by herbivores will be a major risk where Government payment is dependent on pastoralists maintaining the quantity of 'shrub' biomass. Most shrub species in these woodlands are of low palatability but herbivores, such as goats, are capable of heavy browsing. Similarly wildfires (difficult to control in these landscapes) would significantly reduce shrub density and biomass.
Payments made from this scheme (estimated to be $673M to about 130 pastoral businesses) provide unprecedented capital to some pastoralists. If this capital is used to remove large herbivores from land where clearing is avoided then it may be possible to achieve a sustainable outcome for pastoral businesses. There is evidence that grass will increase episodically under shrubs 'locked up" by the scheme if large herbivores are removed.

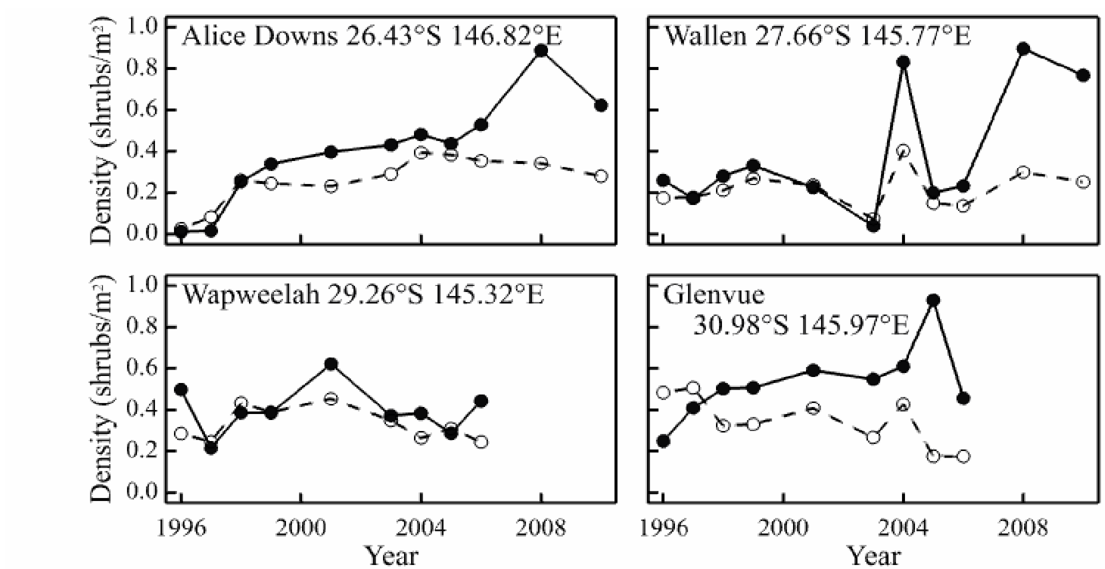

Figure 1. Effect of continuous grazing (broken lines, open symbols) and no grazing (solid lines and symbols) on shrub density at four sites.

Conclusions and Implications

Conflict between 'best practice' shrub management and the new business begun by Australia's Federal Government, may be reconciled if there is investment in removal of all large herbivores from land in the avoided clearing scheme. Given the large payments to pastoral businesses for involvement in this scheme it should also be possible for capital to be used both to acquire further land to maintain profitability of businesses and to eliminate large herbivores from shrub dominated land.

The scheme has been criticised on grounds that pastoralists would not have managed shrubs anyhow because of the high capital needed (Burke, 2016). Certainly shrub management can be limited by lack of sufficient capital but the injection of unprecedented capital to some pastoral businesses through the avoided clearing scheme should encourage innovation to manage the natural resource in new ways that enhance economic viability of pastoral businesses and natural values in these woodlands.

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Simulated Results of Grazing Effects on Soil Organic Carbon (SOC) in Mongolian Rangelands

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Key words: Grasslands, carbon accumulation, Century Model, ecosystem modeling

Introduction

Mongolia's total number of livestock has steeply increased from 25 million in 1990 to 56 million by the end of 2015 (National Statistics Office, 2015). Located in an arid/semi-arid zone, Mongolian grasslands are sensitive to climate change impacts. The objective of this study was to characterize the responses of SOC stocks to changing grazing pressures and assess the size of the accumulated SOC in degraded Mongolian steppe. It allows improved management of grasslands and introducing better grazing practices, which is essential to developing climate change adaptation strategy in Mongolia.

Materials and Methods

We conducted a field survey in Tariat soum, Arkhangai aimag during the summers (July and August) of 2011–2012. We sampled 618 sites scattered across the study area (Fig. 1), including 285 in mountain meadow (MM), 86 in riparian meadow and marsh (MWM), 208 in riparian meadow (RM) and 39 in mountain steppe (MS). At each site, a typical quadrat of 0.5x0.5 m2 was randomly selected. Within the selected quadrat, all plants were harvested to measure aboveground biomass. Then we collected three soil cores using a 5-cm corer from 0-20 cm depth. Bulk density samples were obtained using a standard container of 100 cm3 in volume, and weighed after being oven dried at 105 _C for 24 h. Soil samples were sieved (2 mm), air- dried and ground to a powder. SOC of ground soil samples were determined by combustion in a TOC analyzer after phosphoric acid treatment to remove carbonates.

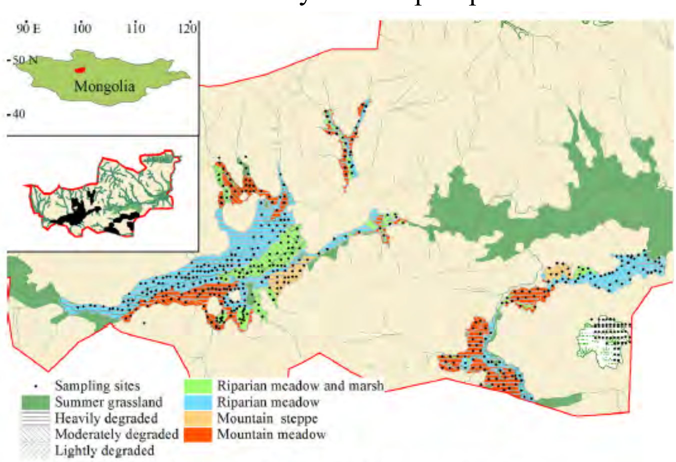

Fig. 1. Distribution of sampling sites and study area in Mongolia.

Figure 1. Study areas of Tariat soum, Arkhangai aimag, Mongolia.

Century is an ecosystem model that simulates biogeochemical fluxes on a monthly time step (Alister K. Metherell, et al, 1993). To represent the long history of grazing on Mongolian rangelands, we simulated an equilibrium period for 5000 years with a perennial grass system under moderate grazing (50% of live shoots removed by grazing event per month) in summer (June–October). From 1990 to 2012, the model was run with higher removal of plant production by heavy grazing. The modeled biomass removal rates for degraded rangeland strata during this period were 80%, which was determined on the basis of an inventory of livestock herds and grazing patterns among households using rangelands in the study area. The climatic data used in the Century model consisted of monthly precipitation, monthly maximum and minimum air temperature provided by Tariat meteorology station, location of which allows collection of data from different types of rangeland. Once the model calculations are optimized, we assessed carbon dynamics according to the different grazing scenarios. Grazing management scenarios for the degraded rangelands were projected: 50% biomass removal for non-degraded rangelands, 45% for lightly degraded, 40% for moderately degraded and 35% for heavily degraded rangelands. The timing of grazing events simulated in the summer grasslands followed local common practice, with grazing beginning on June 1 and ending on October 31 of each year modeled. A 23 years (2012–2035) spin-up was applied on the basis of average historical climate data.

Results and Discussion

Our field inventory revealed that variations of plant and soil variables were significantly across a gradient of degradation (Table 1). Aboveground biomass generally decreased as degradation increased. SOC stock decreased markedly with degradation. SOC in lightly degraded MM rangelands were 18.7% lower than that in non-degraded rangelands. The SOC further declined by about 20% and 50% in moderately and heavily degraded rangelands, respectively.

Table 1. Mean SOC stocks (0–20 cm) and plant biomass for forest steppe rangelands at different degrees of degradation.

	RM			MM			MS	
	L	M	H	L	M	H	M	H
SOC(g kg^{-1})	10.21	15.75	9.02	25.49	14.83	10.62	13.72	5.46
Aboveground biomass(g m^{-2})	121.33	114.44	111.98	—	154.59	1114.23	112.17	87.76
Belowground biomass(g cm^{-2})	1382.05	1457.50	1313.51	—	1600.29	1456.27	1396.53	1671.40

RM: riparian meadow; MM: mountain meadow; MS: mountain steppe; L: lightly, M: moderately, H: heavy degradation)

The model predicted a marked decrease in SOC stock in the period of high grazing intensity (1990–2012). The modeled SOC stocks corresponded well with measured values (Fig. 2; Table 1). Although grazing scenarios were set for each rangeland stratum on the basis of estimated biomass removal rates, reducing grazing intensity on the forest steppe rangelands showed substantial carbon accumulation potential, except for a marginal gain in nondegraded MM Fig. 2).

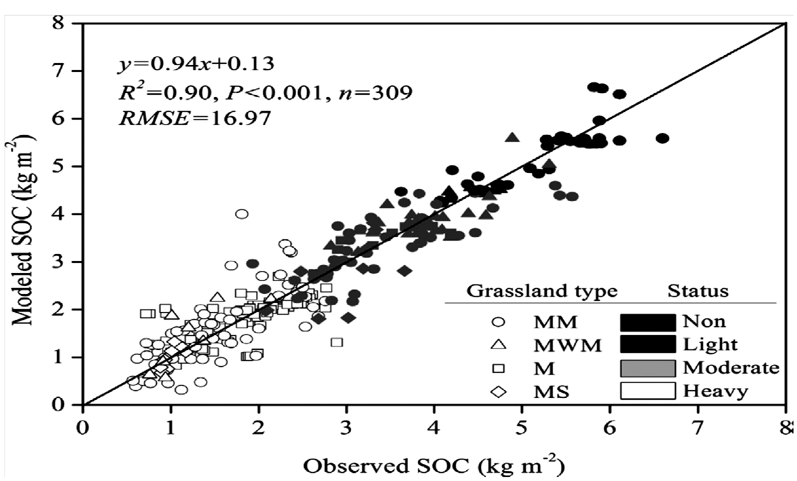

Figure 2. Comparison observed and modeled soil organic carbon (SOC) for non-degraded, light, moderate and heavy degraded forest steppe grassland soils on the Tariat soum. MM-mountain meadow; MWM-riparian meadow with mash; RM-riparian meadow; MS-mountain steppe.

Conclusions and Implications

This study assessed the impacts of rangeland management on SOC stocks using a modeling approach combined with a geospatial inventory dataset. Our results demonstrate that reduction in grazing intensity may provide a near term (by 2035) solution for Mongolian rangeland that have experienced soil carbon loss from intensive grazing managements and due to climate change effects. This study verified that rangeland SOC can be estimated accurately by Century model.

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Effect of Climatic Anomalies on the Productivity of a Modified Rangeland in the Flooding Pampa, Argentina

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Key words: Climate change, rainfall, range, productivity, livestock.

Introduction

Vast areas of rangelands in the world are undergoing fluctuating changes in their climatic variables. These changes occur in periods ranging from one or a few years to decades. Within this regional climate behavior Global Change could promote abnormalities such as extreme weather events or increased variability in weather patterns (Thornton. et al, 2009). Argentina's Flooding Pampa is an 8 million hectare area with an annual average rainfall of around 900 mm and has historically had series of years characterized by flooding or drought, interspersed with years of "normal" condition in which the contribution of rainfall is optimal for livestock activities (Scarpati & Capriolo, 2013). Beef breeding cattle is the main production system developed on 70% of its rangelands, which are typically continuously graze with low stocking rate and animal productivity (0.61 AU/ha and 70 kg meat/ha). In this context, Universidad Nacional de La Plata (UNLP) conducts studies to increase the physical efficiency of this system. Mesophytic rangelands (C3 and C4 vegetation) of the region can be modified with herbicides to promote high forage value species for feeding beef cattle on a more efficient rearing system. This system is effective under normal weather conditions (Agnelli et al, 2013) but cannot achieve its purpose under climate anomalies. The aim of this paper is to describe the impact of such anomalies on modified rangeland productivity.

Materials and Methods

UNLP's farm (57º07`W 35 º01`S, Vieytes) in the Flooding Pampa is where a series of experiments with rearing heifers for early mating (13/15 months old) are developed**.** Weaning of these animals is between March and April and the rearing period from May to October, after which early mating begins. For this, heifers must have reached 2/3 of their adult body weight (260 kg in A Angus frame 3). This rearing system is developed on a modified mesophytic rangeland by the use of glyphosate or 2.4D or 2.4DB, in order to increase the presence of *Lollium multiflorum*, *Bromus catharticus*, *Bromus mollis Gudinia fragilis* and *Lotus tenuis*. Grazing is carried out continuously with a Low Stocking Rate (LSR) of 3.1 and a High Stocking Rate (HSR) of 4.3 animals / hectares. Between 2007 and 2012 five grazing experiments took place under the LSR and HSR treatments. Every 14 days animal body weight (ABW, kg) with electronic scale and total herbage biomass (THB, kg DM/ha) through cuts were measured; and every 28 days rangeland net accumulation rate (NAR, kg DM/ha.day) was calculated using mobile exclusion cages. Groups of 6 heifers were placed in experimental units arranged in random blocks with three replications. Their only feed was the modified rangeland. Daily rainfall was record.

Results and Discussion

During three (2007, 2010, and 2011) of the five years study weather conditions reproduced normal climatic characteristics. 2012, a year with a normal total rainfall, showed significant temporal anomalies and in 2008 the area experienced the most intense drought in 50 years (Fig. 1).

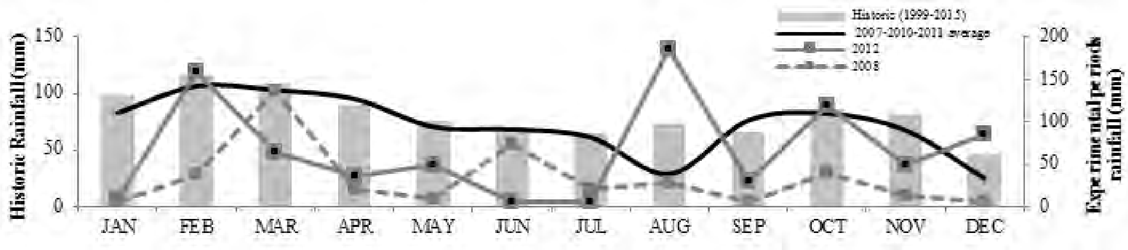

Figure 1. UNLP farm historic rainfall vs. rainfall during experimental periods.

Vegetation growth rate was affected by variation in rainfall (Fig. 2 a). In periods of "normal" weather conditions NAR was able to sustain animal's forage demand and maintained THB levels of 1629±283.16 kg DM/ha average under both stocking rates (Fig. 2 b). The anomalous rainfall distribution of 2012 distorted NAR amount and distribution and negatively affected THB (1010±305 kg DM/ha). During the extreme 2008 drought NAR showed the lowest rates of the studied period, and the accumulation observed in the THB of October (1577 kg DM/ha) was due to the absence of grazing since July (Fig. 2b).

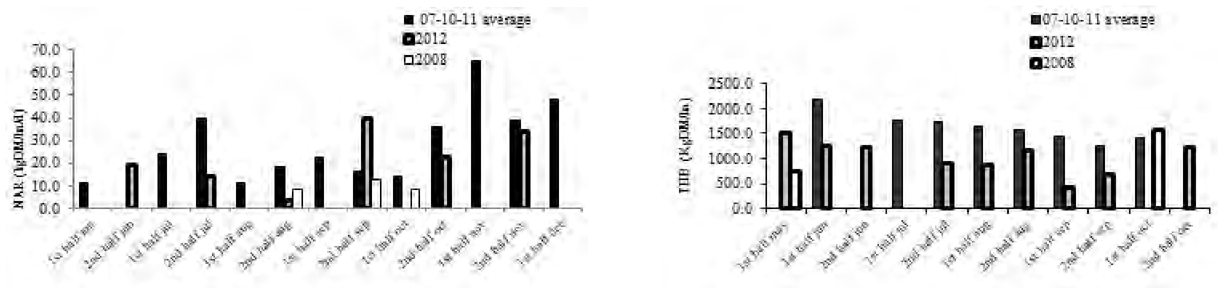

Figure 2. a) Net Accumulation Rate (NAR). b) Total Herbage Biomass (THB).

On the other hand, the rearing heifers growth in "normal" years shows a sequence of stages: initially a weight gain associated with the production of autumn forage, then a stagnancy period during cold and dry winter and finally a high weight gain during early spring (Fig. 3). This behavior was affected in 2012, where the initial growth stage stopped early, followed by stagnation with oscillations observed until the end of the experiment. In 2008, after a brief period of high body weight losses, animals had to be brought into a confined rearing system to receive supplemental feed.

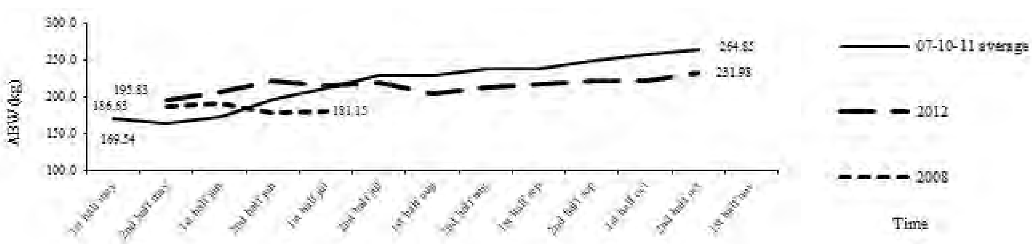

Figure 3. Animal Body Weight (AWB).

This intensive grazing rearing system reached its target on average in 57% of heifers in HSR and 81% in LSR in 2007, 2010 and 2011, while in 2012 only 13% in HSR and 33% in LSR achieved these target. During 2008 0% of both treatments reached 2/3 of their adult body weight.

Conclusions and Implications

In normal rainfall years, rangeland NAR allowed sustained rearing system, with a high stocking rate and stable values of THB. In climatically anomalous years, the NAR was affected to such an extent the system could not produce the necessary THB to achieve rearing system objectives. Climate anomalies as those seen in 2012 and 2008 could become more frequent due to global climate change, increasing the occurrence of negative results in rangelands productivity, as observed in this work.

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Regional Co-Design and Co-Production of Research and Management Actions to Support Climate Change Adaptation Strategies for Managing Natural Resources in the Northern Great Plains

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Key words: Ecosystem services, rural communities, changing climate, Great Plains

Introduction

The Northern Great Plains (NGP) region plays a very important role in providing water and land resources and habitat for wildlife and livestock, crops, energy production, and other critical ecosystem services to support rural livelihoods (Ojima et al 2015). The semi-arid conditions of the region and the tight coupling of livelihood enterprises with ecosystem services in the region creates a situation of increased sensitivity to climate changes and enhanced vulnerability among the rural communities and Native American nations across the region. Recurrent drought conditions across the region have differential impacts on ecosystem services and natural resource management targets.

The changing climate and social-economic situations across the NGP have further challenged current land and water management practices (Shafer et al 2014). Recent research and assessment efforts of current climate stresses have indicated that changing seasonality, impacts of extreme events (e.g., droughts, floods, ice storms), and warming trends on ecosystem services across the region have increased the vulnerability of communities and sectors in the region. Strategies for how resource managers and the research community can better collaborate and to more effectively co–design and co-produce efforts to understand and to respond to these challenges are needed.

Materials and Methods

The Missouri River basin in the central U.S. has been designated by the USGS to be supported by the North Central Climate Science Center (Morisette 2012). Analysis of climate data sets across the region has been conducted and impacts on ecosystems and rural livelihoods carried out in the recent assessment of U.S. Great Plains for the U.S. National Climate Assessment (Ojima et al 2015). Further research based on interviews with natural resource managers, development of a joint USGS/USDA stakeholder advisory committee, ecosystem model analysis, and remote sensing studies have provided a basis for co-designing research and management planning activities across the region. The effort described here deals with the drought response efforts across sectors and ecosystems in the region and is being conducted as a joint effort with USDA Northern Plains Regional Climate Hub and resource managers in the region.

Results and Discussion

The NGP has been undergoing a combination of trends associated with changing climate throughout the region, including areas facing drought in the western and southern portions of the region (Ojima et al 2015). These climatic exposures (e.g., reduced precipitation, increased warming, and changes in the seasonal patterns of soil moisture recharge and retention) have increased the vulnerability of various communities and ecosystem services in the region, especially among the rural and tribal communities.

Research efforts have been undertaken to include stakeholder input from various natural resource management communities to improve the information and focus of the climate science and social-ecological impact and response research communities. The co-design efforts are leading to improvements in forecasting information and technologies, linkages to field observations and ground truthing of instrument data, remote sensing data sets and interpretations, and modelling results across the region. The co-design effort is structured to improve the management to researcher interface and to enhance the knowledge exchange between these communities.

A series of social-ecological system interviews have been conducted to evaluate and understand response mechanisms of various natural resource managers to drought stress. These analyses provide greater insight to the range of coping and adaptation choices to make under various levels of adaptive capacity. Institutional responses to climate change are often best suited for mitigation of emergency situations and isolated events, rather than for slower onset, cumulative or systemic climate-related problems leading to disruption of ecosystem services. Institutional and regulatory entities are even less well-suited to working with underlying social factors that determine vulnerability.

Conclusions and Implications

How we discern and reconcile different social-ecological controlling variables of commodities or ecosystem services exchanged within different system components are not well understood. In addition, how decisions on choices of trade-offs are not well formulated to evaluate feedback in the social-ecological systems. Yet, society needs to address these issues to meet these challenges and to engage in a more informed dialogue in order to formulate options and strategies that will manage changes occurring to natural resources and affecting social-ecological systems. This confluence of research and needs for management actions calls for greater integration of social science and natural research efforts, as well as renewed engagement between research and decision making communities.

Joint activities between the USGS and the USDA provide a platform for enhanced stakeholder dialogue, engagement on resource management issues and the co-design and co-production of research activities to support stakeholder and manager concerns more effectively. These efforts are leading to improved “climate-smart” research-management partnerships and the implementation of improved activities to reduce climate sensitivity and risk, and increase resiliency to climate variability and change. Development of a joint platform to serve as a resource to regional efforts have been established to provide better information to management entities across the region on climate dynamics, impacts of climate changes, vulnerability and risk assessments. These efforts are leading to the development of strategies to better coordinate among local, state, federal, and tribal agencies, to provide a more comprehensive information portal where managers and decision makers can readily find scientific information, including analysis of impacts and consequences to guide development of specific strategies to cope with a changing climate.

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Use of Socio-Economic Indicators in Ecosystem Services of Natural Grassland of Pampa Biome in Southern Brazil

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Key words: Grasslands, ecosystem services, payment for ecosystem services, livestock

Introduction

Sustainable management of ecosystem services in grasslands constitutes as tool of mitigation and adaptation to climate change issues (Secretariat of the Convention on Biological Diversity, 2014). Payment for Ecosystem Services (PES) is a public policy aiming to stimulate farmers to preserve natural resources and environment in many parts of the world. To create PES schemes, clear and objective indicators of Ecosystem Services (ES) coming from grasslands are needed (Tejeiro and Stanton, 2014)., Through funding from the Alliance for the Grasslands (www.alianzadelpastizal.org), BirdLife International promotes sustainable livestock management in Southern America. This project studied properties in the Pampa biome certified through the Grasslands Conservation Index (GCI), created to measure their productivity and environmental conservation capacity. The CGI index does not only indicate the conservation values, but also the productive capacity of the grassland, in the hope of having a positive impact on rural development. The objective of this project was to assess the validity of the GCI and other indicators for future application of PSE policies in natural grasslands in the Pampa biome.

Material and Methods

Two properties in Lavras do Sul, State of Rio Grande do Sul, Brazil, were selected for this study; a preserved natural grassland (P) and a natural grassland in recuperation (R). Soil management practices in P includes mowing, stocking rate adjustment and exclusion of areas aiming to increase seed bank in the soil. In R, the evaluation was made following two years of rest from wheat and corn grain production, with soil traditional cultivation and without fertilization. In each property there were three transects in following the relief: top, middle and lower. In each of them, nine samples were taken. Samples collection was made on January 8, 2015. Soil Organic Carbon and soil stored C from the 0-20 cm layer was calculated according to Embrapa (1997). On each transect, percentage of covered soil was visually evaluated. The GCI was calculated by the following formula: GCI= (native field percentage x vegetal coverage index x species with forage value) x (property agro diversity x ecological system value). This socio-economic indicator looks at what is happening in the surrounding countryside; finally, it takes into account if ranches' grasslands are embedded in an Area of Special Ecological Value (ASEV), as declared by the government or the conservationist community, or if they are part of a zone where grasslands are being replaced actively and extensively. The formula indicators were transformed into a 0 to 10 scale, where more is better. Forage biomass value was estimated accepting that 2,300 kg ha^{-1} is 10. This level of dry matter is considered the best to achieve a moderate grazing intensity in natural grassland at Pampa biome. A C percentage of 5% was considered as 10 in the scale from 0 to 10. The monetary value of C stock used the maximum value of C from CO (6.3 g.cm2) versus the mean density multiplied by the voluntary marked value ($4.8) was considered a 10.

Result and Discussion

The present study considered some useful indicators to assess natural grassland's sustainability potential. Figure 1 shows sustainability tendency of two properties with different state of preservation. An increment in the value of the indicator implies a higher sustainability (Fernández and Woodhouse, 2008).

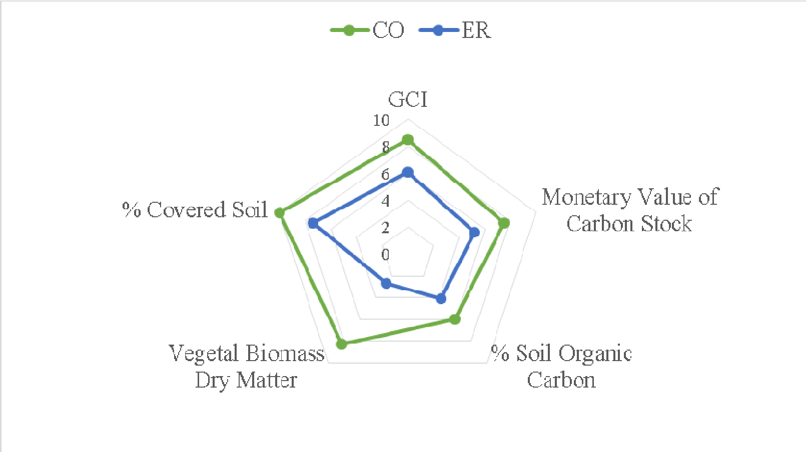

Figure 1. Radar graphic of interaction between socio-economic and ecological indicators of Ecosystem Services of two properties from natural grasslands with different preservation status (P: preserved and R: in recuperation).

The economic performance was directly influenced by forage biomass and by covered soil percentage. The GCI, soil Organic Carbon percentage and monetary value of C stocked are sensitive when there is alteration on above mentioned quantitative indicators, forage biomass and by covered soil percentage. The behavior of the measured indicators in the field demonstrate that GCI is a strong index. Except GCI, all other indicators were measured in this research field. There is a correlation with variables measured in soil and plants.

Conclusion and Implications

Indicators used in this study are easy applicable. The GIC earned recognition of the Agricultural Minister of the State of Río Grande do Sul, in Brazil, not used operationally. This can be an important tool for the local development of PSE schemes. This kind of public policies can assist improving equity and sustainable development opportunities (Peh and Merriman, 2015) in natural grasslands like those of Pampa biome.

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Ecosystem Services at Two Farms of Pampa Biome Using the "Toolkit for Ecosystem Service-Site-Based Assessment" Methodology

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Key words: Grasslands, ecosystems services, soil, biodiversity, livestock.

Introduction

Natural grassland in Pampa biome, in Southern Brazil, offers important ecosystem services (ES). Natural grasslands preserve soil and water and provide habitat for a wide range of flora and fauna. They are the principal source of forage for grazing animals, and thus, the base of milk and beef production in that region. Furthermore, the potential for rural ecotourism provides other social and economic benefits (Pillar et al., 2009). However, cultivation of soil in agriculture, excessive use of agricultural chemicals, and over stocking with livestock have caused soil degradation and loss of this pastoral ecosystem. The "Toolkit for Ecosystem Service-site-based Assessment" (TESSA) (Peh, 2014) is a methodology based in comparisons between two stages of soil conservation, in which one is considered as the "praiseworthy" and the other the "alternative". The objective was to use TESSA on two farms that were members of the "Alliance for the Grassland" (www.alianzadelpastizal.org), which promotes livestock sustainability in Pampa biome through BirdLife International funds.

Material and Methods

Two properties in Lavras do Sul, State of Río Grande do Sul, Brazil, were selected for this study; a preserved natural grassland (P) and a natural grassland in recuperation (R). The P farm was chosen because their soil management practices include mowing, stocking rate adjustment and exclusion of areas as a seed bank and there is no cultivation in the last 60 years. In the R farm, four years of corn and wheat grain production with traditional soil cultivation practices and no fertilization. In each property there were chosen three transects in following the relief: top, middle and lower. On each transect, percentage of non-covered soil (NC) was visually evaluated. Samples of above ground vegetation biomass were taken and analyzed for dry matter (DM). Chemical and physical soil characteristics were determination of the EMBRAPA (1997). Global variance of observation were detected through multivariate analysis of principal components (SAS, 2010).

Results and Discussion

The influence of previous management was analyzed using Principal Component Analysis (PCA) and relief classes were used as the analytic objective. The correlation shows five principal components. Components 1 and 2 explained the global variance of observations. Principal component number 1 explained 99.56% of data, indicating that vegetation biomass, height of vegetation, soil carbon and calcium, as the main indicators influencing this evaluation. Ecosystem Services parameters can be used as a vegetation biodiversity and soil quality indicator using TESSA methodology.
This toolkit helped to select and compare collection sites and to communicate to decision makers so that they can assess the net impact of these changes and, consequently, the benefits for conservation.

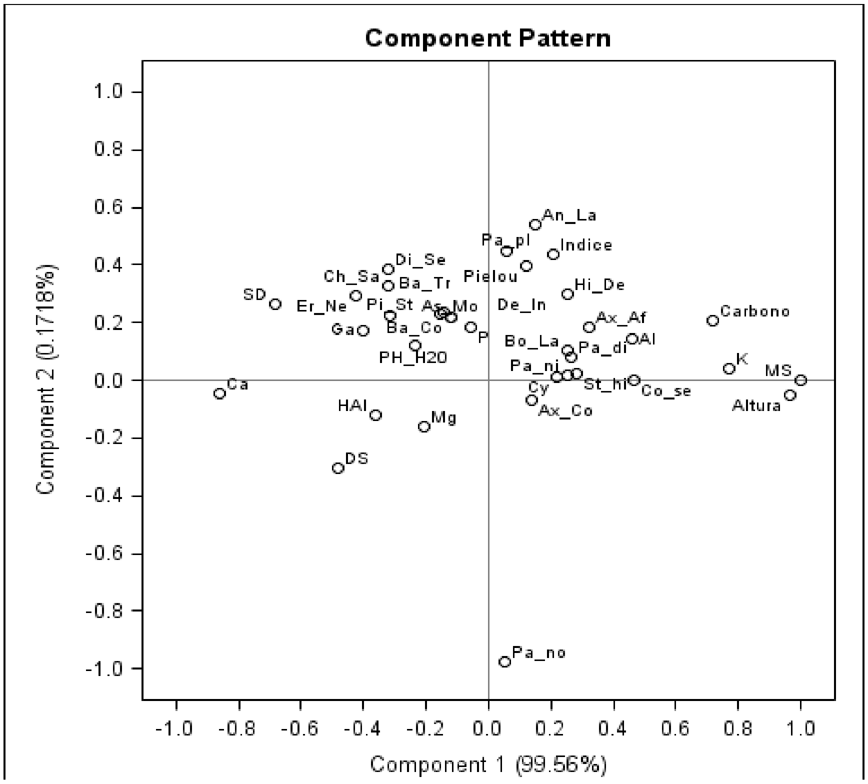

Figure 1. Correlation matrix of Ecosystem Services indicators evaluated in two properties of Pampa biome through principal component analysis.

Correlation matrix of variables of principal components 1 (99.56%) and 2 (0.1718%). Pa_no= *Paspalum notatum* , Co_se= *Coelorhachis selloana*, Ax_Af= *Axonopus compressus*, Pa_ni= *Paspalum nicorae*, Pa_di= *Paspalum dilatatum*, St_hi= *Steinchisma hians*, Pa_pl= *Paspalum plicatulum*, Ax_af= *Axonopus affinis*, An_la= *Andropogon lateralis*, Bo_la= *Bothriochloa laguroides*, Cy= *Cyperaceae*, De_in= *Desmodium incanum*, Hi_de= *Hipoxis decumbens*, Ga= *Gamochaeta sp*, Er_ne= *Eragrostis neesii*, Di_se= *Dichondra sericea*, Ba_tr= *Baccharis trimera*, Ch_sa= *Chevreulia sarmentosa*, Pi_st= Piptochaetium stipoides, As_mo= *Aspilia montevidensis*, Ba_co= *Baccharis coridifolia*, SD = non-covered soil percentage, Ca = Calcium, DS = soil density, Mg = Magnesium, HAL = H +Al, K = Potasium, Carbon = soil organic Carbon; Ph H20; Al = aluminium; P = phosporus MS = vegetal biomass dry matter, Altura = height of vegetal biomass.

Conclusions and Implications

The soil coverage, vegetation biomass and height, must be considered when managing natural grassland at Pampa biome, as they showed to be good indicators of conservation and ecosystem services. The TESSA proved to be a scientifically sound measure of ecosystem services in natural grasslands. More training is needed to professionals understand the benefits and how to use the toolkit.

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In vitro Methane Production of Plants Species from the Pampa Biome in Southern Brazil

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Key words: Natural grasslands, chemical composition, emission intensity, grazing animals

Introduction

The Brazilian grazing cattle herd of ca. 209 million animals is one of the world's major sources of enteric methane. Natural grasslands in southern Brazil cover ca. 13 million hectares with a unique mixture of species interacting in a spatial-temporal fashion (Boldrini et. al., 2010). In the Pampa biome, intensification in pasture use reduced methane emissions per unit of weight gain (Moscat, 2015). The reason for this reduction is unknown; however, it appears related to pasture structure, grazing behavior, diet selection, and differences in the chemical composition of forage species. These factors modify the quality and quantity of the dry matter consumed by animals with impact on fermentation and methanogenesis. Knowing the methanogenic potential of forage species in complex pastoral systems is important in developing grazing strategies capable of reducing methane emission intensity. The objective of this study was to assess the *in vitro* methane emission and fermentation characteristics of major Pampa biome forage species.

Materials and Methods

The experiment was conducted at Embrapa South Livestock, Bagé, in the state of Rio Grande do Sul, Brazil, during three years (2009, 2011, and 2012). Twenty-one grass species: *Andropogon selloanus*„ *Axonopus affinis*, *Cynodon dactylon*, *Dichanthelium sabulorum*, *Eragrostis cataclasta*, *Eragrostis plana*, *Holcus lanatus*, *Lolium multiflorum*, *Luziola peruviana*, *Melica rigida*, *Mnesithea selloana*, *Paspalum nicorae*, *Paspalum notatum*, *Paspalum pauciciliatum*, *Paspalum pumilum*, *Paspalum urvillei*, *Piptochaetium montevidense*, *Saccharum angustifolium*, *Schizachyrium tenerum*, *Setaria parviflora*, *Sporobolus indicus*; and five legumes *Desmodium incanum*, *Lotus corniculatus*, *Trifolium polymorphum*, *Trifolium pretense*, *Trifolium repens*. of major occurrence were collected and transplanted to a greenhouse, using three boxes (replicates) per plant. Plants were collected at two phenological stages: bloom (F) and vegetative (V). Plant samples were dried at 60°C for 72 hours and ground to pass through a 1-mm sieve for the *in vitro* assay. The *in vitro* methane procedure was performed according to Mould et al. (2005). At 24 h of incubation, gas pressure was measured then 5 ml samples of headspace gas were transferred to a extainer tubes for subsequent analysis of methane concentration by gas chromatography. Also, DM disappearance (%), methane (ml g^{-1} of DM degraded) and VFA production (µmol ml^{-1} of acetate, propionate, and butyrate) were measured. Data were analyzed by principal component analysis (PCA) for all parameters and evaluated species (Figure 1) using JMP Pro 12 software (version 12.0.1).

Results and Discussion

Principal component 1 explained 73% of the variation in CH_4 production, while component 2 only explained 14% of the variation in CH_4 production for major forage species from the Pampa biome (Figure 1). The species Loco had the best fermentation characteristics in terms of high DM disappearance, high

VFA production and low methane (ml g^{-1} of DM degraded). Others like Trpr and Trpo were similar at these parameters, but had higher methane emission. The least methanogenic species were Scan and Pani; however, they did not have desirable fermentation characteristics. A lower acetate to propionate ratio is desirable as higher propionate is associated with reduced methane synthesis. Species with lower acetate:propionate (C2:C3) ratio were Scte, Mnse, Erca and Erpl. It is important to note that this is the first time that these species were analyzed for the parameters presented in this paper and this can be considered a great advance to understanding the grasslands ofSouth America.

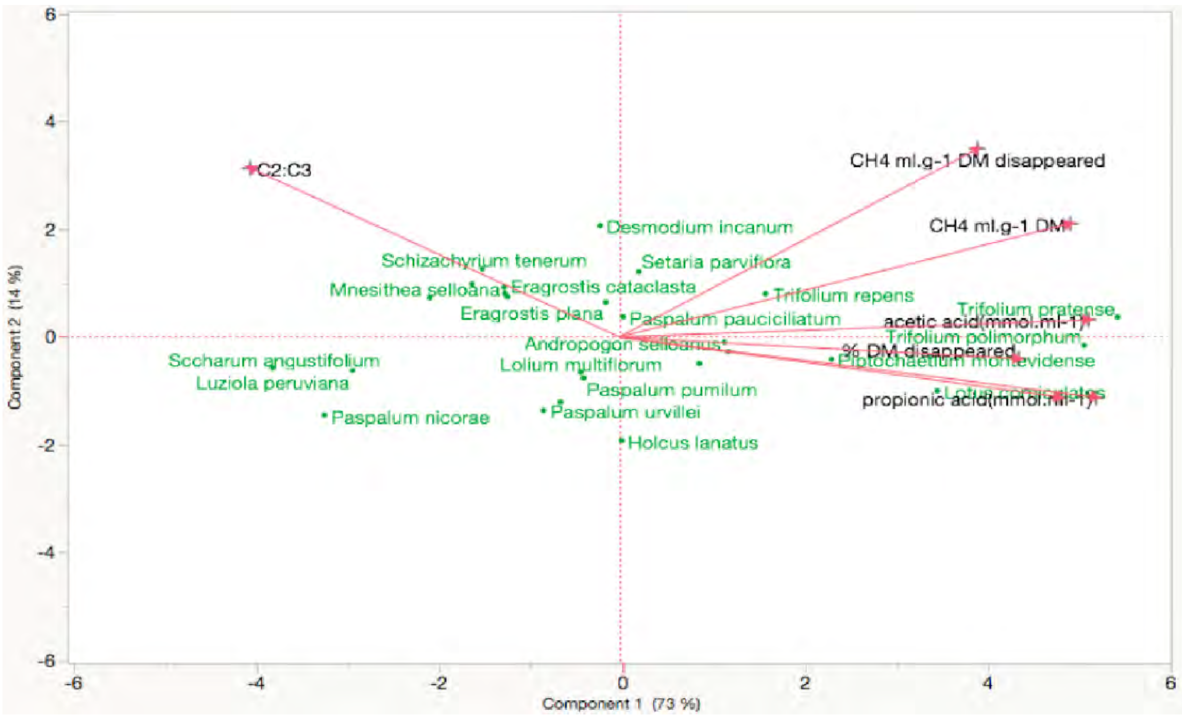

Figure 1. Principal components analysis for *in vitro* methane production and fermentation characteristics of major species in the Pampa biome. Component 1: CH_4 ml g^{-1} DM incubated, DM disappearance, concentration (µmol.ml^{-1}) of acetic, propionic and butyric acids. Component 2: CH_4 (ml.g^{-1} of DM disappeared), C2:C3 ratio.

Conclusions and Implications

This analysis characterized the degradation of the major forage species in the Pampa biome in regard to *in vitro* methane emissions and fermentation. From this study, it should be possible to select species with low CH_4 emissions for future studies on pasture or for *in vivo* digestibility trials.

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Economic and Environmental Performance Assessment of Beef Cattle Production Systems on Natural Grassland in Southern Brazil

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Key words: Beef cattle, carbon, management, methane, mitigation, profit

Introduction

Starting in the last decade, studies and debates about the contribution of beef cattle production to greenhouse gases have intensified, mobilized by different institutions; among them, universities, farmers associations, public figures, the media in general, as well as the Intergovernmental Panel on Climate Change (IPCC). Some recent studies have demonstrated that higher or lower methane production depends fundamentally on the conditions of the production system (Genro et al., 2014; Moscat, 2015).

In addition, the interest sparked by this topic has fostered the necessity for mitigation systems evaluations that integrate economic and environmental performance. These evaluations have the goal of determining if systems that are capable of mitigating the emission of greenhouse gases are also economically feasible. The tools and strategies that are expected to be utilized by producers should be economically sustainable; otherwise, they run the risk of not being implemented (Berndt, 2010).

The objective of this study was to analyze the economic and environmental performance of pasture production systems with different levels of intensification in backgrounding and finishing cattle in southern Brazil. This information will be able to provide important guidelines for farmers making decisions on greenhouse gas mitigation systems.

Material and Methods

The experiment was conducted in an area belonging to Embrapa South Livestock, located in Bagé, Rio Grande do Sul--under the purview of Pecus Network-- during 2013. Economic analysis used current (May 2015) fat cattle prices (C\$2.04 kg LW^{-1}; approximately 1 CAD = 2.50 BRL) and costs. Nine paddocks, approximately seven hectares in size, located in a grassland area were used. Three paddocks were assigned to each of three treatments: natural grassland field (NG); natural grassland with nitrogen fertilizer (NGF); natural grassland with nitrogen fertilizer and overseeding of two hibernal species: ryegrass (*Lolium multiflorum*) and red clover (*Trifolium pratense*) (NGFS). In all the treatments, the pasture was managed in order to maintain the fodder supply at 12% (12 kg of dry matter/100 kg live weight). For this, three Hereford steers were used in each paddock, where methane emission evaluations were conducted. In addition, sufficient animals were used to maintain the forage supply at 12%. The average annual capacity of the paddock, including the regulator animals, was nine animals (NG), 12 animals (NGF) and 13 animals (NGFS). Methane emissions by the animals were measured using the sulphur hexaflouride marker technique, over a five day period, in all seasons of the year (starting on January 21, June 5, July 22, and October 28). Methane samples were collected in the proximity of the animals' noses with the assistance of regulatory air intake valves, and stored in stainless steel tubes. Data relative to pasture management and animal health conditions were collected in the same fashion during the experimental period. The economic analysis of the emissions was obtained by relating the gross margin and the methane emission per hectare.

This emission/benefit relation allowed for the measurement of economic return for each gram of methane emission in each of the three studied systems, taking into consideration the effective operational costs and payments to outsourced mechanized services.

Results and Discussion

Lower methane emissions by area occurred in the NF system with lower meat production per hectare, with a value of 97.32 kg of CH_4/ha/year. However, if we analyze the methane production per kilo of live weight gain (LWG), the lowest observed value was in systems with higher intensification (Table 1). This demonstrates that methane emission per kilo of LWG is lowered with system intensification (Genro et al., 2014).

Table 1. Stocking rate values (kg LW ha^{-1}), live weight gain per area (kg LW ha^{-1} year^{-1}), methane emission by live weight gain (g CH_4 kg LWG^{-1} day^{-1}), gross margin per area (C$ ha^{-1} year^{-1}), and benefit/emission relation (C$ g $CH_4$$^{-1}$ kg LWG^{-1}) in each of the three systems.

	Stocking rate (kg LW ha^{-1})	Weight gain (kg LWG ha^{-1} year^{-1})	CH_4 emission (g CH_4 kg LWG^{-1} day^{-1})	Gross Margin (C$ ha^{-1} year^{-1})	Benefit/emission relation (C$ kg $CH_4$$^{-1}$)
NG	423	123	0.79	41.56	0.43
NGF	583	228	0.49	80.60	0.72
NGFS	628	310	0.43	166.40	1.25

The improvement in environmental performance obtained with intensification also resulted in an improvement in economic performance. There was an increase in economic return per hectare with fertilization and enhancement of natural grassland as compared to NG. The relation between financial benefit and the emission of one kg of methane was C$0.43, C$0.72, and C$1.25 for the NG, NGF, NGFS systems, respectively. If a farmer sought the same profit, but decided not to invest in increasing productivity, on average, this decision would double the amount of methane emissions for the same meat production. It should be noted that the advantages of intensification may be even greater when the soil carbon balance is considered in the economic analyses (Berndt, 2010).

Conclusion

The use of fertilization and the introduction of hibernal species to native grasslands has been shown to be sustainable both in terms of methane emission per kilo of live weight, as well as in productive and economic terms per hectare and in terms of the cost/benefit relation of emissions.

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Impact of Nitrapyrin, N-(n-butyl)-Thiophosphoric Triamide (NBPT) and Dicyandiamide (DCD) on Reducing N_2O Emission from Cow Urine on a Tame Pasture

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Key words: Greenhouse gas emission, urine patch, grazed grassland, N stabilizer

Introduction

Nitrogen stabilizers, such as the nitrification inhibitor dicyandiamide (DCD), have been reported to reduce N_2O losses from urine patches on grazed grassland as DCD temporarily delays nitrification and retains NH_4^+, a less mobile N form. Studies in New Zealand indicate that N_2O emissions from urine patches can be reduced up to 70% when DCD is applied to pastures (e.g., Di et al., 2007; de Klein et al., 2011). An Irish field study found dairy slurry application caused large N_2O emissions from grasslands in wet and mild conditions, but incubating slurry with DCD for six months lowered emissions by 88% (Minet et al., 2016). Other studies suggest that the efficacy of DCD depends on soil properties and climatic conditions (Mazzetto et al. 2015; McGeough et al. 2016). Nitrapyrin, a nitrification inhibitor, and N-(n-butyl)-thiophosphoric triamide (NBPT), a urease inhibitor, are also being used as N stabilizers to limit N losses. The objective of this research was to quantify N_2O emissions from urine patches treated with N stabilizers (DCD, nitrapyrin and NBPT) and better understand their effects on a tame pasture in a semi-arid climate in southern Alberta.

Materials and Methods

The field experiment was conducted over the 2015 grazing season (June 26 to October 6, 2015) on a tame pasture at AAFC, Lethbridge Research and Development Centre (Latitude: 49.693085, Longitude: -120.762350). The Chernozem soil (top 15 cm) had the following characteristics: 7.39 ± 0.03pH (in water), 168.8 ± 7.5 g organic C kg^{-1}, 7.52 ± 0.28 g total N kg^{-1}, and 1.05 ± 0.01 g cm^{-3} bulk density. The pasture was predominantly orchard grass (*Dactylis glomerata* L.) and smooth brome grass (*Bromus inermis* Leyss.). Before 2014, the study site was mainly used as a passway for moving cattle and was occasionally grazed for biomass and weed control. Since summer 2014, the site has been grazed by sheep at stocking rates of 16 AUM ha^{-1} in 2014 and 19.6 AUM ha^{-1} in 2015. Cattle manure compost was also applied in fall 2014 at rate of 1600 kg ha^{-1} (dry weight).

A split-plot design arranged in randomized complete block with urine treatments assigned to the main plots and application frequency assigned to the subplots (one vs two applications) with four replications was used. The treatments were urine (Urine), urine with nitrapyrin (U_Nitra), urine with DCD (U_DCD), and urine with DCD and NBPT (U_Combo), along with a no-urine control (CK). The urine was applied to each plot (1 × 1 m) at 25,000 L ha^{-1} rate, which provides 212 kg N ha^{-1} (285 kg C ha^{-1}), on June 24, 2015 for one urine application treatments and again to the east half of the plot at 148 kg N ha^{-1} (284 kg C ha^{-1}) rate on July 28 for the two urine application treatments. At each application, the CK treatment was treated with distilled water equal to the volume of urine applied. The application rates for DCD, nitrapyrin and NBPT were 10, 10 and 2 g ha^{-1}.

A vented static chamber base was installed to each plot right after the first urine application, each sub-plot after second application. Gas samples from each plot were collected twice in the first week after urine application and weekly thereafter. For each gas sample collection, gas was drawn from the chamber 0, 15, 30 and 60 min after chamber closure and analyzed for N_2O concentration using a gas chromatograph (Varian GC 3800). The N_2O fluxes were calculated based on concentration increases over time and the cumulative emission were estimated assuming daily flux is representative for the week. The MIXED model procedure was used for analysis of variance with treatment as the main factor and application frequency as the sub-factor.

Results and Discussion

The N_2O fluxes sharply increased following the first urine application on June 26, 2015 and thereafter remained elevated for three weeks regardless of whether N stabilizers were co-applied. Peak N_2O fluxes were observed seven days after urine application. Increased N_2O fluxes were also observed following the second urine application on July 28; however, the peaks were less than the days following first urine application.

The cumulative N_2O emissions were affected by treatment (P = 0.004), and application frequency ($P <$ 0.001), but not their interaction. The cumulative emissions followed the order of CK (43.7 g N ha^{-1}) ≤ U_Nitra (167.3 g N ha^{-1}) ≤ Urine (276.5 g N ha^{-1}), U_DCD (279.6 g N ha^{-1}) ≤ U_Combo (340.6 g N ha^{-1}). The sub-plots that received a second urine application emitted significantly more N_2O (266.8 g N ha^{-1}) than the sub-plots that received only one dose (176.3 g N ha^{-1}). The low N_2O emission (167.3 to 340.6 g N ha^{-1}) over the 103-day grazing season relative to large amount of urine N applied (212 kg ha^{-1} or 212+148 kg N ha^{-1}) may reflect the extremely low precipitation in 2015. The 2015 annual precipitation of 255 mm was 64% of the 30-yr average (396 mm). As a result, surface soil gravimetric moisture content varied from 0.104 to 0.259 g g^{-1}, which led to water occupying < 29% (range 18 to 45%) and air occupying 71% (range 55 to 82%) of total soil pore space. The effectiveness of N stabilizers for inhibiting nitrification might have been hindered by the dry soil conditions. Furthermore, the effectiveness of DCD can vary depending on soil properties (McGeough et al. 2016). Thus, the efficacy of N stabilizers may depend on an interaction between soil properties and climatic conditions.

Conclusions and Implications

The N_2O emissions were lower from nitrapyrin treated urine patches than urine patches treated with the combination of DCD+NBPT. Dry weather conditions over the 2015 grazing season may have hindered the effectiveness of N the stabilizers. Multi-year and multi-soil studies are needed to investigate the use of N stabilizers for reducing N_2O emission from urine patches to determine if their efficacy depends on an interaction between weather conditions and soil properties in the semi-arid climate.

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Remote Sensing Estimates of Rangeland Ecosystems Primary Production: A Case in the Central Highlands of Peru

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Keywords: grazing, NDVI, biomass, ecosystems

Introduction

The Puna, region located over 3,800 meters above sea level (m.a.s.l.), covering more than 25 million ha of mountainous ecosystems across the Peruvian territory, enclosing 100% of the tropical glaciers and bofedal (mountain wetlands) of Peru with a key role in the hydrological and water availability and quality for lowland population, is being impacted by climate change and overgrazing. This region is inhabited by almost 25% of the Peruvian population with half of their population considered under extremely poverty situation (Flores et al., 2007). In addition, rangelands of the Puna are used mainly for grazing 80% of the cattle and sheep bred in Peru, and 100% of the alpacas and llamas. Therefore, evaluating the productivity temporal dynamics of these ecosystems using remote sensing techniques is important to design participative adaptation strategies to deal with climate change and land degradation. Multitemporal satellite imagery (2000-2015) MODIS NDVI was used as a surrogate for primary production to investigate climate and grazing impacts on two grassland type performance in the central highlands of Peru (Figure 1).

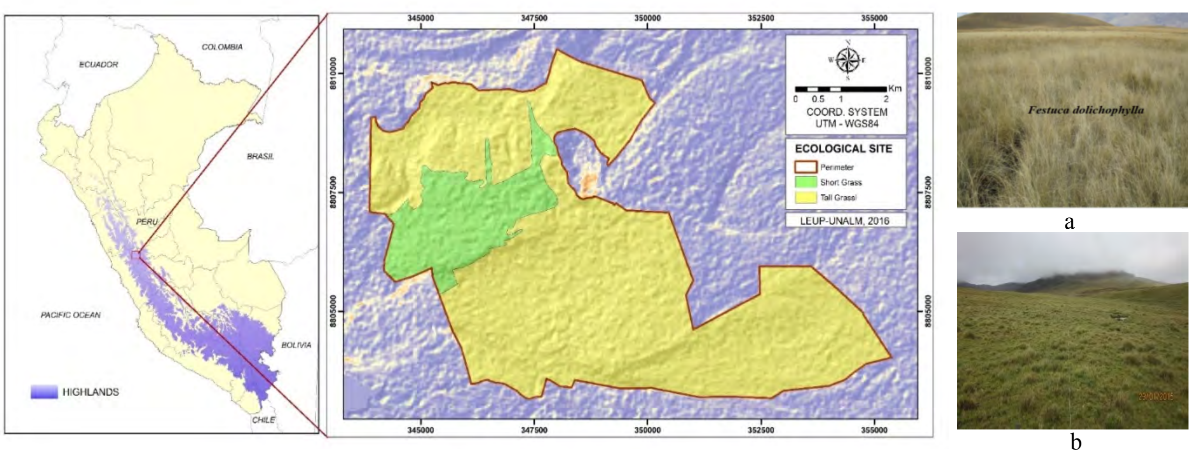

Figure 1. San Pedro de Racco Ecological Site Map. Vegetation types (a) tall grass (yellow) and (b) short grasses (green).

Materials and Methods

The area of study included 3667.9 ha of tall grasses (west and east sites) and 607.9 ha of short grasses in the Communal Cooperative San Pedro de Racco located in areas of moderate water content at 4,200 m.a.s.l (Figure 1). The MODIS 16-day 250 meter Normalized Difference Vegetation Index (NDVI) data were the basis of this study (Global MOD13Q1). Rainfall data was obtained from the National Meteorology Service (SENAMHI) and livestock population from the National Statistic Service (INEI). Trends in the residuals of regressions using annual maximum NDVI and the accumulated rainfall associated with maximum NDVI were used to detect human and climate induced degradation, the RESTREND Analysis (Evans and Geerken 2004). Negative trends in residuals would indicate human-induced degradation since the climate signal is removed from the analysis.

Results and Discussions

NDVI temporal data for both grassland types followed precipitation patterns; however NDVI responses increased after the peak of the rainy season; thus, vegetation NDVI is sensible to precipitation changes causing modifications in NDVI and primary production spatial distribution (Fig. 2).

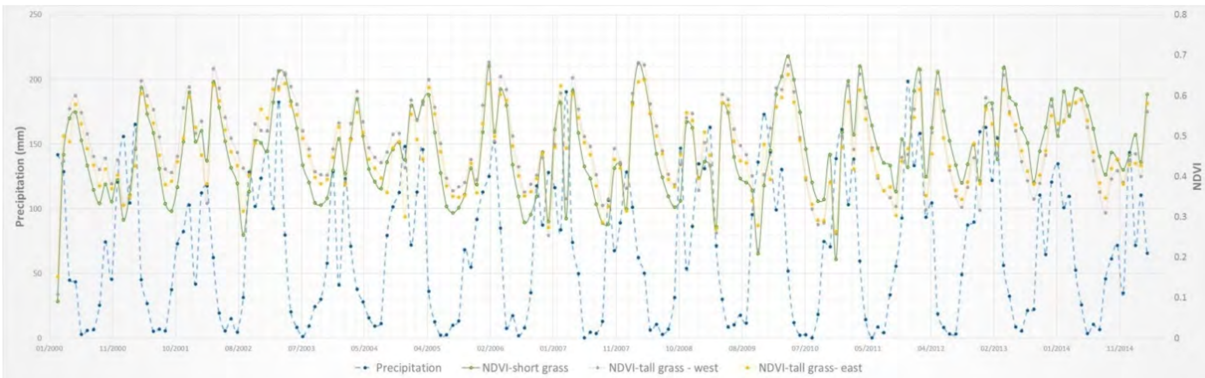

Figure 2. Temporal dynamics relationship between short and tallgrasses NDVI and precipitation (mm).

Tall grasses negative trends in residuals shows overgrazing effects (Fig. 3). The higher NDVI response in short grasslands or puna mat may be due to the species composition that are dominated by cushion plants and dwarf herbaceous forbs that grow below grasses and are protected because they are near the soil or below the soil (Wilcox et al., 1987). Much of the grazing literature indicates that tall grasses are more susceptible to overgrazing because the shoots for regrowth are elevated. In the last 18 years (1994-2012), the alpaca population in this region has increased in 639.2 %, reducing the available biomass and vegetation coverage.

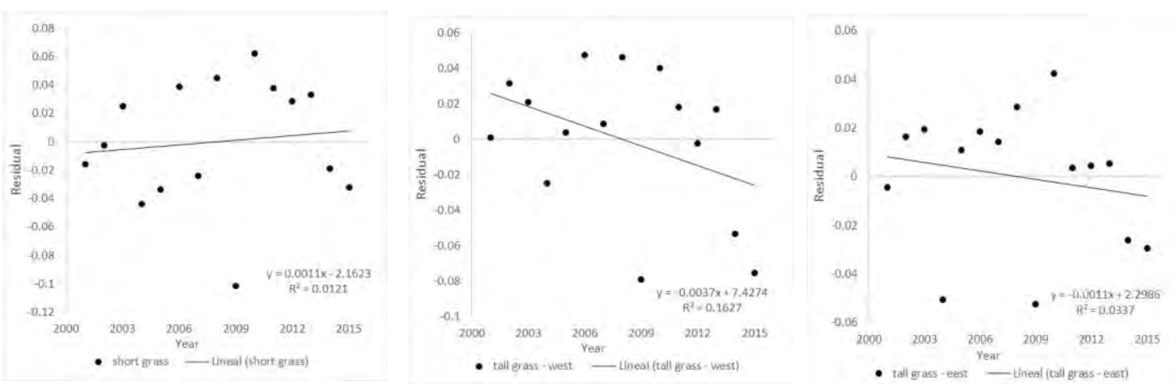

Figure 3. RESTREND Analyses for short and tallgrasses.

Conclusions and Implications

Grassland NDVI patterns in the central highlands of Peru are affected mainly by precipitation and overgrazing that reduces available biomass and primary production. Under climate change scenarios remote sensing techniques to address changes in rangeland primary production is important to adjust stocking rate and sustain and improve rangeland condition.

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Comprehensive Risk Assessment of the Snow-Caused Disaster in Qinghai province, China

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Key words: Snow disaster, risk assessment, Logistic regression model, Qinghai province.

Introduction

Snow disasters have a direct impact on agriculture and animal husbandry, and even the development of the national economy in Qinghai province, China (Liang et al., 2008). It is of great significance to understand the causal factors and strength of snow disaster risk assessment in Qinghai for the purpose of the defense and disaster management (Wang et al., 2013). This study proposed a method of risk assessment of snow-caused livestock disasters in Qinghai.

Methods

Data used for the risk assessment include remote sensing data, statistical data of weather, livestock, and social economy, and 45 typical snow disaster cases from 2000 to 2007. Seven crucial factors that contribute over 85% information were screened out using Principal Component Analysis method for risk assessment of snow disasters. They are slope(x1), number of snow-covered days(x2), annual average temperature(x3), maximum depth(x4) and per capita GDP(x5), Highway density(x6), Livestock stocking rate(x7). Finally, using Logistic regression models to remove those factors that did not reach significant level and identifying five risk assessment factors (per capita GDP, annual average temperature, number of snow-covered days and maximum depth, and slope). These data were then analyzed using ArcGIS software to make the snow disaster average risk zoning map from 2001-2007 for the Qinghai province to provide the space distribution characteristics of different snow-caused disaster levels.

Results

The Logistic regression model derived from the analysis was:

$$Logit(p) = -12.559 + 0.601x1 + 2.544x2 + 3.066x3 + 1.724x4 + 7.837x5$$

where, P is the probability of snow disaster occurring.

Average risk assessment of snow disaster in the Qinghai region during 2001-2007 is shown in Figure 1. It indicates that: risk is high in the south and low in the north; high risk areas were mainly distributed in the south region of Qinghai Province including Chengduo, Yushu, Xiangqian, Dari, and Gande, Maqin; while Qaidam Basin in the northwest and the eastern agricultural were low risk areas. High risk was associated with the topography and geomorphology, where the mountains above 4000 m, (including the Qilian, Kunlun, Tanggula, BalYanlKalLa, and Anyemaqen mountains were high risk areas for snow disaster in Qinghai.

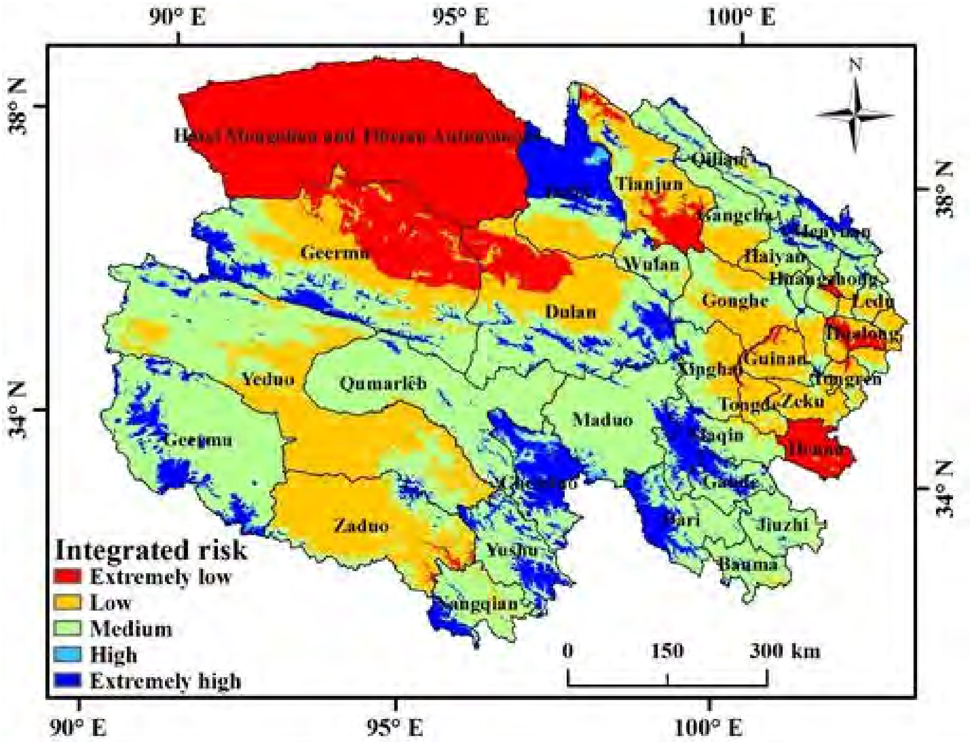

Figure 1. Regionalization of average risk assessment of snow disaster in Qinghai.

Conclusions

The Logistic regression model for Qinghai predicts the greatest risk of a snow disaster primarily in the mountainous areas. However, it can not necessarily be adapted to other areas without first adjusting for regional differences according to climatic conditions, economic development level and an analysis of the different management objectives. Snow disaster had a great harm for the local herdsmen, especially those living in the southern region. In general, herdsmen in Qinghai weaken damage of snow disaster by enclosure Grassland, built permanent stall, reduce inventories of livestock in winter, the Preparation of forage and so on.

Acknowledgments

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Subsurface Recycling Irrigation of Perennial Dairy Pasture in Maritime Canada

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Key words: nitrous oxide, milk yield.

Introduction

Historically, the climate in Maritime Canada has enabled the use of pasture in the ruminant livestock sectors, providing economic and environmental benefits. Pasture has remained the backbone of sustainability in beef and sheep However, pasture use as the principle source of summer forage is shrinking in the intensifying Maritime dairy industry, despite the benefits of pasture which bring a measure of resilience under changes in environmental or economic climate and is predicted to use less land (total of on- farm and off- farm) compared with higher input confinement systems (O'Brien et al., 2012).

Changing climate is predicted to result in uneven distribution of precipitation over the growing season resulting in wet springs, delaying the onset of grazing and mid-summer drought resulting in longer rest periods, and necessitating greater use of land. Recently, these events have become pronounced to the point where pasture use is increasingly limited by spring water logging and midsummer drought. Climate change is predicted to intensify the occurrence of these constraints on grazing. Irrigation and drainage could provide benefits under these conditions (Chapman et al., 2012).

Enteric methane emission from grazing cows is not different from confined cows but overall, greenhouse gas emission is predicted to be lower in pasture systems (O'Brien et al., 2012; Fredeen et al., 2013). However, effects of irrigation and grazing on nitrous oxide emission are unknown.

The objective of this experiment was to establish a subsurface system capable of drainage and irrigation using recycled water and to evaluate its effect on the productivity and N_2O emission of a dairy- pasture system.

Materials and Methods

A five-year study was undertaken to evaluate the performance of an intensively managed perennial pasture with subsurface irrigation using recycled water, or drainage. In 2000, drainage pipe 22cm in diameter was installed on the Dalhousie Faculty of Agriculture Dairy unit in Truro, NS (45°22'N; 63°16'W). Depth of pipe and spacing were 1.5 and 7 m, paralleling the mildly sloping natural topography of a naturalized pasture (4.0 ha) on rapidly draining sandy soil containing a sward composed of composed of a complex mixture of grasses such including bluegrass (*Poa compressa*), timothy (*Phleumpratense L.*), orchardgrass (*Dactylisglomerata L.*), tall fescue (*Festucaarundinacea Schreb.*), reed canarygrass (*Phalarisarundinacea L.*) and the legumes, white clover (*Trifoliumrepens*) and red clover (*Trifolium pratense*). Water coming off the field (precipitation and irrigation excess) through subsurface piping (drainage) was processed through tipping buckets in a pumping station located at the lowest point in the pasture. This water was subsequently returned to a reservoir located at the top end of the pasture. Water held in the reservoir was returned to the pasture by gravity flow through the subsurface pipe (Irrigation) as needed, which was determined using evaluation of soil water content using soil tensiometers. The pipe also provided continuous drainage. The pasture was subdivided into two replicated paddocks 0.7ha which were only drained or irrigated. A fifth paddock was neither drained nor irrigated. Treatment areas were rotationally grazed by eight paired lactating Holstein cows per treatment by strip- grazing and productivity was compared to confinement where cows were fed a total mixed ration (TMR) based on corn silage and haylage. Grazing commenced May 15 and ended September 1. Paddocks were strip-grazed using entrance and exit sward height of 25 and 10 cm. Cows were supplemented with 5kg partial mixed ration (PMR) (DM basis) twice daily at milking, and drinking water was provided free choice. Direct soil surface greenhouse gas fluxes were measured using a non-flow-through, non-steady-state chamber method (Anthony et al., 1995).

Results and Discussion

Weather events were similar to the long-term means for precipitation and temperature during the grazing season Irrigation improved pasture productivity in a year when weather was normal for the region. Milk yield was elevated by irrigation but lower compared with cows in confinement fed more grain and silage. The N_2O flux on pasture was not altered by irrigation or drainage.

Conclusions and Implications

The benefit of irrigating an intensively managed perennial pasture under normal climatic conditions was small. The grazing season in Maritime Canada is marked by a summer spike in temperature and drop in precipitation. Under these climatic conditions, subsurface irrigation increased soil moisture and appeared to elevate pasture yield which was correlated with rumen fill of the cows. Consequently, irrigation improved the lactational performance of grazing cows.

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6.3 Water supply and quality impacts from climate change

Water from Rangelands: Climate and Responsive Management

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Key words: Grazing, ground water, riparian

Introduction

Earth's extended warming trend has reduced fresh water stored as mountain ice and snow. Worldwide, about 90% of mountain glaciers are shrinking or gone (Khromova et al., 2014). Spring runoff now occurs well before the growing season and more precipitation comes as rain. Water is running off the mountains too fast and spilling from reservoirs too soon. During 2010 and 2011, about 3.7 km^3 of water flowed out of the US state of Wyoming's North Platte River after all upstream reservoirs were full (personal communication, State of Wyoming). That water was lost to local users and contributed to disastrous downstream flooding.

Lost frozen storage can be replaced by liquid storage in wetlands, marshes, beaver ponds, peat beds, and other ground-water recharging riparian features—if these are in proper functioning condition. But too many riparian systems show widespread dysfunction from an emphasis on grazing over other ecological services (Belsky et al., 1999). Grazing can remove woody plants, resulting in erosion due to inadequately armored banks, faster flow rates in floods, shallower/ warmer water, and in loss of riparian-associated flora and fauna, including beaver (*Castor spp.*). In previous work we demonstrated that conservation grazing can bring back riparian woody plants (Booth et al., 2012); that wetland grazing often results in large erosion pedestals ("hummocks") whose interspaces are punched holes in landscape "sponges" that reduce flow regulation and water storage (Booth et al., 2015); and that remote-sensing detection of headcuts and livestock trails in riparian zones (major erosion risks) requires ≤ 3cm-pixel imagery, in contrast to the 1-m imagery regularly used by US land management agencies (Cox et al. 2016). There are other issues affecting the capability of rangeland riparian systems to provide perennial water.

We postulate that riparian vegetation has greater long-term economic and ecological value unharvested, than as livestock feed. We further posit that un-grazed riparian vegetation provides wildland habitat more likely to sustain beaver populations than where beaver must compete directly with larger herbivores.

Materials and Methods

We established six rangeland wet-meadow study sites in Fremont County, WY to test the above hypotheses. Preliminary assessments of soil organic matter (SOM), an indicator for both water storage and carbon sequestration, have been completed for three sites. Separately, we used Google Earth to compare inside/outside differences of four 30-year riparian grazing exclosures in Albany County, WY (41.155, -105.337 and downstream).

Results and Discussion

In Fremont County, 50+ years protection from intensive grazing yielded 53±13% ($\bar{x}$±SD) riparian SOM while10-years protection yielded 20±7 and 17±3%. In Albany County, stream sections protected from grazing for 30+ years contain numerous beaver ponds and marshes 80+ m across, and robust willow cover; whereas, adjacent grazed areas contain few or no ponds and willows and are areas where water moves downstream in the channel without adjacent saturated areas for storage and ground-water recharge.

Fresh water is increasingly scarce worldwide due to natural and human causes. Northern India, the North China Plain, the Middle East, and the western US are predominately arid and semi-arid ecosystems where groundwater overuse is a concern (Dimick, 2014). From 2004 to 2013, ground-water losses in the Colorado River Basin far exceeded losses from the river's large reservoirs, accounting for 50.1 km^3 of the total 64.8 km^3 of freshwater loss (Castle et al., 2014). In India from 2002 to 2012, ground-water levels dropped 1.4 m/a as pumping outpaced replenishment by 8% (Postel, 2015). Over pumping can bring surface subsidence and aquifer-capacity shrinkage, as in the 8-m surface subsidence in areas of California's San Joaquin Valley. The world's top irrigators—China, India, Pakistan, and the US—are pumping at unsustainable levels in crop-producing areas that are critical to world food supplies (Postel, 2015). Our results strongly suggest grazing management influences water storage in rangeland ground-water recharging features and therefore influences the level of sustainable groundwater use.

Conclusions and Implications

An emphasis on grazing over other riparian services has reduced aquifer recharge and sustainable pumping rates. Restoring and protecting rangeland riparian systems is crucial to preserving or increasing sustainable water yield. Such protection can help support irrigated agriculture through greater aquifer recharge and will increase dryland forage due to water's longer residence on the landscape; however, recovering systems may need 30+ years to achieve real functionality.

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Climate Compatible Development in Mongolia: Analysis of Vulnerability and Adaptation Response to Global Changes

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Key words: Pastoral vulnerability and resilience; household adaptive capacity

Introduction

Climate change and increased climate variability, and market and policy changes are shaping pastoral communities' decisions on what pathways their future livelihoods will take and how the steppe landscapes and river basins, are managed. Recent droughts and damaging winter storms (*zuds*) of the past two decades have exacerbated the situation and undermined the natural capital on which pastoral livelihoods depend. River basins provide the ecosystem services that support pastoral communities, and industrial and urban development. Green development strategies are strongly dependent on water resources. Consequently, integrated planning of river basin management is needed to maintain these critical ecosystem services to meet the multiple needs of livelihoods of communities and to support sustainable development activities in these basins.

Materials and Methods

For this study our team worked in nine *sums* (i.e., county level administrative areas) in three river basins in two *aimags* (i.e., provinces) to collect household data from 144 households. We selected 3 *sums* in each river basis, representing forest steppe, steppe and desert steppe regions for comparison across river basins and ecological zones. We also collected census data from the *aimags* and at the national level to understand trends within ecosystems and river basins. We also had series of group discussions at community, *sum*, river basin, *aimag* and national levels.

Results and Discussion

Results from the study indicated that many pastoral communities have reduced adaptive capacity to deal with regional droughts and harsh winter conditions leading to greater vulnerability among the communities studied. Contributing factors to this vulnerability were related to reduced capacity to *otor* (move herds long distances) to find adequate forage, lack of winter forage areas, and lack of forage reserves. In addition, the increased mining extraction in the region has resulted in competition for a clean supply of water for livestock and human usage.

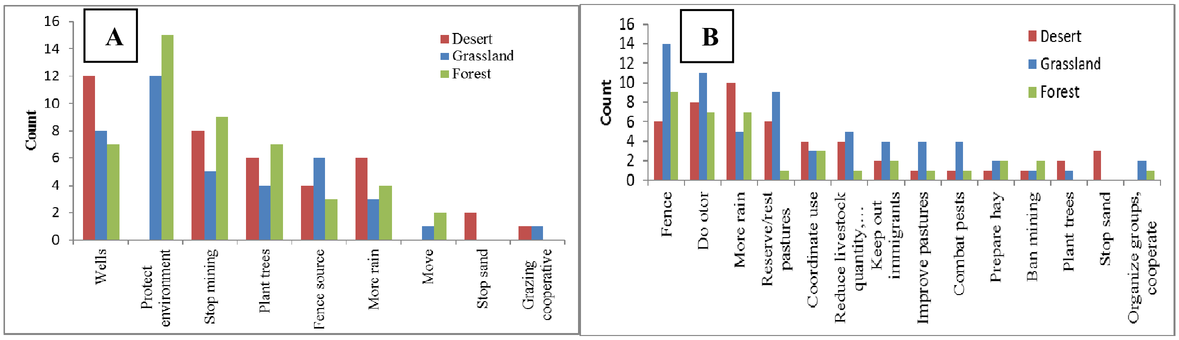

Figure 1. Frequency with which interviewees reported various coping strategies as the best ways to adapt to changes in A) water and B) pasture resources in each ecosystem type.

Building wells in the desert steppe and protection of environment in the steppe and forest-steppe zones were the main strategies for coping with changes in water (Figure 1A). Fencing and doing *otor* were the main coping strategies for changes in pasture resources (Figure 1B).

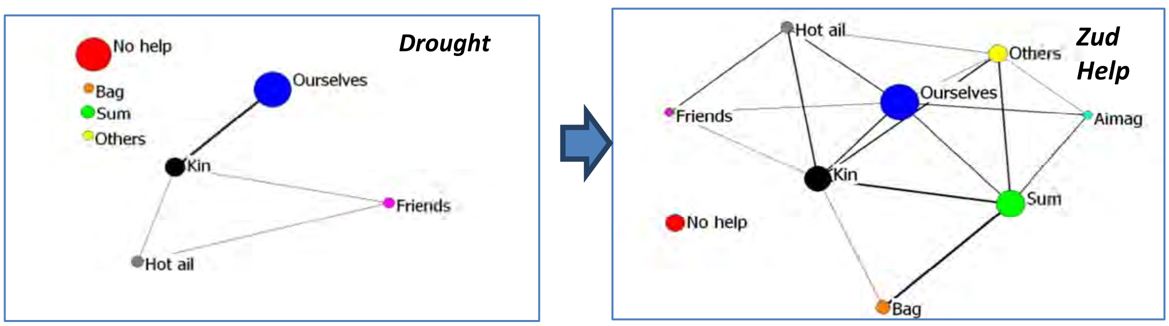

Figure 2. Help networks during (A) drought and (B) *zud*. The size of the circles show how often a source of help is mentioned by interviewees. Line thickness shows how often two sources were mentioned as being used together.

Among these communities, coping ability and sources of help (Figure 2) varied depending on whether the environmental stressor was a drought (Fig. 2A) or a *zud* (Fig. 2B), though many households indicated that they were mainly self-reliant (Figure 2). Communication with kin and local sources also proved to be important sources of help and information.

Key recommendations from study included:

- Integrated planning efforts would be enhanced through use of a social-ecological framework and the development of a cross-ministerial working group to address natural resource considerations.
- Development of a cross ministry and cross-sectoral working groups to develop and implement plans and actions which cut across aspects of land, water and livelihood resource needs.
- Establish indicator metrics for multiple water, land and livelihood resources and outcomes.
- Evaluate vulnerabilities and capacity of natural capital, ecosystem services, and livelihoods.
- Provide early warning for *zud*, based on summer and early winter conditions.
- Provide training for integrated management that provides tools and skills for assessing and monitoring natural capital, ecosystem services and socio-economic conditions across the river basin region.
- Provide green development courses for local communities and schools systems. Also provide training to resource managers on how to access and communicate information on climate change, natural resource management, and green development opportunities. For example, develop a webinar program to learn and disseminate skills.

Conclusion and Implications

While there are a number of actions that can occur at the local level, support from the national government to the county levels were also needed. Further development of 2-way dialogue between local and central government decision makers was also seen as needed. The most frequently listed "best coping strategy" across all ecosystem types was for herders to have enhanced capacity for cooperation, both among themselves and with administrators. Furthermore, one herder said that in the past, "we deeply understood that the most important thing is cooperation during natural disasters." Herders want improved education and training to cope with climate and market changes. This can be done by strengthening and building pastoral networks, and combining that with modern technology like TV, apps on cell phones.

Bringing Rangelands into the Backyard: Educating Urban Audiences about Rural Landscapes

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Keywords: education, landscaping, water conservation, rangelands

Introduction

Rangelands cover 85% of Wyoming and the average precipitation is less than 13 inches per year (National Atlas 2005). This arid climate is not conducive to most water-hungry landscape plants without significant water and nutrient inputs. However, there is a plethora of native plants that thrive in this tough environment. A growing number of home owners are looking for ways to conserve water and save money. If low-water-use plants, such as those found in rangelands, are incorporated into the landscape, inputs are greatly reduced and resources are conserved (Sovocool et al 2006).

Materials and Methods

An online survey was developed and distributed to community members, land managers, and educational entities across Wyoming. The results from that survey showed the need for a class on rangeland plants and native landscaping.

The class developed was a 3-session event entitled “Keep Wyoming in Your Backyard”. Two evening classes introduced participants to Wyoming’s climate, soils, native plants and how to incorporate them into Wyoming landscapes. A Saturday class followed where participants learned about landscape design and created a home landscape using native plants (Figure 1). The class culminated in a field trip where participants toured nearby rangelands and homes with native landscaping design elements (Figure 2). Native seeds and numerous informational resources were offered to participants.

◂ **Figure 1. Participants creating home landscape design.**

Figure 2. Students learning about rangeland soil and plant adaptations on field trip.

Participants requested more in-depth training in plant identification so they knew what to incorporate into landscaping. Plant identification and nature walks were organized in different locations in spring and summer.

Results and Discussion

Results from the online survey showed that 270 out of 278 respondents (97%) wanted to learn more about native plants. In addition, 95% said they had some interest or were very interested in learning more about native landscaping.
An evaluation was completed at the conclusion of the class. Some examples of how participants planned to use the information included:

- *I will use the information to do landscape plans with natives to reduce water use and help native pollinators.*
- *Learning what to put where in my two acres. Starting almost from scratch. This class has answered many questions and has given me a lot of options to think about.*

An evaluation was also complete five months after the class. 100% responded they have completed projects this summer related to using natives in the landscape. Examples included:

- *A rock garden with native plants. Spread wild flower seed received from the class.*
- *I used the wild flower seeds to fill a space in yard where I did not want grass and didn't want high maintenance. I also did a rock area and plan to do more next year with that to reduce areas needing special watering. The wildflowers look great. Thanks for info on the seeds.*

When asked what benefits will result from your planned or completed projects, the following were selected: use of regionally adapted plants, soil conservation, water conservation, pollinators, reduced non-native or noxious weeds, wildlife habitat or food, reduced pest management and medicinal or other uses.
Hurd (2006) found that water cost, education and regional culture are significant determinants of landscape choice. Home owners reach out to their local Extension offices for plant lists, landscaping ideas and other education on water conservation. By teaching clients about rangelands, soil, locally-adapted plants, micro-climates and water needs, they can incorporate those concepts into landscaping design. If enough home owners convert to a "rangeland-type" landscape, a culture of acceptance forms.

Conclusion and Implications

The online survey results and evaluation information show that people are interested in learning about native plants and, when given education on what plants to use and how, they will implement projects that bring rangelands into the backyard. These projects have benefits that include soil and water conservation as well as benefits to pollinators, wildlife and reduced weed pressure.

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6.4 Historic & cultural response and adaptations to drought in grasslands

Temperature and Precipitation Influences on Grassland Production across Natural Sub-Regions of Southern Alberta

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Key words: Temperature, precipitation, yield, climate, forage

Introduction

Smoliak (1986) researched the relationship between climatic conditions and forage production over a 50-year period for a southern Alberta mixed-grass plant community. Findings include that spring and early summer precipitation, as well as May and June temperature, can predict plant production. Precipitation and temperature conditions change from drier and warmer to wetter and cooler across southern Alberta grassland natural subregions (NSRs) of the Dry Mixedgrass (DMG), Mixedgrass (MG), and Foothills Fescue (FF), respectively. A question remains regarding how the relationship between climate and forage yield also changes across this same gradient.

The Government of Alberta Range Management Branch has collected long-term forage yield information at range reference area (RRA) sites. We replicated Smoliak's study in a nearby DMG RRA and in one more RRA within each of the other aforementioned NSRs. We also more broadly examined climate influences on forage yield within each NSR. Long-term climate data show that, in southern Alberta, growing seasons are getting longer, and warmer conditions occur more frequently (Wheaton et al., 2014). Understanding climate and forage relationships may provide insight into how changing climate regimes alter forage resources across southern Alberta.

Materials and Methods

RRAs are small exclosures within grazing dispositions. Exclosures exclude livestock grazing over a small area (1-2 ha). Forage yields are measured annually by clipping 10, 0.25 m^2 plots from August-September within the exclosure. There are 34 RRAs in southern Alberta; 18, 7, and 9 of these are in the DMG, MG, and FF NSRs, respectively. Most were established in the 1980-90s, but some date to the late 1960s.

Alberta Agriculture's weather station data viewer was used to obtain historical climate data. Local climate conditions are estimated by extrapolating from a network of weather stations. Given their importance and availability, we used monthly precipitation (mm) and average daily maximum temperature (°C). Stepwise multiple regression and correlation were used to determine how these variables influence and relate to forage yields.

Results and Discussion

At Onefour (DMG) regression identified May temperature and June precipitation as predictors of forage yield, but the relationship was relatively weak compared to Smoliak's study (r^2 = 0.25 vs 0.63). Later-season precipitation perhaps played a greater role in Smoliak's plant community because of the greater dominance of *Bouteloua gracilis*, which is a major warm-season forage within the largely cool-season dominant DMG. Smoliak also removed litter, which can ameliorate climate effects on forage yield, and captured data over a longer period (1930-1983 vs 1970-2014). However, a stronger relationship occurred ($r^2 = 0.57$) when we included climate conditions from the previous year, after which regression identified additional variables of the total monthly precipitation for February, April, and September of the previous year as well as February and March average temperatures of the current year as factors. For Twin River (MG), regression identified June and July precipitation totals as factors predicting forage yield, albeit the relationship was weak ($r^2 = 0.16$). Including climate conditions from the previous year in the regression again improved the relationship (r^2=0.39). This model identified precipitation totals for June, July, and October from the previous year as well as March and August precipitation for the current year as factors. For Willow Creek (FF), regression selected predictors of May and June total precipitation, but the relationship was again weak ($r^2 = 0.13$). The estimation of forage yield was improved when May precipitation for the current year, combined with precipitation for June and July from the previous year, were included in the regression ($r^2 = 0.25$).

For RRAs across the DMG, regression showed that April-June precipitation influenced production, but the relationship was weak ($r^2 = 0.14$). The same occurred for MG (April-June) but the relationship was stronger ($r^2 = 0.21$). For the FF RRAs, forage yields were influenced by May, June, and July precipitation coupled with August temperatures ($r^2 = 0.13$). This suggests that precipitation and warmer conditions later in the growing season play a greater role in the cooler and wetter FF NSR. Correlation showed that forage yields were negatively associated with April-June temperatures for the DMG and MG NSRs ($r < -0.19$, $P < 0.002$). Monthly temperatures did not correlate with forage yields for FF ($P > 0.15$). For DMG and MG, April-June precipitation of the current year best correlate with forage yields ($r > 0.36$, $P < 0.001$); and including this interval from the previous year's growing season improved the correlation for both NSRs ($r > 0.39$, $P < 0.001$). Only May and June precipitation correlated with yields ($r > 0.18$, $P < 0.007$) for the FF NSR.

Conclusions and Implications

Our results suggest that precipitation and temperature effects on forage yields are complex, interactive and operate at multi-year time scales. This makes speculation on how climate change may affect forage yield across the three NSRs tenuous. What is clear is the relative importance and contrasting effects of moisture and temperature across grasslands of southern Alberta. Our results suggest earlier-season (April-June) precipitation plays a more important role in the DMG and MG. Moreover, warmer early-season temperatures are negatively associated with yields in the DMG and MG, whereas warmer conditions later in the growing season are positively associated with yields in the FF. This suggests that warmer temperatures during the growing season may reduce yields in the DMG and MG, but increase yields in the FF. Climate change may therefore differentially influence forage resources across the grasslands of southern Alberta.

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Modeling Spatial Distribution of a Moroccan Silvo-Pastoral Tree under Climate Change (e.g. *Argania spinosa* L. Skeels)

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Keywords: Argan, SDM, MaxEnt.

Introduction

The geographical location of Morocco explains its wide diversity of ecological conditions. As such, altitude varies from sea level to 4100 m, the geology is diverse, and rainfall ranges from less than 30 mm/year in the south to more than 2000 mm/year in the north. As a result, Morocco is characterized by 39 terrestrial-ecosystems and is one of the most diverse countries of the Mediterranean region in terms of plant species, housing the most species in North-Africa with 4200 floral-taxa, including 1282 subspecies, representing 920 genera and 130 families (Fennane et al., 2012).

According to Moroccan law, people living near forest domains are allowed two special permissions:

1) the right to collect dead wood and
2) the right to graze livestock.

Grazing within these forests covers almost 9 M ha, of which 0.87 M ha are known as Argan-ecosystems. Argan is endemic to southern Morocco and is characterized by water scarcity and vulnerability to desertification. It provides many functions and ecosystem services, including providing an important source of income for local populations. The main tree uses are leaves (grazed by goats) and fruit production (argan oil). As rangeland, it produces 170 to 200M FU/year (Forage-Unit is equivalent to the average energy produced by 1kg of barley).

Climate changes, including increased temperature, more variable rainfall, and frequent droughts, are expected to result in a significant loss of crop yields leading to negative consequences on food security and safety (IPCC, 2014). Under climate change, Morocco is expected to be severely impacted. Sustainability of Argan-forests and its associated rangeland are a key factor for ensuring inhabitants' survival.

A holistic approach is needed to address the various components of the Argan forest and ensure sustainable rangeland management, including tree regeneration and reforestation efforts. It also requires a better understanding of Argan land suitability while taking into account the effects of climate change. This paper aims to 1) identify the factors limiting Argan-tree distribution, and 2) maps the potential distribution of this silvo-pastoral species, which predicts the change in its geographic distribution and habitat suitability due to climate change.

Materials and Methods

This study focuses on the Argan tree (family Sapotaceae) in Morocco (21°-36°N; 1°-17°W). Due to the fact that it is a valuable natural resource, Argan-ecosystems have been designated as UNESCO's Man and Biosphere-Reserve in order to protect the species, forest function and to improve local population revenues.

A thousand occurrence points were randomly recorded from the national forest inventory database (IFN, 2005). In addition, 19 bioclimatic variables, extracted from the WorldClim database, distance to ocean and Topographic Wetness Index (TWI) were used. These variables have been projected under a moderate climatic scenario (RCP 4.5) in order to predict the future species distribution map.

Species Distribution Modeling (SDM) was used to link species locations with environmental characteristics in order to predict species occurrence likelihood and assess the contribution of each environmental variable. The Maximum-Entropy algorithm (MaxEnt) was chosen since it is considered the best-performing model. MaxEnt (3.3.3k) platform (Phillips et al., 2006) was used to produce the assessment of model performance, tabulate contributions of each predictor, and develop current and future probability maps of species occurrence. QGIS was used to prepare data. R (v3.1.3) was used to analyze the data and derive zonal statistics. Area-under-the-curve (AUC) of the receiver-operating characteristic is a threshold-independent measure of model prediction accuracy. The model is excellent where: $AUC > 0.90$, good: $0.80 < AUC \leq 0.90$; acceptable: $0.70 < AUC \leq 0.80$; bad: $0.60 < AUC \leq 0.70$; and invalid for values ranging between $0.50 < AUC \leq 0.60$.

Results and Discussion

Output from SDM is a continuous probability map showing the present and predicted area suitable for Argan. The AUC is 0.964. It indicates excellent quality predictions of the model.

The relative contribution of covariates to the MaxEnt model, assessed through Jack-knifing, showed that the coldest quarter and wettest month of rainfall, in addition to temperature seasonality and the maximum temperature of the warmest month, all contributed significantly to explaining the spatial distribution of Argan.

Using a predefined threshold, the area suitable for Argan tree distribution seems to be highly dependent on climate change. As shown in Fig. 1, the land area suitable for Argan will go further north of the present area. However, more lands located in the southern part of the country will become unsuitable.

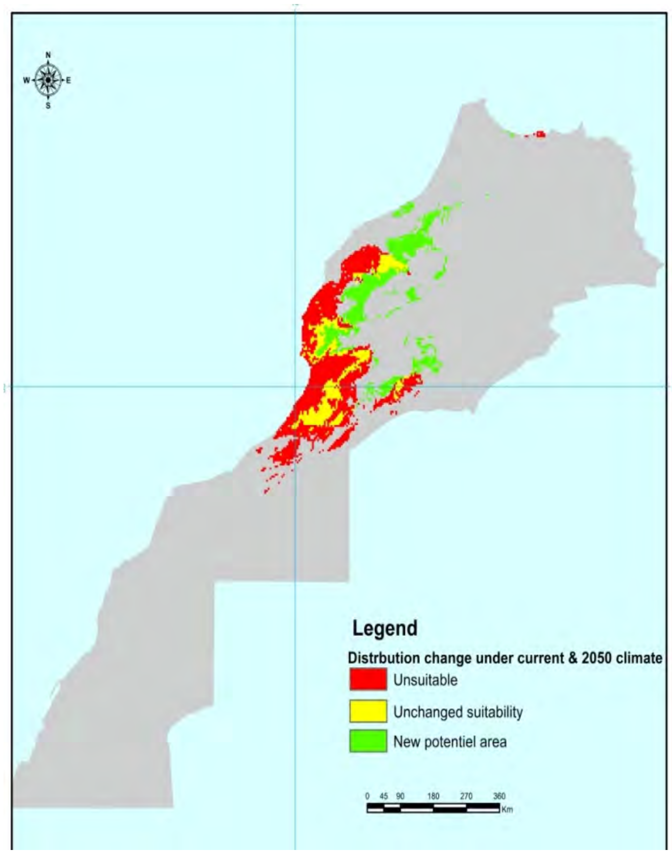

Figure 1. Project effect of climate change on Argan distribution.

By 2050, projections show that 34% of current Argan area will be lost. In addition, 75 % of the current suitable area will become unsuitable. Moreover, Argan will migrate to new areas (unsuitable under current conditions), which will constitute 60 % of the future area covered by this species. Only 25 % of current Argan cover will remain unchanged.

Conclusions

This study provides the first predictive map for the spatial distribution of Argan in Morocco under climate change scenarios. MaxEnt modeling accurately predicted the existing tree distribution.

The ability of species to survive in changing climates relies heavily on the specific capacity to locally adapt to climate, their phenotypic plasticity, and on species migration abilities (because this species is believed to be one of the oldest and few surviving relict-breed species of the tertiary period). Given this, the use of predictive maps for important plant species is a valuable tool for rangeland conservation, monitoring and management in the context of climate change.

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Modelling the Impact of Human and Climate Change on *Stipa tenacissima* Distribution in the Arid and Semi-Arid Rangelands of North Africa

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Key words: Ecological modeling, niche, species occurrence, climate adaptation, crop encroachment

Introduction

Rangelands in the Southern part of Tunisia are characterized by the extent of the impact of human induced activities in particular overgrazing and encroachment of cultivation into best rangeland sites (Ouled Belgacem et al., 2008). Furthermore, climatic changes are expected to increase the inter-annual variability of rainfall for many locations and to raise annual mean temperatures globally (IPCC, 2012). In fact, the scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) project a further increase in global mean surface temperature of 2–6 °C above pre-industrial levels by 2100, increased incidence of floods and droughts, and spatial and temporal changes in precipitation patterns (IPCC, 2007). However, these projections provide little information on how this might affect rangeland plant communities at the local scale. The purpose of this study is to assess the vulnerability of the ecologically and economically important native rangeland plant species *Stipa tenacissima* L. This research is needed to develop strategies for climate change adaptation. The adaptation measures should focus on building and strengthening the resilience of these fragile ecosystems.

Materials and Methods

The study was conducted in the southern part of Tunisia. The climate of the site is characterized by an extreme irregularity. The long term mean annual rainfall is ranges between 100 and 220 mm/year. *Stipa tenacissima* L. is a perennial grass considered as one of the last barriers against the encroachment of the desert thanks to its highly developed root system that protect soil and limit erosion.

Modeling the climate envelope is a tool used to quickly assess the potential impact of climate change on the distribution of species and ecosystems. This type of modeling uses species occurrence environmental data to predict its climatic niche. The methodology involves the use of thematic layers. The modeling is performed with ARC GIS software and Maximum Entropy (MAXENT) Model (Phillips et al., 2006).

Climate projections were made for the years 2020 and 2050 using the average of predictions about global circulation model widely used (HADCM3) under the scenario A2 of CO2 emission (Ouled Belgacem and Louhaichi, 2013).

Results and Discussion

The vulnerability of *Stipa tenacissima* to climate change in the current situation and that expected for 2020 and 2050, show that the predictions are highly pessimistic since the situation can be considered as catastrophic in the future because the entire area of this ecosystem is classified as vulnerable to highly vulnerable. The results of modeling showed that both classes of none and slightly vulnerable will disappear by 2020. This will induce a high decrease of the range production both in biomass and in forage unit to more than 75%. Consequently this will further increase the deficit of feeding balance already marking the area. In addition to the reduced quantitative indicators (cover, density and biomass), this vulnerability will also lead to qualitative and physiognomic (species composition and diversity) changes resulting in the scarcity of the key species *Stipa tenacissima* in all parts of its current range with the exception of those which are more favorable and may benefit from a supplement water runoff. Other undesirable species (low palatability) such as *Haloxylon scoparium* and *Reaumuria vermiculata* which are more adapted to high temperature and drought stresses may have the opportunity to dominate and invade the area.

Conclusions and Implications

The combined effects of climate change and animal pressure on *Stipa tenacissima* rangelands located in southern Tunisia are having significant adverse impacts on this species under high CO_2 emissions scenarios. Already threatened, the species appears to be, coming under greater threat and present a very high vulnerability to climate change. These results suggest that without improved management, these sensitive communities could experience further degradation. An adaptation strategy is needed to increase the resilience of the most vulnerable species through proper grazing management, the selection of more drought tolerant taxa and the establishment of other mitigation measures, such as water harvesting techniques.

Acknowledgments

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Environmental Resilience of Rangeland Ecosystems: Assessing Climate-Driven Land Degradation in Arid and Semi-Arid Zones of Central Asia

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Key words: Rangeland ecosystems, Central Asia, bi-monthly NDVI, climate anomalies

Introduction

Spatial extent of dryland rangelands in Central Asia (Tajikistan, Kazakhstan, Kyrgyzstan, Turkmenistan & Uzbekistan) is vast. Vegetation trends in this area are mostly driven by precipitation and temperature dynamics, e.g., warming temperature trends lead to decreasing of palatable rangelands plants. The effects of shrinking of the Aral Sea Basin coupled with the USSR collapse have caused increased population migration and uncontrolled grazing, which lead to salinization and further deterioration of rangeland ecosystems in the region. This research assessed vegetation dynamics in Central Asian rangelands to determine which are associated with climate patterns and which are associated with anthropogenic pressure.

Materials and Methods

Remotely sensed vegetation data and climate parameters were used to assess land degradation in rangelands in the last decades. Climate impacts in Central Asian drylands were coupled with socio-economic changes caused by the USSR collapse (Kariyeva et al., 2011; Zhou et al., 2015). To assess dryland ecosystems' responses we explored resilience factors for biodiversity elasticity and vegetation distribution patterns (dense/sparse) following land degradation. Preliminary objective of this study was to demonstrate and measure a general trend of vegetation degradation and inter-decadal changes in vegetation patterns due to climate anomalies (past & present) and anthropogenic effects on local and regional scales in Central Asia.
To determine whether and how vegetation dynamics in Central Asian rangelands are associated with climate patterns vs. anthropogenic pressure, we used bi-monthly 8-km GIMMS AVHRR data (1982-2011), 250-m MODIS MOD13Q1 data (2000-2009), and compared with time series data (CRU TS (v3.23)) for precipitation and temperature effects during selected period of time. The CRU time series (0.5x0.5 degree) grid datasets were extracted for 1981-2010 to assess month-by-month variation for climate/precipitation on a larger scale. We assessed various rangeland habitats to evaluate temporal dynamics of vegetation in these ecosystems. To account for surface biophysical properties we applied a sparse vegetation index that was developed to classify land cover, identifying "bare lands" where the index value more or less than 15 % of vegetation cover.

Results and Discussions

The long-term assessment of vegetation cover dynamics has demonstrated clear NDVI-based responses and changes (values ranging 0.1-0.4) over time in arid and semi-arid areas of the region (Fig. 1). Classification of vegetation patterns demonstrated alteration of positive and negative changes in vegetation responses during last decades in Central Asian drylands. The vegetation change detection analysis between 2000 to

2009 (Fig. 2), has revealed regeneration and increased vegetation trends responses in the northern latitudes of Kazakhstan and in the south-eastern part of the country along Uzbekistan and Kyrgyzstan border, whereas the southern part of Turkmenistan has demonstrated decreased vegetation on last nine years. The green areas in (Fig. 2) are observed as grazing and fodder production areas, which are susceptible and vulnerable to overgrazing, soil salinization, and loss of fertile lands. The former highly productive livestock system has deteriorated negatively affecting livelihoods of the local people: besides cropland abandonment, the region has also been affected by a fractional recovery of grasslands as a result of declining livestock numbers since 1990 (Karnieli et al., 2008).

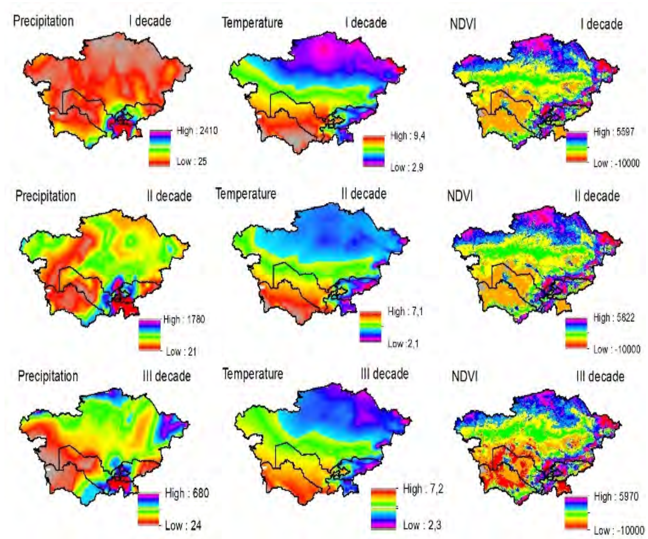

Figure 1. Study region divided in three decades and observed precipitation/temperature/NDVI values for period 1982-2011; with classified NDVI range values (multiplied *10000).

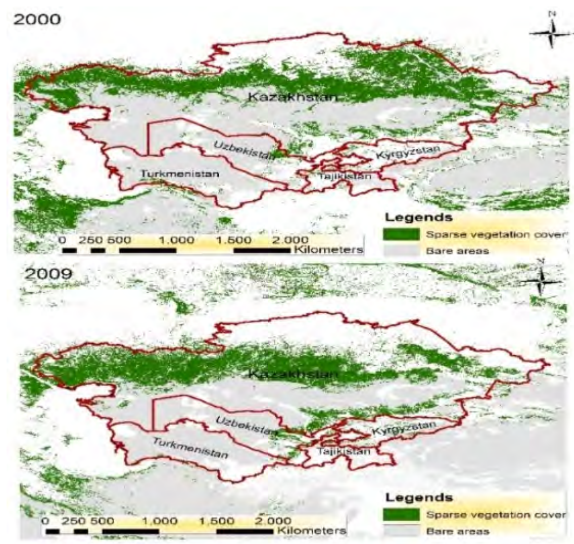

Figure 2. Time series analysis highlighted for rangeland assessment with extraction two legends as sparse vegetation and bare areas which is observed on dryland ecosystems of Central Asia (2000 & 2009).

Although there are signs of partial vegetation recovery, agricultural and food production indices in almost all of the Central Asian countries remain below the pre-independence levels. As a consequence of a mono-cropping of wheat and cotton, the arable land resources in this region, particularly the desert and semi-desert plains, have come under serious threat of soil erosion, loss of soil fertility and organic matter due to overgrazing, expansion of cropped area, increasing of soil salinization and waterlogging.

Conclusions and Implications

Monitoring rangeland's vegetation under changing climate and institutional conditions are important for understanding the drivers of the developing economic infrastructures (i.e., quantity of livestock flocks, crop rotation system). Sound management of rangelands, main pools of carbon stock of the region, is playing an indispensable role and needs an enhanced understanding of nonlinear interactions and vulnerability induced by human versus climate-driven impacts in Central Asian arid regions. Drought and loss of arable lands can have a direct and far-reaching effect on food security in Central Asia in upcoming years.

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Theatre as a Sustainable Communication Tool in Addressing Climate Change Impact on Affected Communities

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Key words: culture, sustainable development, climate change, theatre for development

Introduction

In recent past, the needs for an all-encompassing global approach towards addressing climate change concerns have been evident in all spheres of development thinking. In advancing these arguments, the triple bottom-line of sustainability argument has been advanced variously with specific reference to economic, environmental and social dimensions. However, in developing African countries, the overarching impact of culture on virtually all aspects of development cannot be overlooked. Throughout indigenous socialization process, the role of music, dance, drama and other traditional activities in this process has been very persuasive within the Ghanaian context and other African countries. In terms of nomadic livestock activities and climate change, the impact of climate change has been obvious and continues to contribute towards sustainable development. Culture is described as a total of meanings or knowledge that human beings need to function in a certain situation: knowledge of language, habits, rituals, opinions, values and norms (Shadid, 2007). During the past decades, Theatre for Development which involves the use of popular theatre has been practiced in developing countries.

This technique has proven successful in areas such as poverty alleviation, health education among others. For some authors, like Dale Byam, Theatre for Development (TFD) represents an evolution in relation to the 'less interactive styles of popular theatre (Byam, 1999). She characterizes TFD by the increase of people's participation in the theatrical process: 'Theatre for Development aims to encourage the spectator in an analysis of the social environment through dialogue' (Byam, 1999, p. 12); while for others, like Wurff, (2009) Theatre for Development is also identified with scripted plays performed to live audiences or broadcast over the radio, lacking people participation in the creation and in the performance. Thus, it is evident that popular theater as theater for development technique is well situated within the African culture Bai et al., (2008). In recent time, climate change issues have been discussed on both national and international platforms. Scholars and practitioners have therefore sought to identify how climate change mitigation strategies will be adopted and communicated among citizens of various countries. This has led to several researches on issues pertaining to climate change activities. However, little is said with regards to communicating Climate Change in Ghana through theatre. This study therefore sought to examine how popular theater can be used to communicate the effect of climate change activities on affected persons of Tafi-Agome a community located in the northern path of Volta Region of Ghana.

Materials and Methods

This study adopted the use of the indigenous cultural values such as the use of drama and traditional dance movement to identify the effect on climate change activities on the affected community. The convenience sampling technique was used to select twenty (20) women form the Tafi-Agome Community in the Volta Region of Ghana and this method was deemed appropriate for the study because the researcher engaged only respondent who were available and ready to use dance and drama as a medium for communicating their challenges within the community. A post performance discussion was undertaken by the researchers with the respondents and observers on how their challenges could be addressed.

Findings and Discussions

Findings from the study indicated that the people from Tafi-Agome a community in the Volta Region of Ghana are affected by climate change activities. The inhabitants of this community are mainly into the cultivation of cassava and the rearing of animals. During the post-performance discussion, women who were heads of families during to the passing away of their spouses indicated some of the challenges they faced in managing their homes.

Implication of Climate Change on Livelihood

Changes in the climatic conditions have enormous implication on their financial resources. They are unable to cater for the socio- economic needs of their families and the inability to save. With regards to their natural capital, climate change activities had affected the life expectancy of some of their livestock, certain trees which used to provide them with shade had withered off and some water bodies which were used for their domestic activities were dying up. They indicated that the changes in the climatic conditions have adversely affected their crop yield.

Communicating Climate Change with Theater

The implication of climate change activities was communicated through the use of popular theater this included drama and dance movements. Through the drama and dance movement patterns, the indigenes of the community portrayed how they used to have abundance of food during certain seasons. However, in recent time the rain fall pattern and other climatic conditions had changed leading to drought and poor crop yield (Millennium Ecosystem Assessment, 2005). Though, most of these rural folks did not understand the reason for this drastic change in the climatic conditions, It was evident from their dances and drama that they attributed these changes to the lack of allegiance and respect for the lesser gods during this current dispensation.

Conclusion and Implications

From the findings, the study concludes that although these rural folks do not understand the dynamics and complexities of climate change, through the use of their indigenous cultural settings they are able to communicate and appreciate the challenges of climate change activities on their livelihood. Thus, the study recommends the use of theater art as an indigenous research methodology in communicating; educating and empowering especially women within rural communities' to the various livelihood adaptation strategies to enable them cope favorably in this era of climate change.

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Grazing Land Assessment and Management in a High-tech World

7.1 Technology in land resource data acquisition and modeling

Grassland Mapping, Measuring, Monitoring, Modeling, and Prediction (4MP) Using Remote Sensing Methods

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Key words: remote sensing, mapping, measuring, monitoring, modeling.

Introduction

Grasslands, cover about 40 percent of the Earth's terrestrial area providing vital global ecosystem services, are sensitive to disturbance and invasion, and are prone to rapid functional collapse. Critically, grassland ecosystems are carbon sinks or sources depending upon management practices largely surrounding cropping and grazing. Grasslands worldwide have been degraded in recent decades due to intense human activity and climate change and this degradation not only threatens ecosystems but negatively affects ecosystem services. Pressures from degradation emphasize the need to understand, evaluate, and monitor grassland ecosystems. For over the past 10 years, my research group has applied remote sensing on grassland mapping, measuring, monitoring, modeling, and productivity prediction. More specifically, we have used remote sensing to 1) determine solitary measures of grassland growth and productivity, 2) evaluate grassland condition in response to climate change, grazing and fire, 3) map wildlife habitats, 4) estimate forage quality, 5) measure leaf CO_2 exchange rate, and 6) investigate biotic and abiotic relationships. In this paper, I will summarize our research and indicate some challenges we are facing.

Materials and Methods

Field data, including biophysical parameters, remote sensing variables, and environmental conditions, have been collected over the Grasslands National Park of Canada (GNPC) and surrounding pastures during maximum growing season each year since 2002. Biophysical parameters include vegetation cover, canopy height, leaf area index (LAI), and biomass. Remote sensing data include spectral reflectance for the wavelength range of 350-2500 nm using an ASD spectroradiometer. Environmental conditions include climate components and soil properties. Grasslands National Park, located in southern Saskatchewan bordered with the USA, was started to establish in 1985. It excluded domestic grazers for about 20 years before bison was reintroduced into the west block of the park in 2006. Therefore, the park and pastures outside of the park owned by federal and provincial governments and ranchers are ideal for grassland study under different management schemes. Field sites are randomly selected from upland, sloped land, and valley with different disturbances (grazing, fire, and invasive species). Because of the collaborative study and to capture the spatial variation of the field condition, two 100 meter cross transections were consistently laid out for each site, each year, all data were collected on quadrats along the transects with 10 or 20 meters' intervals.

Results and Discussion

Grassland mapping: Remote sensing provides a suitable tool to map grassland at different levels with different spatial resolutions. Grassland masking was mainly based on grassland area delineation, which is separating grassland from other land cover types. Different grassland community mapping is mostly conducted because of the management needs and the available satellite imagery resolution. Species level mapping is still a challenging issue because of the requirement of high special resolution imagery that is at a high cost (He 2008) (Table 1).

Table 1. Grassland Mapping Levels with Satellite Imagery.

Mapping	Applications	Challenges
Masking grassland from other land cover types	Grassland inventory; grassland insurance purpose; grassland management.	Tradeoff between accuracy and coverage: to map a larger area, the accuracy especially for boundary is low because of the low spatial resolution of satellite imagery. Most products are as by-products of land use land cover classification, so grassland has less attention.
Community mapping	Grassland management; monitoring; health condition assessment; carrying capacity estimation.	Additional ancillary data are a requirement to create high accuracy map, e.g., topography, soil type, climate data, etc.
Species mapping	Species composition; invasive species mapping; health indication through species identification.	High resolution imagery is necessary but the cost is high. UAV/drone technology is becoming popular on this aspect, but the coverage is relatively small.

Biophysical variables measurements: Deriving biophysical properties using remote sensing is one of the major applications of remote sensing on grassland study (Zhang 2006, He 2008, Li 2010), while some of the properties are easy to estimate using empirical models through building direct relationships between biophysical properties and remote sensing variables (reflectance or vegetation indices). However, some parameters are difficult to reach with a high accuracy (e.g., canopy height) (Table 2).

Table 2. Grassland Biophysical Properties Estimation Using Remote Sensing.

Biophysical Properties	Accuracy	Challenges
Cover	High	It is hard to map the canopy when it has more than two layers
Leaf area index	Medium	Most products are plant area index instead of leaf area index when using remote sensing products
Canopy Height	Low	High accuracy LiDAR data are needed
Biomass/productivity	Varies	It is hard when non-photosynthetic vegetation presents.
Heterogeneity/diversity/ species composition	Varies	Different biophysical properties with different scale of spatial, temporal, and vertical heterogeneity.

Monitoring (Yang 2013, Xu 2016): The significant contribution that remote sensing can provide is in monitoring grassland historical changes caused by ecosystem succession, disturbances (grazing, burning), conservation action, and climate change. This advantage is becoming more promising as archived satellite imagery can go back much earlier. As one example, Landsat imagery can reveal the story of Grasslands National Park from before the park was established up to the re-introduction of bison into the park (Fig. 1). In Fig. 1, all images were in standard false colour composite (RGB: NIR, Green, Red). Image a is a Landsat TM image with the park folding boundary (yellow line) before the park was established in 1985. Clearly, there is no difference for the grasslands within the park and the outside pastures. Image b is a Landsat TM image without the park boundary line after the park was excluded from domestic grazers for around 20 years. The park boundary can be seen clearly without a boundary line. The conservation effects are prominent. Image c is a Landsat TM image after bison was re-introduced into the park for two years. However, the bison mainly stayed in the northern boundary. As the result, the difference between within the park and outside the park is disappearing for the northern sector, especially the north east corner where the bison primarily grazed. Image d is a Landsat OLI imagery after the bison was moved around the entire fenced portion of the west block of the park. Other than different land cover types, the difference between the park holdings and outside pastures cannot be viewed from satellite imagery anymore.

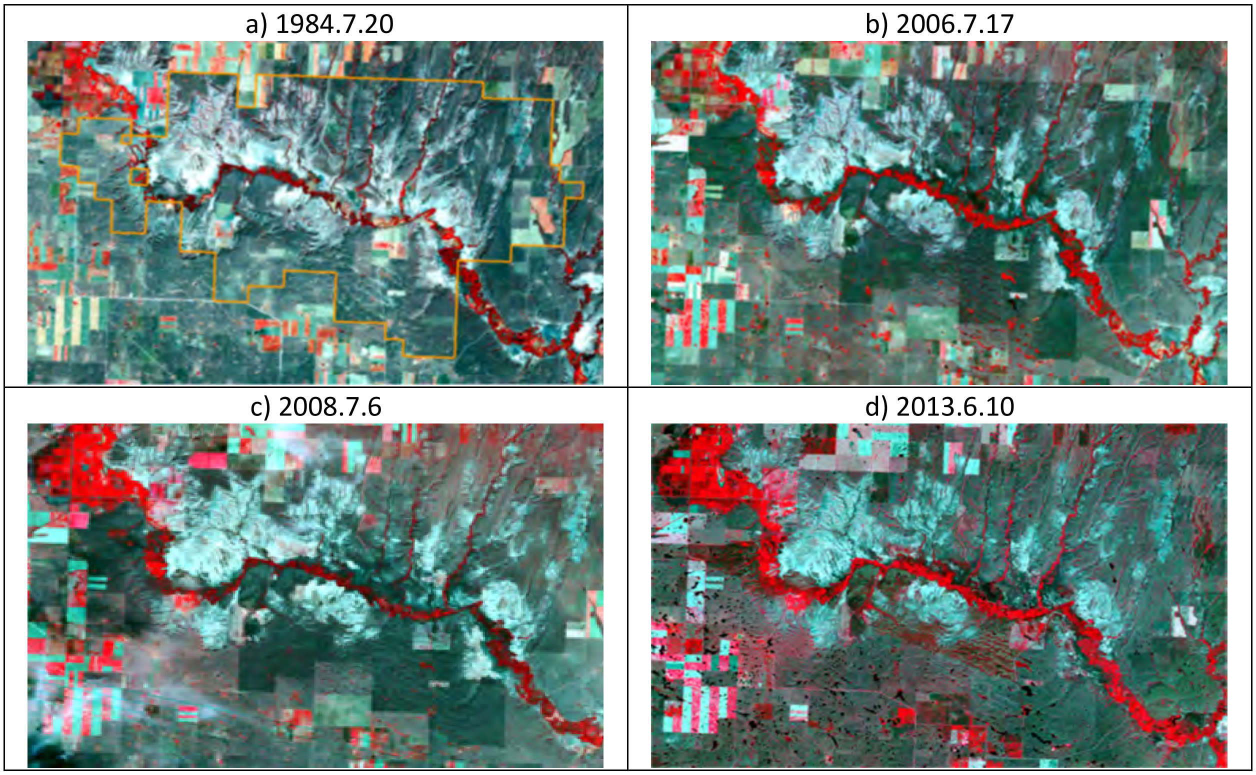

Figure 1. Historical Change of Grasslands National Park from Landsat Imagery.

Modeling: Processing models have been used for grasslands especially for biophysical parameters derivation. With the limitations of site specific process modeling, remote sensing adds the spatial dimension into modeling. Even though many efforts have been made on developing empirical models to estimate biophysical properties, attempts were also made with a combination of site-based process models and spatial-based satellite imagery with the advantages of ecological processing of grassland ecosystem and the spatial variations (He 2008).

Productivity prediction: Remote sensing, challenged as the fact that satellite imagery is historical data (past), has limitations on prediction. However, any prediction model is based on the understanding of the historical performance. With a longer range of historical remote sensing data, it has increased the potential to predict grassland productivity, health conditions, and the future trajectory.

Conclusions and Implications

While these studies have advanced our understanding of how to measure, monitor, and model specific elements of the grassland community in isolation, an obstacle to continued progress exists. Assessing community effects of herbivory and human use for ecosystem services is a comprehensive assessment of vascular, non-vascular, biotic and abiotic features of grasslands. In addition, we found that the accuracy of retrieved biophysical variables (e.g., leaf area index & productivity) was limited by presence of non-photosynthetic vegetation (NPV), biological soil crust (BSC), and bare soil because of their unique spectral responses. Although using satellite imagery with suitable spatial resolution can improve estimation accuracy of biophysical variables, the accuracy was the greatest during the peak growing season when the green vegetation was dominant, suppressing NPV, BSC, and bare soil effects. However, there is no solution yet to quantify NPV, a vital component in mixed grasslands. NPV is critical for determining herbivore carrying capacity (HCC) in the winter; unfortunately, it is a virtually unstudied field for remote sensing. Thus, to make the next important advance in large scale grassland ecosystem monitoring and conservation using remote sensing tools, it is necessary to study BSC and NPV and integrate this with established spectral relationships and to open the door to large advances in regional scale, multi-season measurement, monitoring and conservation through carrying capacity estimation.

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Mapping Canada's Rangeland and Forage Resources Using Earth Observation

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Key words: Rangeland, forage, remote sensing classification, random forest, vegetation index

Introduction

Differentiating rangeland, pasture and forage crops using Earth Observation (EO) is generally difficult because of their spectral reflectance similarities and partly as a result of the variability of climate, soil type and management practices. This variability becomes increasingly problematic over larger areas. Previous efforts to create an inventory of rangeland and forage resources across the Canadian Prairies using classification of EO data have not achieved desired accuracies. The objective of this research is to determine which variables derived from remote sensing (optical, SAR or both) and the acquisition timing during the growing season can be most effectively used to produce increased classification accuracy of Canada's forage resources. Results to date will be presented.

Materials and Methods

Two pilot sites were selected which represent the variability of climate, soil, and ecoregions across the Canadian prairies. The first pilot site is located in the Aspen Parkland ecoregion of Southwestern Manitoba. The second site is located in the mixed grassland ecoregion of Southern Alberta. Field data related to land cover type and dominant species composition were collected across each pilot site during the 2015 growing season using a GPS-enabled ArcPad tablet. Additional reference data were acquired from provincial crop insurance datasets.

Due to the costs associated with acquiring a high resolution EO dataset for the prairie region, data sources were limited to cost-effective optical data and SAR as the results of this study may eventually be incorporated into an operational framework. Two sources of EO data were used to examine the potential of optical multispectral data as well as the applicability of available SAR data. Landsat-8 images were obtained from the US Geological Survey. All available 1T (terrain corrected) imagery with limited cloud/haze cover was obtained for the 2015 growing season over both study sites. The Landsat-8 scenes were radiometric and atmospherically corrected using the ATCOR 2 algorithm (Richter, 2010). Three or four scenes were used in the final classification for each site as images were reduced to those of acceptable quality, i.e. with no residual haze or clouds effects (Table 1). At each site a pre-crop greening and mid growing season scene were available, for the Manitoba site a late fall image was available after all crops had been harvested. Several studies have shown that C-band SAR data have proved to increase final map accuracy of agricultural classifications when used alone or in combination with optical data (McNairn et al., 2009; Smith and Buckley, 2011). Because of the visible difference in plant structure observed between rangeland, cropland and forage cover types, Radarsat-2 wide beam mode dual polarization imagery, acquired in July, 2015 and then resampled to 30m pixel spacing, was used in addition to Landsat-8 optical data.

Table 1: EO Data Sources

Sensor	Date of Acquisition	Study Site
Landsat 8 OLI	May 27, 2015	Manitoba
Landsat 8 OLI	July 30, 2015	Manitoba
Landsat 8 OLI	August 31, 2015	Manitoba
Landsat 8 OLI	October 18, 2015	Manitoba
RADARSAT-2 (Wide)	July 8—July 15, 2015	Manitoba
Landsat 8 OLI	May 19, 2015	Alberta
Landsat 8 OLI	July 6, 2015	Alberta
Landsat 8 OLI	August 23, 2015	Alberta
RADARSAT-2 (Wide)	July 20—July 27, 2015	Alberta

Due to the limitations of the spatial resolution of available optical and SAR data and based on initial classification tests of detailed classes, reference data were aggregated into three broad classes of rangeland, seeded forage, and cropland. All non-agricultural land was masked out using an existing AAFC dataset. The rangeland class is comprised of cover types such as upland native grassland, upland non-native grassland, reverted pasture, meadow and native shrubland. The seeded forage class aggregated perennial pasture and hay, as the two were determined to be indistinguishable at the spatial and temporal resolution required for the study. All annual crops were aggregated into one cropland class.

In addition to atmospherically corrected optical data, vegetation indices were derived from Landsat-8 multispectral bands. They included vegetation indices which highlight productivity and phenological differences in land cover types such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Senescent Vegetation Index (NDSVI), an indicator of the amount of senescent vegetation; and Tasseled Cap Wetness (TCW), which responds to soil and vegetation moisture. The potential of these variables was assessed in subsequent classifications.

Although there are many available pixel-based unsupervised classification algorithms, the random forest (RF) classifier was chosen for this study (Breiman, 2001). RF is a machine learning classifier which has shown improved results over more traditional classifiers such as maximum likelihood and other decision tree classifiers (Sonobe et al., 2014). RF was selected because it does not depend on parametric data, can be used with large numbers of variables, and it produces analyses of variable importance and internal classification error (the out-of-bag (OOB) error). An independent accuracy assessment was also conducted for each classification. Several classifications were run using logical groups of variables and the performance of classifications were compared using overall accuracy.

Results and Discussion

Several tests were conducted to determine which combination of optical and SAR variables produced the highest overall class accuracy. The first classifications were run using the Landsat multispectral data for all combinations of one, two and three dates (spring, summer, and late summer/fall). Generally, overall accuracies were improved when two or more dates were used. Ideally three dates should be used, representing pre-crop greening, mid growing season, and post-harvest, respectively. The addition of SAR to the optical variables increased accuracy for both the rangeland and seeded forage classes; however, a significant improvement was not shown for the cropland class for either site. The use of phenological variables derived from three dates of NDVI as well as three other vegetation indices improved classification results when compared to using only multispectral bands as optical variables. Again, using two or more dates significantly improved accuracy over using variables from a single date. The stability of the RF classifier was tested by reducing variables to the top ten and top five as determined when all available variables were included in a classification. The RF variable importance measure was used to reduce the number of unimportant and correlated variables (Breiman, 2001). Variables derived from spring imagery were determined to be the most important for distinguishing between rangeland and forage, specifically TCW and NDVI. Additionally, NDSVI, the indicator of senescence in late summer, was an important variable for all classes.

Conclusions and Implications

Knowledge-based variables including vegetation indices derived from optical imagery have the potential to increase classification accuracy for rangeland and forage classes over the use of multispectral band reflectance alone and in combination with backscatter values derived from SAR. With this knowledge, steps can be taken to improve the accuracy of existing EO-based inventory products to better monitor Canada's rangeland and forage resources at a national scale.

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A Risk-Based Vulnerability Approach for Rangeland Management

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Key words: Soil erosion risk, soil erosion thresholds, soil and water conservation, vulnerability

Introduction

In semiarid rangelands, continuous grazing may decrease vegetation cover, accelerate soil erosion and eventually cause a transition to an alternative, degraded state. State and Transition Models (STMs) illustrate possible changes in plant communities and soil properties and their interactions. They can be used to help decide where to monitor based on where change is most likely to occur. Williams *et al.* (2015) proposed a framework and methodology for inclusion of key eco-hydrologic relationships in STMs for assessing rangelands and guiding resilience-based management strategies. These key eco-hydrologic relationships govern the ecologic resilience of the various states and community phases on many rangeland Ecological Sites (ES) and are strongly affected by management practices, land use, and disturbances. The future challenge for rangeland erosion modeling is to aid in the process of defining thresholds and assessing the risk of crossing a threshold between different ecological states. In this context, this paper presents a methodology to inform rangeland management decision support utilizing STM methods and probability of occurrence of yearly soil losses between ecological states to define different soil erosion damage levels.

Material and Methods

Experimental Site

We illustrate the use of the risk assessment approach at the Kendall Grassland site located in the Walnut Gulch Experimental Watershed in Tombstone, AZ. The mapping unit consists of a complex of Loamy Upland and Limy Slopes. The STM for the Limy Slopes 12-16” p.z. ES included 4 states: Historic Climax Plant Community (HCPC), Eroded, Shrub, Lehmann Love Grass (hereafter referred to as Grass). Within the HCPC state, fire and drought could cause temporary shifts between two plants communities. In the STM, the Eroded state is considered to be so degraded that it has crossed a threshold and now has a less productive plant community. Total foliar cover and total ground cover for each ecological state on the STM were: (HCPC=61%, Eroded=35%, Shrub=38%, Grass=38%); (HCPC=70%, Eroded=25%, Shrub=29%, Grass=54%), respectively.

RHEM Risk-Assessment Tool

The risk assessment tool, implemented in the Rangeland Hydrology and Erosion Model, partitions a probability model to address different soil erosion damage levels and their probability of occurrence. The empirical probability distribution of annual soil losses of the reference state was partitioned in four ranges. They represent four soil erosion damage levels: low, medium, high, and very high. The assumption was that partitioning the probability distribution by specifying the 50^{th}, 80^{th}, and 95^{th} percentiles of the reference state enables comparisons of annual soil losses of alternative states for different damage levels. There is no consensus in the literature on the level at which events should be considered as extremes, so our thresholds were established for practical reasons.

Results and Discussion

RHEM was run with the same 300 years synthetic climate record for each state condition. The 50th, 80th, and 95th percentiles were extracted. Simulated average annual runoff and soil loss for each ecological state were: HCPC=15.84 (mm), Eroded=27.19 (mm), Shrub=26.04 (mm), Grass=20.29 (mm); HCPC=0.36 (ton/ha/year), Eroded=3.95 (ton/ha/year), Shrub=2.90 (ton/ha/year), Grass=0.73 (ton/ha/year), and the occurrence probability for each state was found (Table 1). Annual soil loss thresholds, [β_1=0.367 (ton/ha/year), β_2=0.655 (ton/ha/year), and β_3=1.049 (ton/ha/year)], were estimated from the empirical probability distribution of the reference state (HCPC).

The lower perennial grass and litter covers in the Grass state resulted in higher erosion compared with the HCPC state. Before the Lehmann lovegrass invasion, the formation of debris dams was a characteristic for the Kendall site where small terraces formed upslope of large clumps of vegetation. With die-out of native grasses and greater spread of Lehmann lovegrass, there were fewer obstructions, which allowed water to move down the slope more rapidly, increasing runoff and erosion. The results suggest that a shift from the High to Medium soil erosion damage class may be possible if management practices are implemented to promote litter production and reduce runoff and erosion. In contrast, in the STM, the Eroded and Shrub states are considered to be so degraded by soil erosion that they have crossed a threshold and now have a different, less productive, potential plant community. These states are within the Very High soil erosion damage class and the probability of bringing them back to the reference state is very low.

Table 1. Probability risk functions and their corresponding damage class, and probability of occurrence of yearly soil losses associated with the change from one state to another on the STM.

Probability Risk Functions	Damage Class	Probability of Occurrence			
		HCPC	Eroded	Shrub	Grass
prob ($X \leq 0.367$)	Low	0.500	0.010	0.036	0.249
prob ($0.367 < X \leq 0.655$)	Medium	0.300	0.041	0.039	0.260
prob ($0.655 < X \leq 1.049$)	High	0.150	0.047	0.102	0.221
prob ($X > 1.049$)	Very high	0.050	0.902	0.823	0.270

Conclusions and Implications

A probabilistic-based approach was developed to characterize rangeland conditions (or states) subject to the presence of a set of soil erosion thresholds. These were determined by partitioning the probability axis of the reference state annual soil loss empirical cumulative distribution. Thus, four possible soil erosion damage classes (condition classes) were generated. Furthermore, our approach is consistent with the model of range behavior proposed by Williams *et al*. 2015. Thus, this approach highlights the advantages of linking management actions to the structure and function of rangelands. For example, we illustrated the case where the Eroded state had crossed a soil erosion threshold, and the likelihood to move the eroded rangeland back to the grassland state was very low. This approach can be used to provide a quantitative rationale and indicators for distinguishing transitional and stable states on rangelands.

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Assessing the Provision of Ecosystem Services in Alberta's Rangeland Using a Modeling Approach

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Key words: CENTURY model, calibration, carbon dynamics, native grasslands, uncertainty

Introduction

Robust, reliable and comparable data on the provision of ecosystem services are increasingly important for the effective conservation and management of rangeland systems. As the end-products of various inter-related biophysical processes, ecosystem services do not vary independently of one another and the responses of a suite of related ecosystem services (e.g., organic carbon stored in soil and in plant biomass) to disturbances such as grazing may differ in both strength and direction. In addition, there is considerable uncertainty about the biophysical production of ecosystem services under varying ecological conditions. The incorporation of these aspects in accounting for the provision of multiple ecosystem services is needed to inform management decisions in rangelands.

To support a better accounting of the provision of multiple ecosystem services in Alberta's native grasslands (6.5 million hectares), we developed a regional grassland carbon dynamics model through an inverse modeling approach to: (i) represent two rangeland ecosystem services of soil organic carbon storage (SOC; top 20 cm of soil profile) and aboveground plant biomass production (AGB); and (ii) assess the level of precision and uncertainty in simulation of these ecosystem services across different grassland regions.

Materials and Methods

We extracted soil polygons associated with native grassland areas from the Agricultural Region of Alberta Soil Inventory Database (AGRASID version 3.0; ASIC 2001). This resulted in 25,093 soil polygons associated with nine distinct grassland regions with homogenous soil and climate conditions. We used the widely applied ecosystem carbon model CENTURY (Parton 1988), with the AGRASID polygons serving as the smallest spatial units. Historic monthly climate data (1901-2011) for each AGRASID polygon were extracted from ClimateWNA (4 x 4 km gridded climate data; Wang et al. 2012). Input parameters related to nitrogen and vegetation were modified for Alberta's grasslands. The remaining parameters were left to default values or, in the case of initial soil organic matter, established through equilibrium. We first used 1901-1990 climate averages to run a 4900 year equilibrium period, specifying a fire event every six years and a two-month bison grazing event (shifting annually by two months) out of every year. The monthly climate data were then used to run a 110 year period (1901-2011), specifying cattle grazing (during the months of June, July and August) under a low-to-moderate grazing intensity regime (40% offtake of AGB).

To account for regional variations in climate and vegetation across the province, we performed independent parameterization and calibration of the carbon model for different grassland regions. We identified sensitive input model parameters, including grazing parameters, by conducting an absolute sensitivity analysis (i.e., changing the value of one parameter, while keeping all other parameters constant). We used two different approaches to calibrate model parameters and estimate model output uncertainty in different grassland regions. These include: (i) the single-variable calibration, where either measured SOC or AGB data was employed; and (ii) the multi-variable calibration, where both measurement types were integrated into the calibration analysis.

A lack of geo-referenced, consistently measured and harmonised data on SOC and AGB is a major challenge for large-scale modeling of grassland carbon storage. Through its ongoing monitoring program, the Alberta Biodiversity Monitoring Institute (ABMI) has completed SOC measurement in the top mineral soil layer at approximately 300 terrestrial monitoring sites systematically spaced throughout native grasslands of the province. In addition, the Range Resource Program of the Alberta Environment and Parks (AEP) has collected long-term AGB measurements at more than 100 Rangeland Reference Areas (RRA) spaced throughout different grassland regions that date back between 1980's to 2000's, mostly to 1990's. We employed ABMI's SOC measurements and AEP time series of AGB measurements for model calibration setup and uncertainty analysis. Our regional parameterization, calibration and uncertainty scheme resulted in a number of iterations (each with 500 simulations) to reach a desirable model performance. Finally, we employed time series of remotely sensed proxies of AGB (2000-2010 growing seasons) to validate grassland carbon model at the regional scale.

Results and Discussion

In general, the initial model was not able to capture the spatial pattern of SOC and AGB measurements at different grassland regions. Most of the initially selected input parameters were sensitive to both SOC and AGB measurements across Alberta's grasslands. The optimized parameter ranges were different among calibration approaches and grassland regions. The results of calibration based on single-variable approach were satisfactory but only for one variable (measured SOC or AGB), while the multi-variable calibration approach produced satisfactory results for both variables across grassland regions. The latter approach accounted for more of the variability in both SOC and AGB measurements across different regions. It also improved model performance at regional scale compared to single-variable approach. In addition, the multi-variable approach resulted in reduced uncertainty in model estimates for both SOC and AGB. Our findings suggest that calibration of an organic carbon model against SOC or AGB measurements alone cannot provide sufficient confidence for assessing multiple carbon-related ecosystem services in diverse rangeland systems with a wide range of variation in climate, soil and vegetation.

Conclusions and Implications

Using a multi-variable calibration approach, we successfully developed a comprehensive, organic carbon dynamic tool for consistent assessments of SOC and AGB across Alberta's rangelands. This regionalized carbon model provides the foundation to assess the current status of grassland carbon storage, and to predict potential impacts of alternative land management practices on organic carbon storage and the uncertainties associated with these predictions across different grassland regions. It also helps identifying alternative adaptive strategies and management scenarios that might mitigate potential negative impacts of climate change on grassland carbon storage. In addition, it supports a more complete cost-benefit analysis of potential climate change adaptation strategies and provide a baseline to assess whether such strategies will lead to resilience of socio-ecological systems in Alberta's rangeland.

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Improving the Framework of State and Transition Model for Condition Assessment of *Artemisia* spp. Rangelands in Uzbekistan

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Key words: overgrazing, undergrazing, plant response, vegetation succession, conceptual model

Introduction

Artemisia spp. dominated vegetation is largely expanded and forms economically important rangelands throughout arid zones of Uzbekistan. The most critical factor impinging current *Artemisia* spp. rangelands is the high and localized animals stocking rate. Alongside the overstocking, undergrazing in remote rangelands with water scarcity is another major factor shaping the vegetation state. Due to such unbalanced grazing systems, large rangelands are subject to significant alteration of vegetation properties and thus degradation tends to increase; but exact magnitude of rangeland degradation is largely unknown. Development of the countrywide ecological frameworks for condition assessment of *Artemisia* spp. rangelands is thus of high importance.

In recent years, the concepts of resilience-based frameworks including State and Transition Models (STM) are explicitly improved (Briske et al., 2008; Bestelmeyer et al., 2009) and have been widely adopted for rangeland assessment (Bagchi et al., 2012). In this paper we illustrate some advances on improving the earlier developed STM framework for *Artemisia* spp. rangelands with the special focus on plant behaviour in response to overgrazing vs. undergrazing in semi desert zones of Uzbekistan.

Material and Methods

Study area

Field observations were conducted in Karnabchul semi desert in West of Uzbekistan. The area possesses typical environmental conditions (with high temperature and rainfall variability) for semi arid zones of Uzbekistan. Vegetation cover is represented by homogeneous *Artemisia diffusa* semi shrub plant community with ephemeroids (*Carex pachystylis* and *Poa bulbosa*) dominated understory synusia (Rajabov et al., 2013). Qualitative and quantitative parameters of vegetation and their changes in response to grazing was observed along the apparent grazing gradient.

State and Transition Modelling

Based on the theoretical frameworks (e.g. Briske et al., 2008) original conceptual STM of vegetation succession was developed in case of *A. diffusa* rangelands in the condition of gypsous loamy and sandy loamy soils (Rajabov, 2009). This model was built based on empirical field data collected during 2005-2007 in Karnabchul. Through the enhanced analysis of existed data base and recent field observations (2009-2014) the attempt was made for deepened analysis of vegetation dynamics in response to grazing. Special attention was given to vegetation behavior in case of absence of grazing. This was achieved through monitoring of rangeland plots around abandoned watering wells for last 15-20 years and 10-year enclosure site with *Artemisia* spp. rangelands. Obtained experimental and experiential knowledge were applied in improving the framework of existed STM for *Artemisia* spp. rangelands.

Results and Discussions

Developed STM included into its configuration 4 distinct alternative states in the condition of gypsous loamy soils and 3 states in sandy loamy soils. Different soil condition in the studied communities has resulted in significant changes of vegetation structure in response to intense grazing. Plant communities in sandy loamy soils compare to those in gypsous loamy soils have expressed rapid successional changes of vegetation states. This tendency is derived by strong expansion of ephemeroid plants as *C. pachystylis* and *P. bulbosa*. Increased grazing has led intense colonization of strong rootstock holding ephemeroids in sandy loamy soils, and therefore created extreme competition for *A. diffusa* for space and nutrients, particularly for soil moisture. Due to such strong competition vitality of *A. diffusa* has considerably reduced and resulted in the increased rate of its mortality.

Plant community in gypsous loamy soils has showed higher resistance in response to intense grazing which is possibly connected with relatively favorable soil moisture condition. Existence of gypsum in soil composition of this site increased moisture holding capacity of the soil and thus created less competition for soil moisture between *A. diffusa* and ephemeroids (Rajabov et al., 2013). Gravelly content of gypsous soils has also mechanically prevented the occupation of the soil space by rootstock of *C. pachystylis*. Continuous trampling combined with favorable soil moisture has resulted in greater establishment of seedelings of *A. diffusa* in this site. These indicators caused the *A. diffusa* dominated vegetation to be more resistant to increased load of grazing. Due to the continuous overgrazing in both sites for last 10 years spatial scale of degraded alternative states has noticeably increased, being greater in sandy loamy soils than in gypsous loamy soils. *Peganum harmala* - a native invader has significantly increased in number for last years causing intense transition of vegetation state from *A. diffusa* dominated towards invader occupied states.

Vegetation in the condition of limited and absence of grazing has showed specific behavior in observed sites. In sandy loamy soils long term absence of grazing has allowed expansion of annual plants as *Bromus tectorum*, *Hordeum leporinum* and others. In contrast to this, vegetation in gypsous loamy soil during 10 year of absence of grazing in enclosure site showed steady decline of annual and ephemeroid plants. However, quantitative parameters (density, projective cover, biomass) of *A. diffusa* have significantly increased compare to outside of enclosure. Alongside of high biomass, absence of grazing resulted in accumulation of significant dead material in *A. diffusa* individuals which negatively influenced to regeneration of buds and plant as a whole. We suppose that vegetation is subject to more rapid deterioration in the condition of no grazing compare to overgrazing. Resistance of *Artemisia* spp. rangelands is lower in the condition of absence of grazing compare to intense grazing in both soil conditions.

Conclusion

Obtained results and analysis enhanced our understanding to some extent on the resistant and resilience capacity of the vegetation in different soil properties and grazing conditions. Vegetation in sandy loamy soils found to be highly prone to rapid changes whereas in gypsous soils it is more impermeable to increased grazing. STM framework is greatly benefited of the results to understand the key mechanisms underlying the stability and resilience of *Artemisia* spp. rangelands in response to grazing disturbance.

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The NRM Spatial Hub: Turning Big Data into Decisions in the Paddock

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Key words: ground cover, remote sensing, Geographic Information Systems (GIS), Cloud Computing, safe carrying capacity.

Introduction

The rangelands cover more than 80 percent of Australia's landmass and are home to less than 3 percent of the population. The challenges of adopting new technologies in support of more profitable and sustainable landscapes is further amplified by reduced workforces; relatively poor communications and internet access, and a lack of technical support and extension staff to assist land managers in raising awareness, and the adoption of new technologies.

It is therefore crucial that any new technologies introduced must: be inherently easy to use and require minimal training; use and leverage the latest science and technology through collaboration; offer real benefits to grazing land managers in terms of improving productivity and sustainability; be low cost and low maintenance, and critically, must perform with low internet speeds and data transfer.

The NRM Spatial Hub (the Hub) (www.nrmhub.com.au) has addressed these issues through a new online mapping and satellite monitoring capability built specifically for rangeland land managers. The Hub uses cloud computing technologies to provide graziers and extension staff with an easy to use solution for mapping, assessing and monitoring their properties. With a few hours of training, property infrastructure and land resources can be mapped, and ~30 years of Landsat satellite data can be analysed.

The Hub provides a secure on-line environment for producers with very low bandwidth availability; minimal training requirements; direct access to high resolution imagery; access to 30 years of time-series imagery products tracking within paddock ground cover and pasture growth variability, and safe carrying capacity analysis tools based on 20 years of science. Through individual property demonstrations users are already seeing opportunities to lower costs; save time in planning while optimising investment; improving safe carrying capacity and feedbase decisions; increasing profits and improve NRM outcomes.

Materials and Methods

The NRM Spatial Hub has been developed through a close collaboration of over twenty Australian organisations supported by the Australian Government National Landcare Programme. The partners include the Australian Rangeland NRM Alliance regions; Meat and Livestock Australia; State Government primary industry, NRM and science agencies, and the Cooperative Research Centre for Spatial Information (CRCSI).

Stage 1 of the NRM Hub Project commenced in April 2014 and was completed in June 2016. The primary objectives of Stage 1 of the initiative were to:

1. Put in place on-line spatial information systems and data necessary to enable the development of best-practice digital property and grazing plans for any location in Australia.

2. Develop simple dashboard tools to allow non-specialist users the ability to access, analyse and visualise paddock-scale time-series remote sensing indicators of land condition and trends.
3. Provide technical & extension support & training for land managers.
4. Evaluate the innovative use of this information with pastoralists and land managers.

Results and Discussion

The Online Property Planning and Information System (OPPIS) was released in beta form in April 2015. Figure 1 shows the system interface. OPPIS has demonstrated capability to operate on low bandwidth 3G mobile phone connections. The project had a demonstration target of 40 properties across the rangelands. Due to the rapid development and demand for involvement from graziers, comprehensive training and property mapping was completed on over 100 properties in late 2015. By March 2016 over 300 properties with an area of more than 50 million hectares are using the system. OPPIS provides tools for mapping: infrastructure and landtypes; planning new infrastructure; analysis of grazing circles; time-series remote sensing analysis and reporting; and estimation of safe carrying capacity.

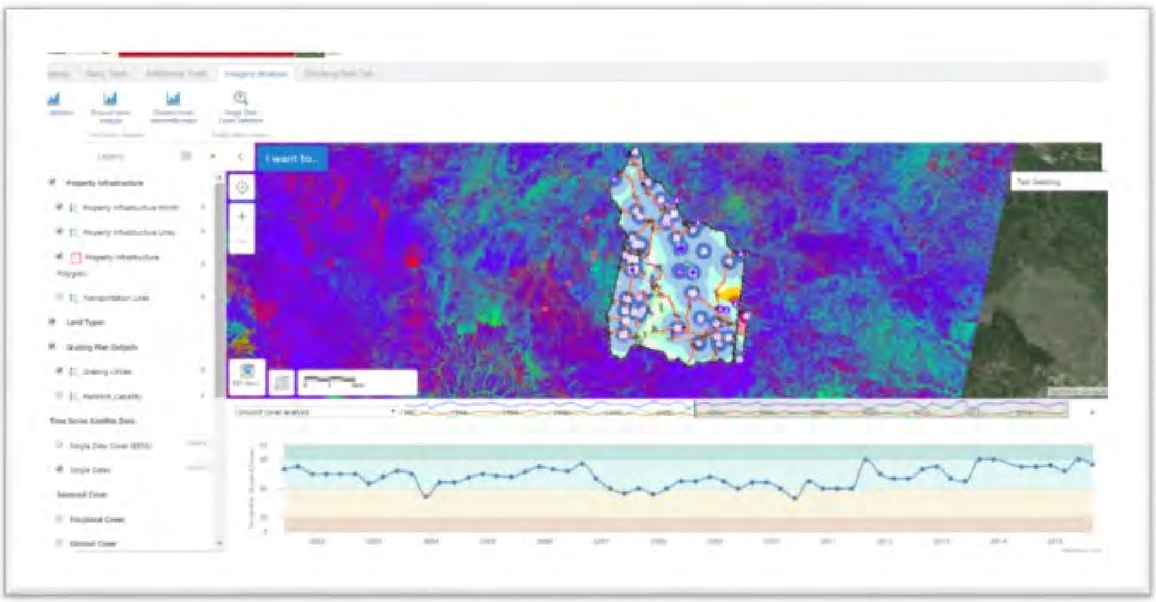

Figure 20. The NRM Spatial Hub interface. This images shows property infrastructure mapping; a high resolution image in the background; grazing circles calculated for each water source; a fractional ground cover image in the foreground (red = bare ground, blue=non-photosynthetic ground cover, green=photosynthetic ground cover). The graph on the bottom is a ~30 year analysis of ground cover over the entire property relative to the neighboring properties.

Simple dashboard tools allow non-specialist users to access, analyse and visualise paddock-scale time-series remote sensing indicators of land condition. Fractional cover products developed by the Joint Remote Research Program, TERN AUSCOVER and Geoscience Australia have been critical to the Hub's development (Flood 2013, Flood *et al.* 2013, Trevithick *et al.* 2014. A non-specialist user can now analyse and report on seasonal ground cover trends in each paddock or the entire property in 10-30 seconds. This is an Australian first.

An on-line survey was conducted with landholders who have participated in the project in February 2016. Ninety percent of respondents found the Hub easy to use; 95% said from their experience to date that the Hub has the potential to measurably improve the productivity, profitability and sustainability of their property. More than 50% felt the Hub would save them between 10 and 30 labor days a year. Seventy-five percent said it would measurably increase safe carrying capacity through better paddock utilization. It is also important to note that around half of survey participants considered their property was only around 50% developed, suggesting that a large proportion have opportunities for increasing total stock numbers with investment in infrastructure. Around 72% rated this type of technology as important to making their business both viable and sustainable in the future.

Conclusions and Implications

The NRM Spatial Hub has demonstrated the enormous potential for cloud-computing; user-driven application development and collaboration to increase technology adoption across the rangelands. Increasing adoption will lead to; lower costs; savings in labour time; improvements in safe carrying capacity and feed-base decisions; increased profits and improve monitoring of NRM outcomes. The Hub is now moving into an operational platform in 2016 and seeking partners for international implementations.

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Plant Species Identification via Drone Images in an Arid Shrubland

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Key words: Drone, arid rangeland, biodiversity, unmanned aerial vehicle, monitoring

Introduction

Desert shrubland protected rangelands (<250 mm annual rainfall) are often hundreds to tens of thousands of square kilometers in size (IUCN & UNEP, 2015). Vegetation is sparse, spatially heterogeneous, and low in biodiversity. Vegetation monitoring of these habitats by satellite or manned aircraft is prohibitively expensive due to the scale. Ground based monitoring is very labor intensive due to large and distant sample sizes. Consequently, most conservation reserves on the Arabian Peninsula are monitored too infrequently to properly inform management. The aim of this study was to assess whether low altitude aerial photography via drone stratified sampling could provide a feasible alternative to ground based monitoring.

Plant biodiversity is more important than total biomass as a long-term indicator of herbivory (Holechek, Pieper, & Herbel, 2010), particularly in shrublands where much of the plant biomass is unavailable to managed herbivore populations either proximally or nutritionally. For measuring biodiversity, the sparseness and low species count of this habitat is a distinct advantage. The total number of plant species that have been recorded at the Dubai Desert Conservation Reserve, a protected area of 225 km^2, is just 45, of which 13 are ephemeral (Khafaga, 2009). Measures of biomass would be significantly more useful if they were estimated for taxonomic groups, since they could then be related to herbivore preferences. Therefore, an assessment of plant identification accuracy is the logical first step.

Materials and Methods

Between 30 and 44 individual plants for each of 17 abundant species were numbered and identified by the resident botanist, and then photographed from above at 10, 30 and 100m (ground sampling distances, GSDs, of 2, 6 and 20 mm) using a DJI s1000 multirotor drone with a Sony NEX7 24MP camera. Twelve less common species were also photographed opportunistically. This represented a complete sample of species bearing green vegetation within the Dubai Desert Conservation Reserve at the time of study (Mar-Apr 2015). Images were selected and cropped to include one sample of each labeled plant at each GSD and assigned a randomized filename such that each image contained between one and 54 labeled plants. Two botanists who were familiar with the region, but not the specific location, then classified each image to species, genus, and plant group (tree, shrub, herb, grass, sedge).

Results and Discussion

Larger species (trees and large shrubs) and higher resolution images both resulted in increased accuracy (Figure 1), as could be predicted. At the highest resolution of 2 mm GSD, all plant groups were classified to genus with 70% accuracy or more. Some results were strongly affected by repeated misclassification of one species for another. Misclassification of established *Lycium shawii* shrubs with juvenile *Acacia tortilis* trees by one of the botanists at the 6 and 20 mm GSD resulted in a 20% difference in accuracy for the large shrub categories between the two botanists. A botanist familiar with the plant communities at sampling locations would therefore be able to classify perennial species from photos with greater accuracy.

Surprisingly, almost 40% of the annuals, biennials and dwarf shrubs were classified to species level from 20 mm GSD images, despite this representing the smallest plants and poorest image resolution. Many fixed-wing drones that are marketed for routine survey work claim 20mm as their most detailed setting. These results indicate that a rough estimate of plant biodiversity could be obtained even at this resolution.

The results obtained were only possible because of the sparsity and extremely low plant biodiversity that exists in this arid shrubland habitat. Further accuracy is likely achievable if infrared imagery is added.

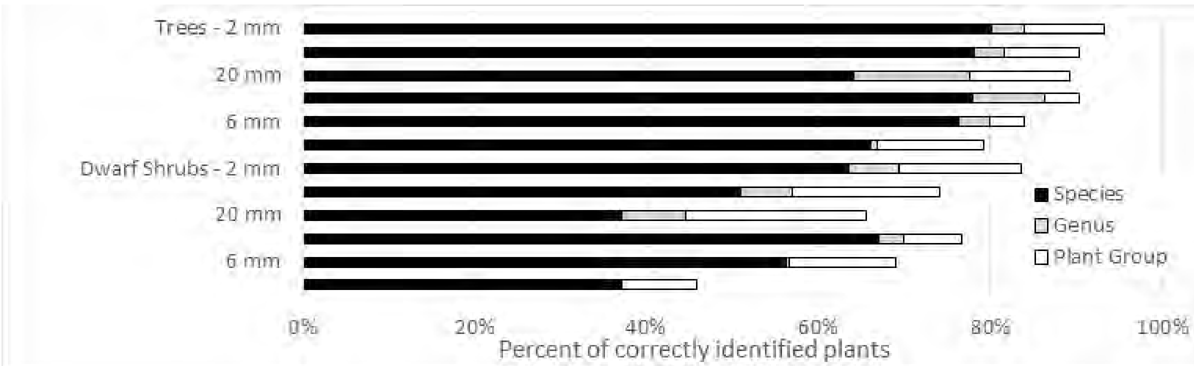

Figure 1. Accuracy of classifying plant species from RGB aerial images taken vertically at 2, 6 and 20 mm ground sampling distance.

Conclusion and Implications

Plant species identification by drone is less accurate than ground-based assessment at any resolution, but it does provide several other benefits, including

- Collection of data from large sample areas (e.g.; 2 / 50 ha at 2 / 20 mm GSD) in a short period of time. More data could therefore be collected during seasons of peak growth or reproduction.
- Remote assessment of data. Image analysis is not location dependent, though it is far preferable for the botanist to be familiar with the study site

Our study indicates that it would be feasible in this habitat to establish a database of all perennial plants within predefined sample areas, and thus aerially collect biomass estimates (e.g.; cover, height, normalized difference vegetation index) periodically for georeferenced perennial species. Non-perennial species could be identified with sufficient accuracy to estimate changes in species richness and biomass of taxonomic groups that are of importance to herbivore classes.

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The Use of the Double-Sampling Procedure and the Dry Weight Rank Method (DWR) for Herbage Mass and Composition Determination

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Key words: Double-sampling, dry weight rank, herbage mass

Introduction

It has been noted that the theory of rangeland condition embraces ecological change, productivity and other measures of production, as separate attributes of condition (Wilson, 1982).

Range managers and ecologists nowadays are more concerned to develop monitoring systems that give them quantitative estimates of factors such as species herbage mass. In the present study, two methods were adopted to estimate herbage mass and composition and included using the dry weight rank method (Mannetje and Haydock 1963) and the Double-Sampling procedure (Wilm *et al.*1944).

The principal objective of the study was to investigate the reliability of vegetation assessment techniques that help in attaining suitable management indicators.

Materials and Methods

Methods to assess herbage mass and species composition by weight

The DWR method (Mannetje and Haydock, 1963) was used to assess the species composition by weight. The method was used in conjunction with the double-sampling procedure (Wilm *et al.,* 1944). Field procedures are thoroughly described in Zahran, 1986. 100 quadrates from 5 transect 100 m long were used to collect data.

The annual and biennial herbaceous forage plants from (***EI Baja***) area (13° 36' and 14° 10' N ; 31° 45' and 32° 23' E), White Nile State, Sudan were assessed between *15th* and *30th* October 2002. The most effective rainfall period occurred between June and July 2002.

Results and Discussion

Herbage mass and composition of herbaceous forage plants

Herbage mass was assessed by two methods. The first was the quadrate method by which herbage mass was assessed to be 314 kg/ha and 394 kg/ha when 10 quadrates of areas 1.0 m^2 and 0.5 m^2 were used, respectively.

The second method, was the double-sampling procedure. Linear regression for each single operator for the different quadrate sizes of I and 0.5 square meters.The regression was in the form: Y = a + b x, where Y is actual herbage mass, x is estimated herbage mass, a and b are constants (Table 1).

Table 1. All operators regression, R^2 and herbage mass determined by double-sampling procedure (quadrate sizes $1m^2$ & $0.5m^2$).

Quadrate size	Equation	R^2	Herbage mass gm./m^2 (kg/ha)
1.0 m^2	0.254 + 1.047 x	0.985	30.77 (308)
0.5 m^2	1.233 + 0.998 x	0.991	31.84 (318)

Herbage mass composition by weight (%) was determined by the DWR method for 1.0 and 0.5 meter square quadrate sizes. For the 1.o m^2 quadrate, the results show that herbage mass composition ranged between 0.2 % and 36.7 %, with *Aristida adscenionis* and *Eragrostis tremula* having the highest composition of 36.7 and 34.8 %, respectively. *Heliotrobium* spp. and *Euphorbia* spp. had the lowest composition of 0.1 % and 0.2 %, respectively. The results have also indicated that preferable forage plants showed the lowest herbage mass composition of about 25% as compared with the less preferable forage plants of about 75% composition.

Using the $0.5m^2$, the results have also indicated that preferable forage plants showed the lowest herbage mass composition of about 25% as compared with the less preferable forage plants of about 75 percent. The results show that herbage mass composition ranged between 0.1 and 55 percent with *Aristida adscenionis* and *Eragrostis tremula* having the highest composition of 55 and 31 percent, respectively and *Cucumis sativus* and *Indigojera* spp. having the lowest composition of 0.1 and 0.3 percent , respectively. The results have also shown that the preferable forage plants have the lowest composition of about 11% as compared with the less preferable ones of about 89 percent.

Cost of the methods

The calculated cost of the methods, included time spent to collect data. Results indicated it took 25 – 30 minutes /Transect when using the quadrates and 9 – 15 minutes/Transect using the double sampling + DWR were used.

Adequacy of the quadrate method

* The quadrate method is accurate but destructive, laborious and time consuming.

* The Double- sampling procedure when used in conjunction with DWR is not-destructive, laborious and not time consuming. For these reasons this method was found to be useful and can be used in the field to assess herbage mass.

General conclusions of methods

- The Double sampling procedure was found to give reliable information in the assessment of herbage mass. The method was considered to be productivity-based and data obtained could be useful in calculating the carrying capacity, stocking rates and hence the level of utilization.
- The DWR method used in conjunction with the double sampling procedure was found to give sufficient and adequate data about the contribution of herbaceous forage plants to the total herbage mass.

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Insight into Sediment Transport Processes on Saline Rangeland Hillslopes Using Three-Dimensional Soil Microtopograhy Changes

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Key words: Rangeland Hydrology and Erosion Model, runoff, soil erosion, salt

Introduction

Hillslope runoff and soil erosion processes play a vital role on rangeland ecosystem sustainability due to their control on resource mobility but they also have significant implications in off-site resource transport. In general, physically-based soil erosion models such as the Rangeland Hydrology and Erosion Model (RHEM) divide erosion and sediment transport processes into their primary components. Yet, many primary processes (namely sheet and splash, concentrated flow erosion as well as deposition) are still poorly understood due to a historic lack of measurement techniques capable of parsing total soil loss into these primary processes. As part of an effort to quantify salt transport from rangelands to Upper Colorado River Basin (UCRB), experimental rainfall simulation studies were conducted in saline rangelands communities of this basin. The aim of this paper is to gain insight into interaction processes between hillslope topography, vegetation and sediment transport processes by (1) parsing soil microtopographic information into erosion and sediment transport processes (erosion vs. deposition, diffuse vs. concentrated flow processes) and (2) relating these processes to hydrologic input, hillslope topography, and vegetation.

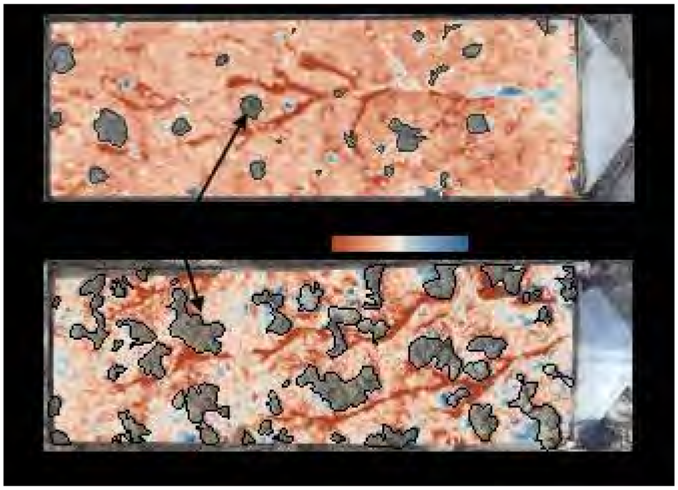
Material and Methods

Previous researchers (e.g., Hawkins, et al., 1977, Tuttle and Grauch, 2009) have identified upland areas of the Upper Colorado River Basin in the Mancos Shale and Eagle Valley Evaporite geologic formations as major contributor to the river's salinity. For our study, two sites (Price and Ferron hereafter) in the Mancos Shale geologic formation were then selected to conduct rainfall simulation experiments. These sites were selected for their contrasting slope ranges and differences in soil intrinsic properties. The soil at Price was mapped as a Persayo loam soil series with 16% clay, and 71% silt. Slopes at this site ranged from 0.6 to 10%. The predominant soil type at Ferron was mapped as a complex of Chipeta soil series and Badland areas with 23% clay and 69% silt. Measured slopes at this site ranged from 11.4% to 24.5%. On each experimental site, a series of rainfall simulations were conducted on 6 m x 2 m erosion plots to quantify sediment and salt transport processes during rainfall-driven erosion processes. Erosion and hydrologic responses were assessed by measuring soil loss, runoff and solute transport under four rainfall intensities corresponding to return periods of 2 (44.1 mm/hr), 10 (80 mm/hr), 25 (104.4 mm/hr) and 50 (135.9 mm/hr) years. Soil surface microtopography was reconstructed using Structure from Motion photogrammetry performed on photos taken before and after each rainfall event. To characterize soil surface response to erosive events, various areal and volumetric surface metrics were calculated from pre and post rain DEMs as well as the difference of DEMs (Fig. 1).

Variables presented in this paper include: the overall spatial extents (m_2) of erosion processes *TXE* and deposition *TXD*, the volumes (m_3) *TVE*, *TVD* and *TVN* corresponding to erosion and deposition and net loss processes. A multiple regression was performed on each of the surface change metrics described above using hydrologic input represented by discharge *Q* and run duration (*Rdur*), topography, captured by slope *SLP* and vegetation *Veg* as explanatory variables.

Results and Discussions

The equations to the right describe the relationship between surface change metrics and the statistically significant explanatory variables. Erosivity which in this study is represented by runoff discharge drives detachment and transport processes (*TVE* and *TXE* increased with *Q*) while factors controlling surface roughness such as vegetation oppose transport of the detached particles (*TVD* increased with *Veg*). This is well illustrated in the response of the net erosion volume, log(*TVN*) which shows an increasing effect of *Q* and a decreasing effect of *Veg*. Patterns observed plot-wide held true within the channel network.



$$TXE = 3.89 + (2.93 \text{ at Price}) + 0.03Q, R^2 = 0.76 \quad (1)$$

$$Log(TVE) = -4.92 + 0.02Q, R^2 = 0.81 \quad (2)$$

$$TXD = 5.15 - 0.03Q, R^2 = 0.61 \quad (3)$$

$$Log(TVD) = -4.62 + 8.29Veg, R^2\ 0.45 \quad (4)$$

$$Log(TVN) = -5.89 + 0.02Q - 15.12Veg, R^2\ 0.73 \quad (5)$$

Figure 1.

Conclusions and Implications

The three dimensional surface change metrics developed in this study were successful at capturing the expression of various erosion and sediment transport processes and how these processes were influenced by hydrologic input and biotic and abiotic land surface characteristics. Erosion volumes were lower at Price than they were at Ferron, due to the lower slopes at the former site. Deposition volumes were a function of vegetation cover. For the saline sites of the UCRB, the key to runoff soil and salt load reduction likely lies in promoting deposition by creating specific zones along concentrated flow pathways where roughness is increased through vegetation enhancement.

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Parameterization of Erodibility in the Rangeland Hydrology and Erosion Model

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Key words: Erodibility, erosion models, rangeland management, soil loss

Introduction

The magnitude of erosion from a hillslope is governed by the availability of sediment and connectivity of runoff and erosion processes. For undisturbed rangelands, sediment is primarily detached and transported by rainsplash and sheetflow (splash-sheet) processes in isolated bare batches, but sediment generally only travels a short distance before deposition. On disturbed rangelands, bare ground is commonly more extensive and runoff and erosion rates are higher. Increased erosion following disturbance occurs due to a shift from splash-sheet to concentrated-flow-dominated processes. Amplified runoff following disturbance transports splash-detached sediment further downslope into concentrated flow paths with high flow velocity, sediment detachment, and transport capacity. On long-disturbed sites, years of soil loss can limit sediment availability and soil erosion. In contrast, recently burned landscapes typically have ample sediment available and generate high erosion rates. This paper presents recent advancements in hillslope erosion prediction by the Rangeland Hydrology and Erosion Model (RHEM; Nearing et al. 2011) that accommodate a wide range of vegetation, ground cover, and soil conditions and the associated dynamics in runoff and erosion.

Materials and Methods

The RHEM tool is a process-based model that was developed specifically for predicting hillslope runoff and erosion on rangeland ecosystems. The sediment delivery rate in RHEM is the total detachment rate of splash-sheet and concentrated overland flow processes. The sediment detachment rate by rainsplash and sheetflow in RHEM is derived as a function of soil erodibility, rainfall intensity, and discharge. Sediment detachment by concentrated flow uses a stream-power based erodibility (Al-Hamdan et al. 2015). The new approach presented here required development of empirical equations to predict a splash-sheet erodibility parameter (*Kss*) for undisturbed and disturbed conditions. The data used for developing and evaluating the erodibility parameter equations were obtained from rainfall simulation databases maintained by the USDA-Agricultural Research Service. The data span undisturbed and disturbed conditions. Multiple stepwise linear regression analysis was used to derive the relationship between erodibility as dependent variable and ground and canopy cover attributes, slope, and soil texture as independent variables. Piecewise (segmented) regression analysis was applied where two continuous relationships between the log-transformed erodibility and the independent variables were fitted to improve the linear relationship. Applicability of the erodibility parameterization approach in RHEM was evaluated using a test of percent bias (*PBIAS*, Gupta et al. 1999).

Results and Discussion

Splash-sheet erodibility was negatively correlated with canopy and ground cover, and was positively correlated with slope. A single generalized and four cover-type (bunch grass, sod grass, shrub, and forb) equations were developed for predicting splash-sheet erodibility. Applying piecewise regression, the best two-piece regression (R^2 = 0.708) was obtained with a ground cover of 0.475 as the break point (Fig. 1). The break point is consistent with that commonly identified as the 50-60% bare ground point in which small changes in bare ground promote large increases in sediment yield. Dividing the data into four groups based on the dominant vegetation community minimally improved the coefficient of determination (R^2=0.713). The single versus vegetation specific approaches did not change the performance of prediction significantly (Fig.1). The overall performance of the *Kss* approach in RHEM was satisfactory with a *PBIAS* of 41.8 (Fig. 2), and the model predictions were able to match more than 50% of measured sediment yield even for disturbed sites. Model performance was slightly improved through a multiple parameterization approach using the *Kss* parameterization described in this study and the concentrated flow parameterization suggested by Al-Hamdan et al. (2015). The dual parameterization approach is recommended for conditions with abrupt disturbance (e.g., fire) on steep slopes with ample loose sediment.

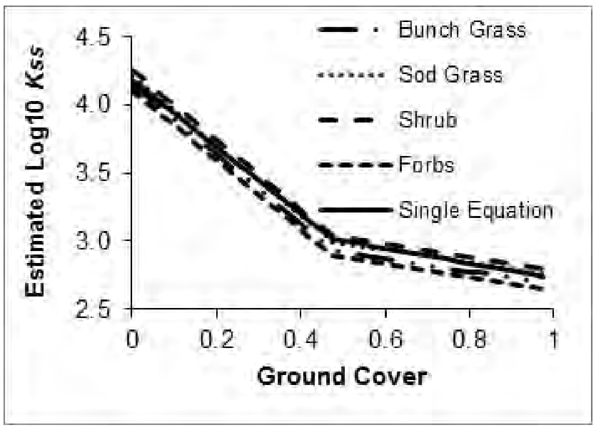

Figure 1. Values of $Log_{10}Kss$ given hillslope gradient (Slope) of 0.15 and 0.5.

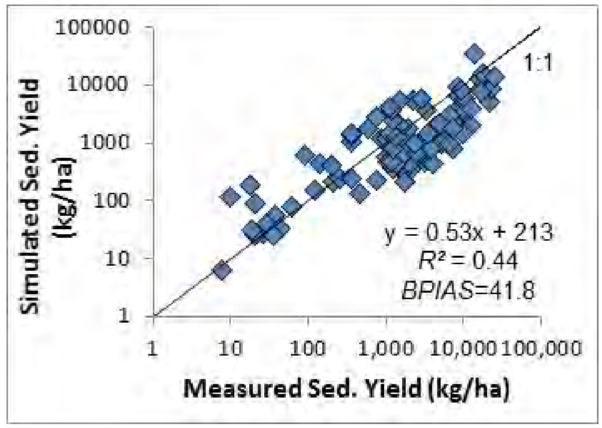

Figure 2. Measured sediment yield vs. sediment yield estimated by RHEM.

Conclusions and Implications

Results demonstrate a single erodibility approach in RHEM is effective in predicting erosion across a wide range of conditions. A dual parameter approach, splash-sheet and concentrated flow, is only needed for cases of abrupt disturbance with steep slopes and ample sediment (e.g., immediately post-fire). The new parameterization approach expands the applicability of RHEM to a greater scope of conditions.

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Rangeland Runoff and Soil Erosion Database

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Key words: Rangeland, soil, erosion, database

Introduction

Rangelands comprise over 40% of the landmass of the United States, including nearly 80% of the lands of the western states. The estimated annual costs of damage caused by soil erosion and excessive sediment in surface waters within the U.S. is approximately $6 billion to $16 billion annually (Osterkamp et al., 1989; Lal, 1994). Over 55% of sediment and salts entering the Colorado River are derived from accelerated soil erosion from federal rangelands with damages estimated to be $385 million per year to water users. Historically, information on the types, patterns, causes, spatial location, severity, and extent of land degradation through soil erosion at global or national scales have not been available in sufficient detail for developing specific policies for targeting conservation in a cost-effective approach. ARS and its partners NRCS, BLM, USFS and BOR have implemented large scale experiments to evaluate rainfall/runoff/soil loss/water quality on rangelands for the last forty years across the west using a rotating boom rainfall simulator (Swanson 1965) and for the last ten years using a new fixed boom rainfall simulator (Paige et al. 2003) with standardized sampling protocols (Simanton et al. 1991). These data have not been archived and are vulnerable to being lost as the majority of scientists who conducted these experiments have retired or are planning on retiring in the next 5 years. Cost to reproduce this data would exceed $20 million and take eight years to resample if even possible. A Rangeland Runoff and Soil Erosion Database is in development to support the need to secure and make accessible this historical data.

Materials and Methods

We propose to develop a relational database and recover historical ARS datasets and make them available to ARS scientists and the public. We have identified 23 sites and over 1,500 plots/runs that can be added to the existing WEPP-IRWET rainfall/runoff database developed to support the Rangeland Hydrology and Erosion Model (RHEM) and other tools developed by ARS. The RHEM model was developed from 204 plots at 49 rangeland sites (Figure 1). The data recovered from this effort will expand the existing data available five-fold for use in developing runoff, soil loss, and water quality models for use in land management planning on rangelands. We have received data in various formats from these scientists (paper field datasheets, floppies in obsolete formats (Quattro Pro spreadsheets), Access database, Excel spreadsheets, SAS database, publications, etc.). We have identified an additional 15 sites and approximately 250 plot/runs and are seeking collaborating arrangements with these scientists to recover this data.

Results and Discussion

The Rangeland Runoff and Soil Erosion Database will classify and display plant community types using the Omernik Level IV ecoregions with sites cross-referenced and hot-linked to NRCS soil series and ecological site databases. Photos of all sites (where possible) will be available for users to compare their sites. Sites will be cross-referenced and hot-linked to publications that can be retrieved through the National Agricultural Library associated with these datasets. The database will standardize methods of archiving new experiments in support of the LTAR mission. The database will offer a high degree of automated output that will be available to run ARS decision support tools such as RHEM.

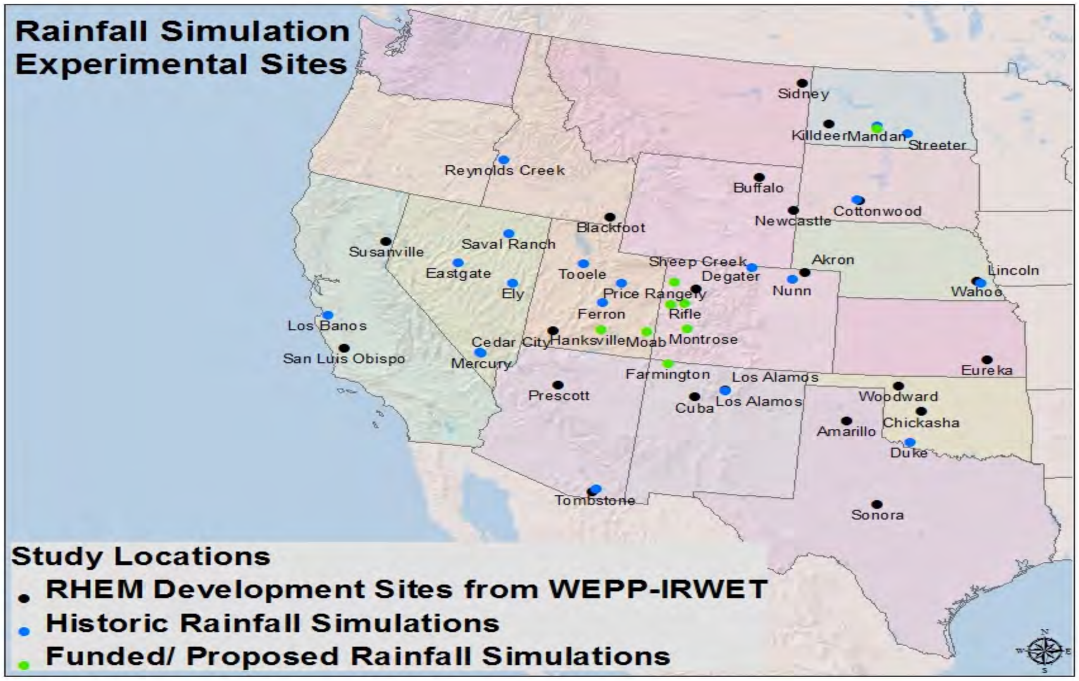

Figure 1. Map of historical, current and proposed future research that will populate the Rangeland Runoff and Soil Erosion Database.

Conclusions and Implications

Scientists working on this project, with a team of National Agricultural Library (NAL) IT Specialists are developing the relational database using a SQL Server with sites cross-referenced to NRCS soil series and ecological site databases. The database will be stored on a NAL server for public access and sustainability. This new database (73 plant communities and 2,000 plots/runs) will be utilized to validate and expand the utility of Rangeland Hydrology and Erosion Model (RHEM) for plant communities not currently addressed by RHEM (i.e., meadows, salt desert shrubs, etc.); develop new equations to estimate total dissolved solids in runoff water; and use RHEM to develop standardized hydrologic section for NRCS rangeland Ecological Site Descriptions that describes optimum vegetation cover for reducing soil erosion and improving water quality.

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Water-Use-Efficiency of Southern African Rangelands: What Does It Reveal about Pattern and Process?

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Key words: MODIS NPP, ET, degradation, land use, woody encroachment

Introduction

Water use efficiency (ƛ) defined as the ratio of carbon gain relative to water used is one of several unifying concepts for comparing different rangeland condition classes and the impact of different land-use options (le Houerou et al., 1988). Throughout southern Africa there are examples of degradation attributed to over-grazing, abandonment and salinization. We suggest that lower than expected ƛ may reflect and help identify landscape-scale degradation or dysfunctionality. With increasing levels of atmospheric CO_2, there is a call to improve the efficiency of CO_2 extraction (Bond and Midgley, 2000; Gago et al., 2014), and to better understand which land-uses will increase the efficiency of CO_2 uptake. Water use efficiency concept is routinely applied to analyse productivity in the irrigated and dryland agricultural systems, but seldom in rangeland ecosystems. At landscape level λ is determined as the weight of dry matter (kg) accumulated per mm of evapotranspiration (kg DM ha^{-1} mm^{-1} $year^{-1}$). A cost effective way of acquiring ƛ for large landscapes is to use earth observation products and moderate resolution satellite sensors to predict annual above-ground primary production (NPP) (Running et al., 2004)(e.g. MOD17). Actual evapotranspiration has been modelled by combining earth observation and data from the World Meteorological Network (Mu et al., 2011). Using MOD17 to estimating NPP and MOD16 for ET we obtained ƛ = NPP/ET and prepared response surfaces for this variable for southern Africa. We had previously assessed the quality of the MODIS products using ground surveys of annual biomass production at five sites in southern Africa (Palmer et al., 20--). At these sites we had collected above-ground production data for transects in four major southern African biomes, namely the Succulent Karoo, the semi-arid savanna, the dwarf shrublands of the Nama-karoo and the grasslands of the north Eastern Cape and Kwa-Zulu Natal. We compared our ground-based measurements with those predicted by the MODIS product and obtained satisfactory agreement between remotely sensed NPP values and those measured destructively on the ground. We also assessed the accuracy of the MOD16 ET product using data from the eddy covariance flux tower located at Skukuza. These assessments indicated that we could use both of these MODIS products as reliable estimators of primary production and evapotranspiration across a range of vegetation types in southern Africa. In the current study, we calculated l using these products for annual NPP and ET between 2000 and 2013. These data, one of which is presented here as an image, provide the first database that can be used to evaluate the impact of contrasting land cover types and land use strategies on ƛ. The range of ƛ values that have been calculated for the region are directly comparable to those derived from the ratio of DM production to rainfall which has been applied in other studies (Palmer and Ainslie, 2007).

Materials and Methods

MODIS NPP and ET Products

The MODIS NPP and ET products have been available every 8 days at a 1 km^2 spatial resolution since March 2000, and provide above-ground net primary production (NPP) and evapotranspiration (ET) data. Pre-processed MODIS imagery was acquired from the Land Processes Distributed Data Archive for the period from 26 March 2000 to December 2014. The images for each decadel were extracted for the four MODIS tiles covering southern Africa, summated for each year and concatenated to form a single image of the whole region.

Validation of NPP and ET products

At each of the pre-selected sampling site, canopy cover of the vegetation was determined using the line intercept method with a single 100 m transect (Canfield, 1941). Annual NPP was calculated following the method of Flombaum & Sala (2007). Along each 100 m transect, five sub-plots (0.2 m x 1 m) were placed immediately adjacent to the line transect at 20 m intervals, and the annual production fraction (fAP) was collected from each sub-plot. The harvested plant material was oven-dried at 70° C for 60 hours. Linear regression models of canopy cover by fAP were prepared for each growth form; this was then scaled-up to the landscape using the fAP canopy cover data for the entire transect. The fAP of all the growth forms encountered along the 100 m transect was summed to get the total fAP. It was assumed that this was representative of the 1km MODIS pixel for estimating the fAP for the standing green biomass of the functional groups of perennials along the entire primary production gradient. We statistically compared the predicted landscape-scale fAP with the MODIS NPP product.

Results

There is an inherent stability across southern Africa when assessing all of the 14 years studied, however this time interval may not be enough to detect significant trends. Although all the image data for the entire 14 years were available, we present results for only 2006 as this was a relatively dry year in the region. This enables us to identify some of the contrasting values across land cover gradients (Figure 1). Some of the highest ƛ values in southern Africa are found in the central Kalahari. A window extracted from the image of water use efficiency in 2013 (Figure 2), shows the boundary between Namibia, South Africa and Botswana, which is an area that is largely under conservation management (Khalaghadi Trans-frontier Park). It is possible that these high ƛ values for this area can be attributed to the water holding capacity of the deep Kalahari sands that has supported increases in woody shrubs in this area in recent times. This trend concurs with the findings of (Brunsell et al., 2014) that infrequently burned grassland, which is also undergoing woody encroachment and in transition to a shrub-dominated ecosystem, had a higher ƛ than frequently burnt grassland. However a great deal more study needs to be undertaken to confirm the underlying reason for these high ƛ values.

The contrast in λ between South Africa and Lesotho for 2013 (Figure 3) reveals that at the low elevation and heavily grazed sites (south western parts of Lesotho), there is little difference in ƛ between South Africa and Lesotho; the λ values across the border values are remarkably close being about ~2. In south western Lesotho, the grass is kept very short by continuous grazing, while crop residues from annual dryland crops provide dry season forage. In contrast, the high elevation areas of Lesotho in the north east are in the rain shadow of the Drakensberg mountains, and have lower ƛ (<1) than the adjacent highland areas in South Africa (>2) that form part of the Maluti-Drakensberg Trans-Frontier Park. This high elevation area of Lesotho is regarded as severely degraded, with extensive shrub encroachment, and the index appears to be detecting this pattern.

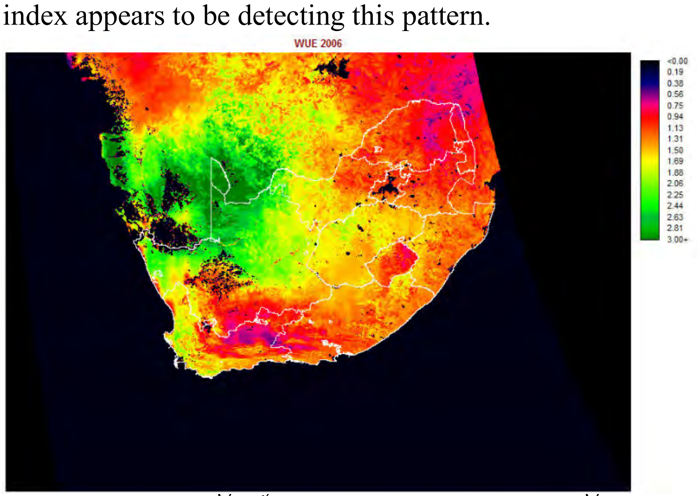
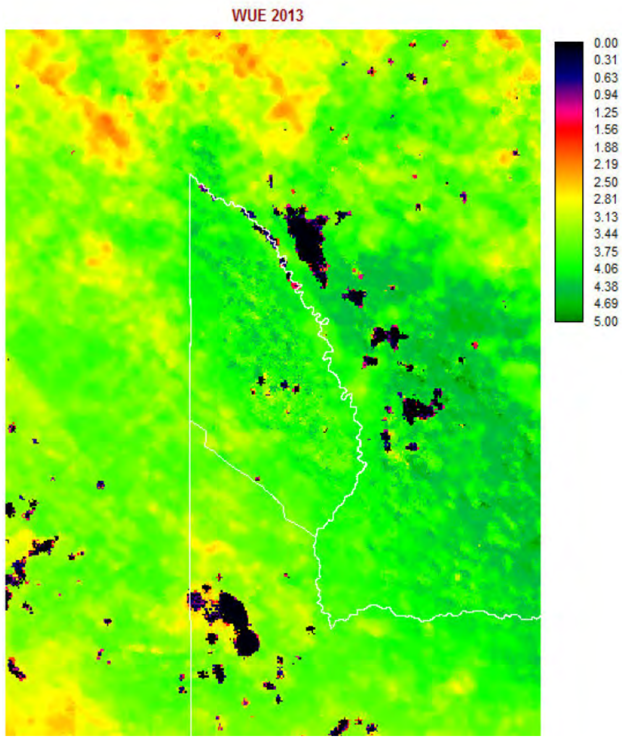


Figure 1. The water use efficiency (λ) from MODIS products for southern Africa during 2006.



◀ **Figure 2. Some of the highest water use efficiency (λ) values in southern Africa are found in the central Kalahari in Botswana.**

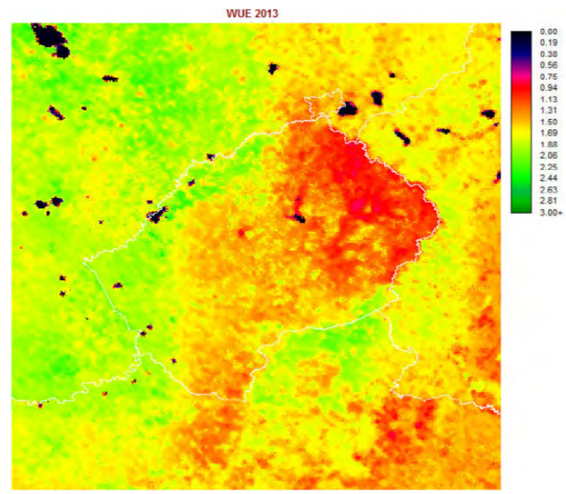


Figure 3. Contrasting water use efficiency (λ) between South Africa and Lesotho for 2013.

Discussion

The maps presented here, and the interpretation of the patterns, represents a first attempt to understand the significance of the application of λ concept to optimizing land management in southern Africa. From this initial analysis, it clear that not all of the patterns are apparent, and more studies are required to improve our understanding and identify those land use options that have the best water use efficiency. The Succulent Karoo biome, particularly the Little Karoo, has some of the lowest λvalues. This may be linked to the prevalence of plants with succulent leaf and stem which tend to use the CAM photosynthetic pathway. In addition, low values are also associated with the semi-arid savanna of the Limpopo Province, where woody encroachment is a serious veld management issue. The moderately high λ values for the maize growing areas of the Free State and southern Mpumalanga suggest good l performance for these regions.

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Estimating Forage Biomass in a Scrubland Using Digital Photography and Reflectance

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Key words: Optical techniques, remote sensing, rangeland, semiarid

Introduction

Identification and development of methodologies to facilitate sustainable rangeland management is essential for management of ecosystems for livestock production. Reflectance could be an inexpensive, efficient, and easy method to determine forage production. However, most studies have used this methodology to determine forage production on grassland areas (flat areas with relatively uniform canopy). The objective of the study was to validate digital photography and ISVI (vegetation index using iso-soil curves) to estimate the amount of forage present in a dry scrubland.

Material and Methods

The study was conducted from April 2009 to July 2010 at two sites supporting dry scrubland vegetation in Queretaro state – Mexico (1 site: 20^o 30' 36''N; 99^o 42' 55'' W; 2 site: 20^o 52' 00''N; 99^o 52' 56'' W). The sites are located in a semiarid climate with different topography and soil features, but a similar vegetation type SIMTOG (2010). Each site covered 225 hectares with 153 samples plot with a distance of 25 meters among plots distributed in two perpendicular transects crossing in the center of the site. Samples were collected four times in a year (two in the dry season and two in the rainy season).

A multispectral and digital photography sample were taken at each plot, along with a clipped sample. A multispectral radiometer sensor (CROPSCAN INC.) with a spectral amplitude from 0.450 to 1.75 µm and a digital camera with 17.2 pixels of resolution (SONY LENS) were located on a platform 3.2 meters above the soil surface. The sample reading (photo and reflectance) covered an area of 1.6 m, which was the same size of the clipped area. The vegetation samples were separated into shrubs (leaves up to 1.60 m we considered forage), grasses, and forbs. Following collection, the plant samples were dried and weighed to determine forage production.

Reflectance readings were used to derive the vegetation index using iso-soil curves (ISVI); Paz-Pellat et al. (2011) recommend this index to areas with high proportion of bare soil. The ISVI is an infrared/red ratio adjusted by parameters specific of reflectance for each type of soil. The digital photographs were used to determine which components in the landscape are the most important to estimate biomass. ENVI 5.0 software was used to determine the percentage of green vegetation, dry vegetation, shaded vegetation, rocks, and bare soil in each photography. Based on ISVI and clipped biomass data, regression models were developed to predict the forage production for the two seasons (dry and rainy). Using the percentage of five components previously analyzed, we used a principal component analysis, which defined the correlated and uncorrelated components in the landscape that explains the accumulated forage ($p \leq 0.95$).

Results and Discussion

The three most important elements relevant to biomass accumulation were different at the two sites and in the two seasons. At the first site during dry season dry vegetation, rocks, and green vegetation were most important. In the rainy season, the main components were rocks, bare soil, and green vegetation. The green component observed in the dry season is associated with shrubs, especially mesquite and acacia, which negatively correlated with the forage available for livestock (Brown et al., 1989). For the wet season, the green vegetation was most important in explaining biomass accumulation. Areas with a high proportion of bare soil and rock tended to have a lower proportion of green vegetation that negatively affected forage production (Fig. 1A and B). Figure 2 shows the main components at site 2. In the dry season, the rocks and shaded vegetation had a negative correlation with forage accumulate. In turn, the dry vegetation was the major factor associated with forage accumulated in the dry season. For the rainy season, the main components were rocks, dry vegetation and green vegetation.

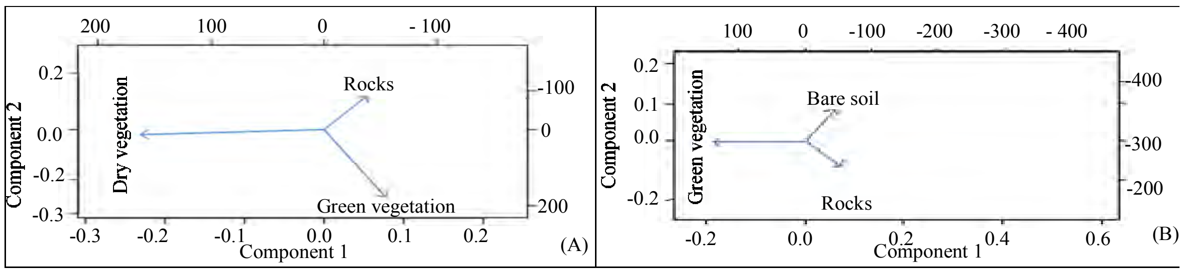

Figure 1. Principal component analysis for site 1 (A) dry season and (B) rainy season.

The results on these sites enhances the importance of dry vegetation in the forage accumulated in arid environments. The proportion of rock in a site seems be an indicator of areas with low potential to forage production, which could is associate with edaphic characteristics (SIMTOG 2010).

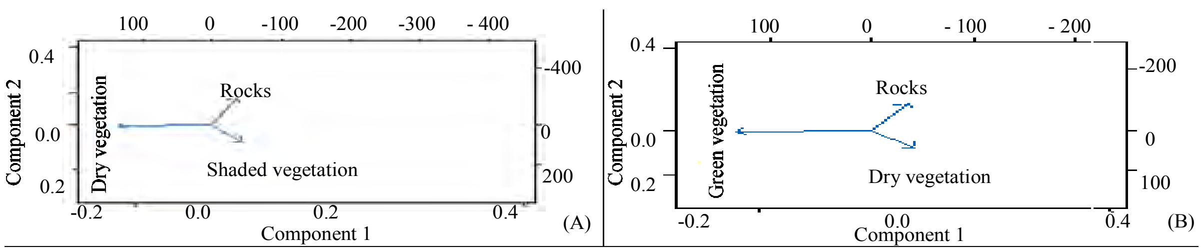

Figure 2. Principal component analysis for site 2 (A) dry season and (B) rainy season.

The coefficients of determination were low, indicating that the ISVI was not a good indicator of accumulated forage (Table 1). The coefficient of determination (r^2) showed high variability within the year, varying between 0.11 in the rainy season (site 1) to 0.38 in the dry season (site2). There was also high variability in the r^2 at each site. The variability in the canopy height in the shrubby vegetation in this plant community limited the use of remote sensing. SIMTOG (2010) affirms that a reflectometer can be used to effectively to estimate forage accumulated in grasslands. Thus, they base their analysis in a two-dimensional plan, assuming that the canopy is uniform between species. Another factor that affected the estimation was a low proportion of forage in the biomass total in the scrubland of Queretaro - Mexico.

Table 1. Coefficient of determination (r^2) for estimation of forage accumulate from ISVI.

	Site 1		Site 2	
	Dry Season	Rainy season	Dry Season	Rainy season
Scrubs	0.17	0.17	0.26	0.19
Grasses	0.12	0.22	0.29	0.23
Forage total	0.18	0.11	0.38	0.21

Conclusions

The most important components associated with accumulated forage were green and dry vegetation, and rocks. The use of the ISVI shows limited ability to estimate the forage accumulation in dry scrublands.

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Animal Unit of Grazing Animal

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Keywords Animal unit, grazing capacity, rangelands, sheep, breeds.

Introduction

Knowing animal unit weight of dominant animal grazing on rangelands of a country is necessary to estimate the grazing capacity of rangelands. The animal unit is used for categories of animals in a united form and usually is defined in terms of a mature animal weight or its equivalent on the basis of the average daily forage intake (Vallentine, 2001). Thus, the animal unit equivalent (AUE) of animals existing in the region should be used in calculations. Melvin et al. (2013) has mentioned the term *animal unit year* (AUY) as 12 AUMs or enough forage to feed an AU for 12 months. As sheep are the dominant grazing animal in Iran (Iranian National Atlas, 1999); this animal was considered in the study.

Materials and Methods

To determine the animal unit weight, 24 sheep breeds were specified, and 2 flocks were selected from each breed. Among them 30 head of 3- and 4-yr old sheep were randomly selected and weighed. Ten head of rams were also selected and weighed in each herd. The average weight of 3- and 4-yr-old ewes was specified as the mature weight of each breed. The size of animal unit of the country was determined based on the average mature breed weight in each category and animal unit equivalent was calculated using the formula suggested by (Vallentine, 2001). Cluster analysis was analyzed to estimate the similarity between sheep. A comparison between treatments was done by the ANOVA method using a Duncan's test.

Results and Discussions

The dendrogram of mature weight of sheep breeds is shown in Figure 1. Threshold criteria 1 and 2 at 80 and 90% similarity levels separated 24 sheep breeds into 3 main groups (I, II, and III) and 4 sub-groups (1 to 4). The ANOVA results as a completely randomized design with unequal numbers of repetitions strongly confirms the groupings. The three main groups, namely I, II, and III, have 5, 14, and 5 sheep breeds, respectively, and the one, two, three, and four sub-groups have 5, 4, 10, and 4 sheep breeds, respectively. The Ghezel breed with 90% similarity level is not included in the above categories. Among the sheep breeds, Zel, Sangsari, Naini, Balouchi, and Farahani are known as small, lightweight breeds; Zandi, Makui, Kurdi Khorasani, Kermani, Afshari, Turki Ghashghaei, Lory Bakhtiari, Moghani, Dalagh, Varamini, Kabude, Kurdi Kurdistani, Karakul, and Lory Lorestani are medium-sized breeds; and Shal, Mehrban, Senejabi, Fashandi, and Ghezel breeds are considered large breeds. The lightest sheep breed is Zel breed with a mature weight of 30.8 ± 0.82 and the heaviest breed is Ghezel breed with a mature weight of 71.6 ± 1.24 kg.

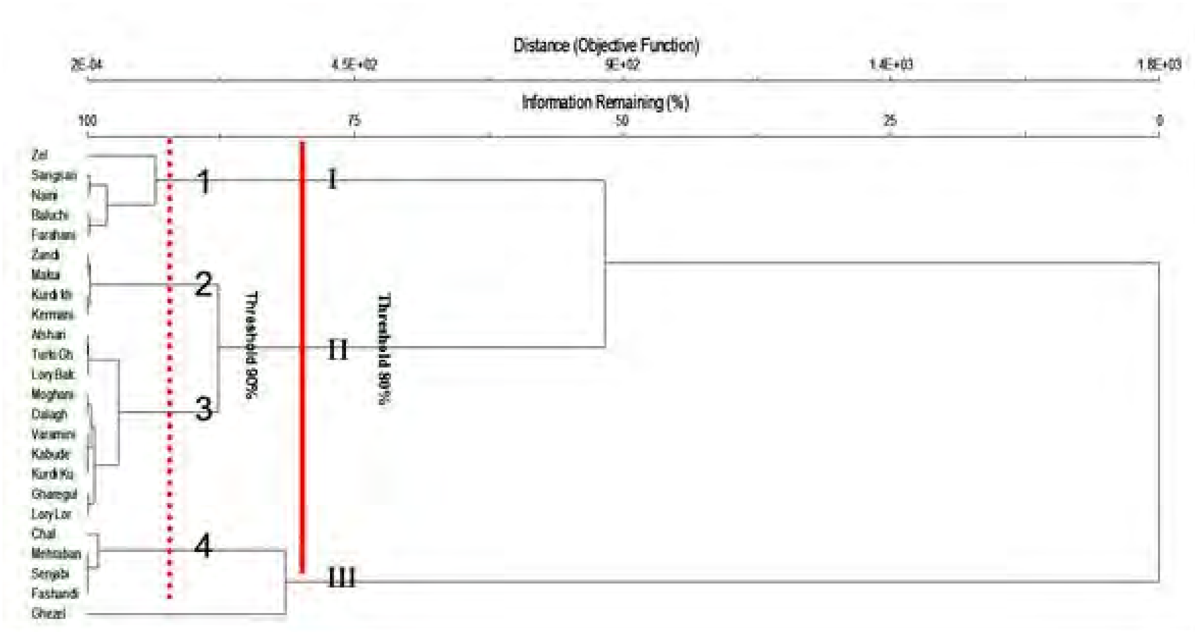

Figure 1. Dendrogram resulting from cluster taxonomy of 24 sheep breeds.

A mature weight of 50 kg can be introduced as an approximate animal unit. Therfore, the conversion coefficients to animal unit for light, medium, and heavy breeds are 0.7, 1, and 1.3, respectively. According to these results, determining animal unit based upon live animal weight of a sheep breed or a weight class is not an accurate or reliable measure since the present breeds are classified based on mature weight into different categories and each category/class has a different average weight. Thus, by combining information of all breeds of sheep, the animal unit was specified as mature sheep of 50 kg and a conversion coefficient of each sheep breed to animal unit was calculated. Based on Holechek (2005), and on the basis of 1.5 and 2.6% live animal weight, the calculated biomass amount can be 0.8 and 1.3 kg of dry pasture forage per d in drought and wet conditions, respectively. Attention to the animal unit equivalent of each breed is necessary for calculating the daily requirement of the grazing animal.

Conclusion and Implications

In Iran, sheep is the dominant animal and is considered to be the animal unit. Due to the breed and body size variety, animal unit size was measured by integrating the information relating to all sheep breeds. Therefore, it is necessary that animal unit size, animal unit equivalent of different animal categories, and its daily requirement be determined to adapt the produced forage be balanced with the animal's requirement.

Acknowledgement

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Is Adaptive Management Based on Plant Underground Biomass Relevant in Mongolian Grazing Systems? A Resilience-Based Modeling Exploration

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Key words: *Dzud*, perennial plants, stochasticity, pasture degradation, herder constraints.

Introduction

Arid and semi-arid grazing systems can behave according to both equilibrium and nonequilibrium models, depending on the spatial-temporal scale of the considered processes (Vetter, 2005). The equilibrium model describes a situation where a balance between livestock and vegetation can emerge, through density dependent mechanisms. In contrast, the nonequilibrium model describes a configuration where stochastic herbivore mortality events and rainfall variations prevent any long term connection.

To manage such systems, adaptive management is well suited because it is adapted to complex situations. Using a dynamic modeling approach, we studied its applicability to a Mongolia grazing system, which exhibits both equilibrium and nonequilibrium behaviors. It is indeed subject, like most Mongolian systems, to peaks of animal mortality locally called *dzud* occurring when heavy snowfalls follow dry summers, while livestock densities are high. We based our work on resilience thinking that recommends focusing on transformative processes and slow variables, to study the sustainability of coupled human / nature systems exposed to shocks (Walker, 2004). We identified a slow variable of interest based on the precepts of functional integrity, which suggests focusing on the maintenance of systems' key features (Hubert and Ison, 2011). We focused on the underground organs that are crucial for the renewal of perennial plant species, predominant in Mongolian rangelands.

Herders of our case study usually let their livestock numbers increase until the maximum permitted by their workforce, so that herds are only reduced by *dzud*. We hence simulated an alternative adaptive scheme consisting in curbing animal numbers before this maximum is attained. This curbing occurs when vegetation underground biomass (UB) falls under a precise threshold, which makes it possible to adapt the pasture use level to the pasture condition. We studied how this management affected the percentage of 'viable' years for herders, defined as the years respecting a set of constraints, based on income, subsistence consumption of livestock products and availability of mount & draft animal. We also studied its efficiency in preventing pasture degradation.

Materials and Methods

We established a time discrete model made up of interacting vegetation and animal sub-models. It simulated over 100 year weather scenarios the dynamics of our system called Khomyn Tal (Zavkhan Province). This vast 2,900 km^2 site is inhabited by a sparse herder population of *circa* 50 households.

The model reproduced our adaptive management and recreated livestock impact on UB, through aboveground forage consumption (both compartments interact in perennial plants). It reproduced the system's dynamics along a UB threshold gradient simulating different levels of management effort. For each level, we generated 10,000 random weather scenarios recreating the frequency of climate hazards, which trigger *dzud* when forage use factor is high. Over these scenarios, and for each UB level, we calculated the percentage of viable years and the percentage of years that required animal number curbing. We also calculated the percentage of scenarios with underground biomass ending below 100 kg/ha. We considered this value much below the observed UB field values (between 400 and 700 kg/ha), as indicator of a degraded state.

The model's level of precision made it possible to consider its results reasonably applicable to the real world, as detailed in Joly (2015), together with the model's structure and calibration procedures.

Results and Discussions

The calculated percentages were plotted against the management effort (Figure 1). The curve describing the percentage of viable years according to UB management threshold has a single humped pattern, that reaches a maximum of 89%, when UB is about 500 kg/ha. Compared to the default viability value of 78%, estimated from the 0 kg/ha threshold under which UB cannot fall, it corresponds to a gain of 11%. This maximum is attained in exchange for a percentage of livestock number curbing years of 65%. The curve describing the percentage of weather scenarios with UB ending below 100 kg/ha starts from a default value of *c. a.* 17%, at UB = 0 kg/ha, and gradually reaches a null value when UB reaches 550 kg/ha. It attains a value of 1% when UB management threshold is 300 kg/ha. This reduction of degradation risk of 16% is obtained against curbing livestock numbers 14% of the simulated years.

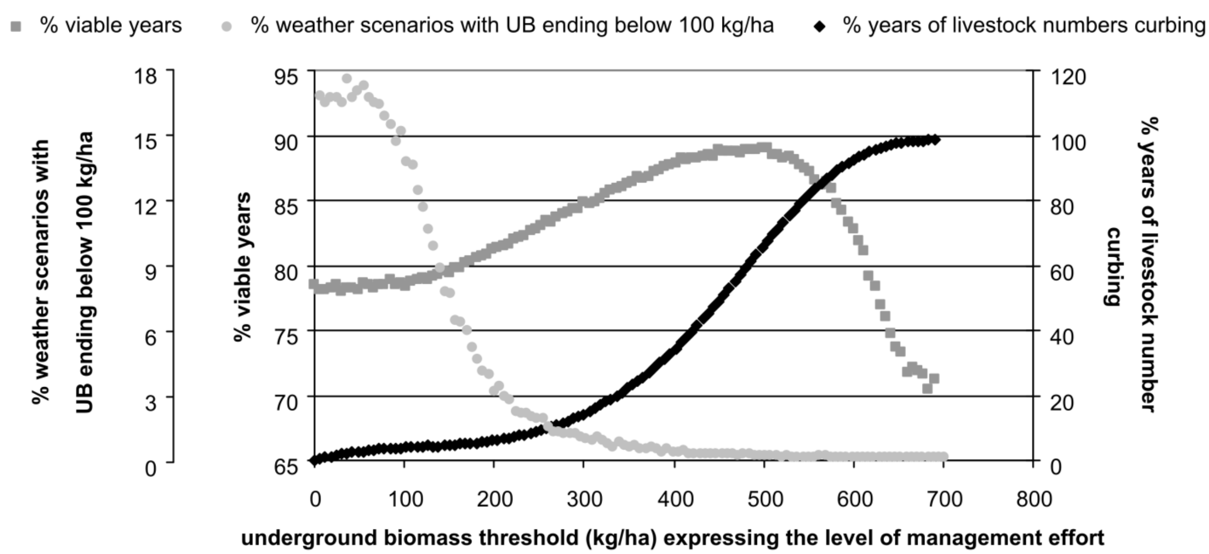

Figure 1: Percentage of viable years, of years of livestock number curbing, of weather scenarios with underground biomass ending below 100 kg/ha, according to the management effort.

The single humped pattern of the viability curve indicates that focusing on intermediate UB values makes it possible to attain a pasture use intensity compromise. At high UB thresholds, management is too cautious and livestock numbers curbed too often, which leaves too few animals to attain decent viability percentages. On the other hand, at low UB thresholds, management is not cautious enough and exposes the system to pasture productivity losses, which also affects negatively viability.

Conclusion and Implications

The model indicates that the implementation of an adaptive management procedure based in UB monitoring yields significant gains in terms of viability and prevention of pasture degradation (resp. 11% and 16%). They are obtained despite the very low herder density of the study site (one household per *c. a.* 60 km^2). This procedure is in addition effective in preventing pasture degradation, in that it reduces risk to

1% in exchange for a small management effort (only % 14 of years of livestock number curbing). For these reasons, we consider this management procedure worth considering.

Monitoring of underground biomass is in place in the study site and its implementation is planed in the Mongolian province of Bayan Khongor, in the framework of a sustainable value chain of fiber-based livestock products. This monitoring paves the way for the implementation of the studied adaptive management procedure.

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A Vegetation Map for the Land Use Planning of the Southernmost Rangelands of the World: The Steppes of Tierra Del Fuego

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Key words: Patagonia, LANDSAT, ecological sites, State and transition models

Introduction

Ecological sites and state and transition models (STMs) are key concepts in range science. However, their application in land management has been relatively scarce, in part due to the lack of large datasets relating vegetation and soil inventories, and those with long-term research data.

We present a map of ecological sites and their physiognomic heterogeneity of an area of c. 5,000 km^2 in northern Tierra del Fuego, Argentina, based on supervised classifications of Landsat ETM images and research data collected over the last 30 years, including inventories at several spatial levels, development of STMs for benchmark sites, manipulative experiments, and on documents prior to European settlement.

The area is covered by the Magellanic steppe, a subarid oceanic biome which was dramatically altered at the edge of the XXth century, when a paleolithic culture was supplanted by a large scale sheep industry. Early fencing of the whole area and the location of management poles gave place to conspicuous degradation patterns driven by both the habits of an exotic herbivore and the management routines.

Materials and Methods

We generated a database of ~200 vegetation-soil surveys and ~600 physiognomic observations from regional inventories (Collantes et al. 1999, Cingolani 1999) and ad-hoc field trips. We also identified additional sites corresponding to water bodies, urban settlements and other non-vegetative covers through visual interpretation of high spatial resolution satellite images.

We mapped vegetation at the physiognomic level by performing a supervised classification of Landsat E TM scenes using the maximum likelihood algorithm as a decision rule to assign a pixel into a class. Following supervised classification of the spectral data, extensive post-classification GIS procedures, using ancillary datasets such as DEM, as well as manual editing, were undertaken to reduce confusion between classes. Before completion, the image was filtered to remove speckle. The final map was quantitatively evaluated by computing a confusion matrix and calculating the overall, user's and producer's accuracies using an independent subset of surveys and observations.

We also mapped ecological sites previously defined from soil and topographic features, using data from the same dataset. This allowed us to assign the vegetation physiognomy to a particular state for each site, according to STMs models developed after studies on fenceline contrasts (Cingolani, 1999, Anchorena et al. 2011) and pre-settlement phytosociological surveys (Dusen, 1905). Sites were located following the DEM patterns.

Results and Discussion

Thirty ecological sites, defined with a hierarchical key of nine landscape positions, three soil-chemical quality classes, three soil-texture classes and five water-table effects (for hydromorphic sites), were mapped. The classification performed on the spectral data was used to map the physiognomic heterogeneity of the area at a scale of 1:150.000 (Fig. 1).

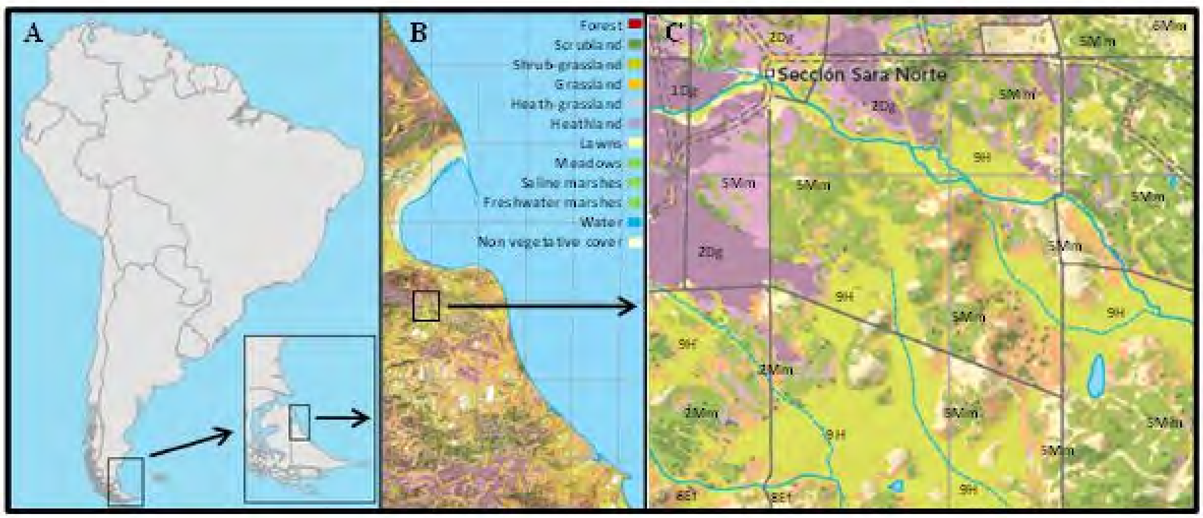

Figure 1. A. Location of the study area. B. The map in a reduced view with part of the legend (physiognomic types). C. A subset of the map at 1:150.000 showing ecological sites (three-character codes), physiognomic types (colors), hydrology, roads and farms' fencing network.

A statistical evaluation of the classification provided empirical support for the spatial patterns of physiognomy. Overall, user's and producer's accuracies exceeded in all cases 80%. Most of the discrepancies were related to the similarities between contiguous classes in terms of total cover or shrub/grass cover ratio. Additional support to the map accuracy was provided by a non-quantitative evaluation based on extensive field observations.

Conclusions and Implications

Spectral data provided by Landsat imagery allowed us to successfully discriminate land cover among physiognomic classes. By making ecological sites and states spatially explicit, the map provides an objective basis for assessment, monitoring and management decisions in the heterogeneous landscape of the steppe. As such, it will serve policymakers, land managers and ranchers.

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Plant/Life Form Considerations in the Rangeland Hydrology and Erosion Model (RHEM)

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Key words: Plant life/growth form, RHEM, hydrology, erosion

Introduction

Resilience of rangeland to erosion has largely been attributed to adequate plant cover; however, plant life/growth form, and individual species presence can have a dramatic effect on hydrologic and erosion dynamics on rangelands (Spaeth et al. 1996, Pierson et al. 2002). Plant life/growth form refers to genetic tendency of a plant to grow in a certain shape and height (e.g., plants may be classified as trees, shrubs, vines, herbs (forbs and graminoids); sod forming; caespitose, tufted, or bunchgrass, sod/bunch; annual, biennial, or perennial). Field studies have shown that infiltration is usually greatest under trees and shrubs, followed by bunchgrass, annual grasses, and sodgrass (Weltz and Blackburn 1995). Grass species with well-defined bunchgrass life/growth forms have been correlated with higher infiltration capacity compared to sodgrass forms (Spaeth et al. 1996). The Rangeland Hydrology and Erosion Model (RHEM) was developed from rainfall simulation experiments on numerous vegetation types throughout the western U.S. (Pierson et al. 2002). RHEM considers the effect of plant life/growth forms with specific effective hydraulic conductivity and splash and sheet erosion equations. This paper demonstrates RHEM hydrology and erosion sensitivity estimates to plant life/growth forms in shortgrass prairie.

Materials and Methods

This study applied the RHEM tool (Version 2.3) to a Deep Hardland Loamy ecological site dominated by blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloë dactyloides*). Soil on the study site is mapped as a Berthoud fine sandy loam (0-5% slopes). The state and transition diagram is shown in Fig. 1.

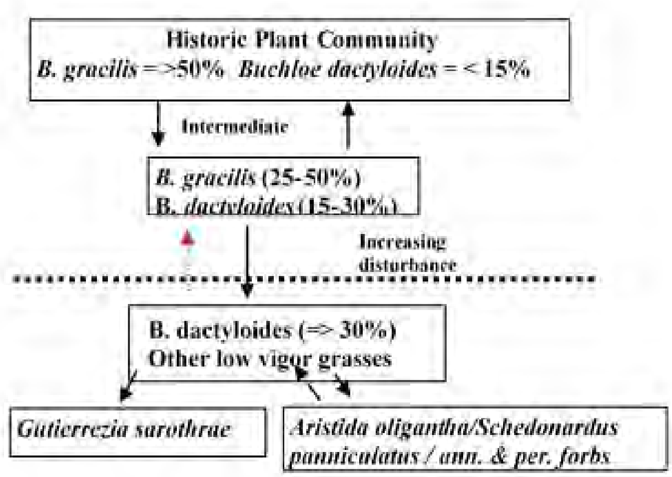

Figure 1. State and transition model for loamy deep hardland site.

The blue grama (BOGR) state represents the "historic plant community" (HPC); the blue grama / buffalograss (BOGR/BUDA) state contains less blue grama and increasing buffalograss due to heavy grazing, but with no present prairie dog activity. The buffalograss (BUDA) community exists directly outside active colonies with no mound activity. Transition from BUDA to BOGR/BUDA is problematic and largely dependent on many environmental factors (Fig. 1, red arrow). Prairie threeawn (*Aristida oligantha*)/tumblegrass (*Schedonnardus paniculatus*)

(AROL/SCPA) is the most disturbed state with active prairie dog colonies. We applied the RHEM tool, parameterized with characteristic vegetation plant/life forms, foliar cover, soil properties, and climate to assess hydrologic and erosion sensitivity estimates to varying vegetation composition and life/growth forms.

Results and Discussion

RHEM predicted runoff and soil loss was highest in the AROL/SCPA state where prairie dogs harvested and largely eliminated the preferred grasses (blue grama and buffalograss) and bare ground exceeds 50% (Fig. 2). The BUDA state, existing on the periphery of prairie dog towns dominated by the sod forming grass buffalograss generated high runoff. RHEM predicted runoff and soil loss were consecutively lower in the BOGR/BUDA a state where the ratio of blue grama and buffalograss is about 1:1. The lowest RHEM predicted erosion was observed in the HPC, BOGR state, which is dominated by blue grama.

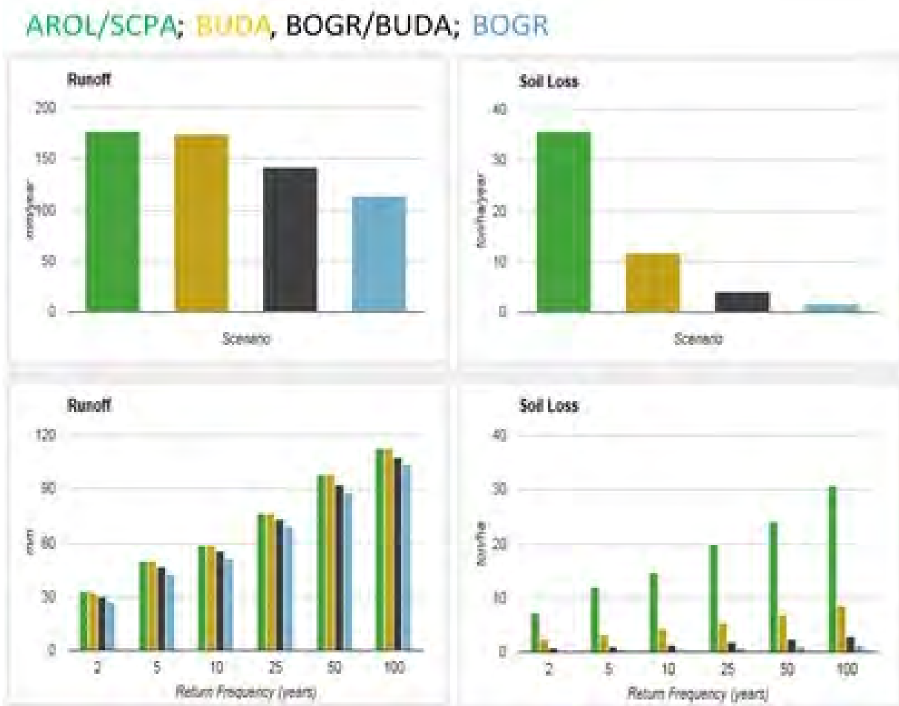

Figure 2. Annual average runoff, annual average soil loss by vegetation state; Return frequency (design storms 2 – 100 yrs) for runoff; and soil loss.

Conclusions and Implications

Our results demonstrate the sensitivity of RHEM runoff and erosion responses to plant life/growth forms i.e., bunchgrasses and sodgrasses. Predictive plant variables such as foliar cover, production, and biomass are commonly used in developing regression equations and modeling hydrology and erosion in rangeland ecosystems. Plant morphological differences above and below ground exist between shrubs, bunchgrasses, sodgrasses, and forbs and are concomitant with differences in above ground foliar architecture and root morphology (taproot, fibrous roots, shallow or deep rooting systems, root pans). Individual equations were developed and incorporated into RHEM to account for life/growth form influences on hydrology and erosion in rangeland ecosystems.

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Evaluating the Grazing Response Index for Use in Western Canada

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Key words: Monitoring, GRI, grazing management, range condition

Introduction

The Grazing Response Index (GRI) was originally developed by the Colorado State University's Range Extension and Integrated Resource Management Program and is a management tool that is designed to help managers evaluate the effects of this year's grazing on the forage plants and to plan the next year's management. The GRI uses an integrated approach asking questions relating to 3 factors that are linked to a plant's response to grazing: the frequency of defoliation (the removal of plant leaves), the intensity of defoliation, and the plant's opportunity to grow before or regrow after, grazing (Reed et al. 1999). The GRI was specifically designed to facilitate planning of grazing management under fluctuating climatic, and therefore growing, conditions.

Agriculture and Agri-Food Canada (AAFC) saw potential in using this tool in management of pastures across Western Canada. Before implementation, the method needed to be scientifically tested for British Columbia and the Canadian Prairies. The objective of this study was to use pre-existing and new grazing data to determine historical GRI scores, and see if those scores could explain any long-term trends in range condition across native grassland plant community types found in Saskatchewan, Manitoba and British Columbia.

Materials and Methods

Study sites were located in Wallace Community Pasture in Manitoba, Auvergne-Wise Creek Community Pasture in Saskatchewan, and Lac du Bois Range Unit in BC. At each site 5-7 transects were selected that represented different grazing management and plant communities. Historical data sets spanning from 1983 to 2012 based on past management and climate data were compiled. Range condition scores were conducted at least two times over the time period for each transect and a third time at all sites in 2012 (eg. for Wallace these were conducted in 1993, 2004 and 2012). In Wallace and Auvergne-Wise Creek transects consisted of 200 m lines with 10 Daubenmire frames sampled at 20 m intervals along the line. In Lac du Bois cover data for range condition scoring was collected using the standard Daubenmire method: 50 m transect, Daubenmire frame at 0.5 m intervals, canopy cover by species using cover classes (Daubenmire 1959). Field GRI scoring was conducted at all sites in 2012 following the criteria developed by Reed et al. (1999).

Using excel a backcasting model was built based on GRI scoring criteria of intensity, frequency and opportunity to grow/regrow and used to generate GRI scores from the historical data sets. These GRI scores were then graphed and compared to range condition score trends overtime. In order to test the model GRI field scores from 2012 were compared to those generated from the model.

Results and Discussion

Individual transect data were graphed to compare GRI trends to range conditions trends overtime for all 18 transects. Figure 1 shows an example of the relationship between GRI scores and range condition for the Auvergne Wise Creek Community Pasture transect line number 1. The data generated from the backcasting model indicates that GRI trends matched range condition trends for 12 out of the 18 transects studies (67%) indicating that there is a fairly strong correlation between GRI scores and range condition scores over time. The 2012 comparison of field based GRI scores to those generated solely using the model showed little variation with regards to frequency, a lower score for intensity when using the model, and variable results for opportunity, indicating that this is the most difficult variable to accurately reflect using historical data. The model tended to score the sites more conservatively than actual field scoring did but was a good fit with the overall GRI score with differences averaging to less than 1.

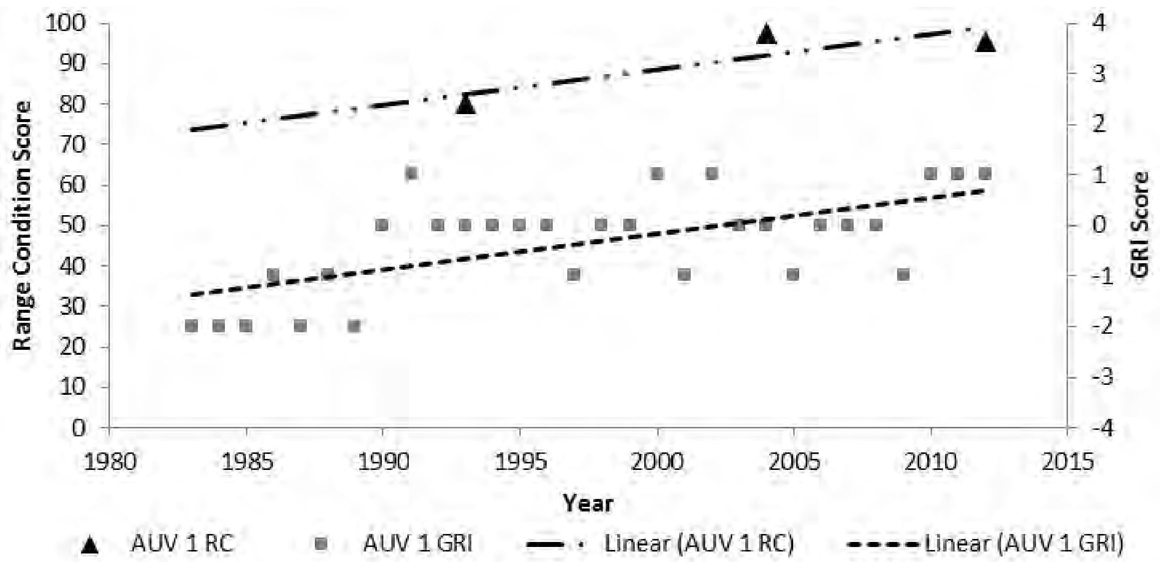

Figure 1. Auvergne-Wise Creek 1 transect Grazing Response Index scores and range condition scores over a 30 year span with trend lines.

Conclusions and Implications

The GRI is intended to be scored in the field and so using a model to generated GRI scores from historical data does have its limitations. Many factors come into play such as size of the fields, plant community, and time lag between GRI scores and plant community change. Overall the results indicate that there are no barriers to adopting the use of the GRI tool in western Canada although it is recommended that this short-term monitoring tool be used in conjunction with longer term plant monitoring. Further field analysis needs to be conducted to better relate GRI scores to plant community change.

The strength of the tool lies in its simplicity. The fact that it encourages land managers to think about the three main factors that impact plant vigour (frequency, intensity and opportunity) and to use this information for yearly management is in itself a positive step. This is a short term monitoring tool to help with decision making and is not meant to replace long term plant monitoring. Another strength of the GRI tool is in establishing clearer communication between land managers and agency staff. Better understanding of the plant community response to management will allow all parties to work together towards management goals. Based on the above findings it is our recommendation to precede with adoption of the tool for use across Western Canada.

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Microarthropod Fauna in Grasslands of Arid Western Plain of India

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Key words: Acari, collembola, factor analysis, *Thar* Desert

Introduction

The western part of India is primarily desert and categorized as Arid Western Plain Zone named as '*Thar*'. The rainfall in this zone ranges from about 100 mm in the west to 370 mm in east. The permanent pasture and other grazing lands are the major land uses of the region (about 60% of total land use). The *Lasiurus sindicus* (LS) is the dominant grass species, supporting the livestock based economy of the region. The grass is called as 'king of desert' owing to its high survival and nutritious fodder.

Microarthropods play important regulatory role in decomposition and mineralization processes in arid and semiarid ecosystems (Whitford and Bestelmeyer, 2006). Acari and Collembola are the dominant soil micro-arthropods, exhibiting great diversity. These organisms live somewhat sedentary life in the soil with specific composition of a site or ecosystem. They are sensitive towards the changing soil and above ground environment.

Lack of knowledge on such organisms in arid ecosystems in India prompted us to study soil microarthropod abundance and soil biochemical properties of LS based natural grasslands under different grazing and management practices.

Materials and Methods

Study sites

Five locations under different grazing regimes were sampled near Jaisalmer city (26˚59'46.7″N, 71˚20'16.4″E). They are defined as (L1) heavily grazed (26˚59'41.2″N, 71˚20'13.7″E) by small and large ruminants in the community land, (L2) moderate grazing with regulated schedule (26˚59'41.8″N, 71˚20'17.2″E) by large ruminants only, (L3) natural grassland (26˚59'43.1″N, 71˚20'20.4″E) where grazing is discouraged through wire fence protection, (L4) cultivation of LS (26˚59'46.7″N, 71˚20'16.4″E) under annual grass harvesting through cut and carry, and (L5) Natural grassland converted to agriculture production system (27˚03'28.2″N, 71˚17'15.3″E).

Figure 1. Study sites photographed in August 2013.

The soil of the locations is sandy and alkaline in nature with pH ranges from 8.51-8.72. Tussock density of LS (ha^{-1}) at L1 was 1060, L2 was 4040, L3 was 3060 and at L4 was 6420 with cover area (m^{-2}) of 0.053, 0.109, 0.06 and 0.082 respectively. The important index value (IVI) of LS was 100 per cent in L2, followed by 97.43 per cent in in L4, 87.58 per cent in L3 and 45.64 per cent in L1. The line transect study revealed that herbaceous species like *Cenchrus ciliaris, Bracharia ramose, Dactyloctenium aegyptium*, *Eragrostis poaeoides, Mollugo cerviana, Cymbopogon citratus, Cyperus rotundus, Eleusine compressa, Cenchrus setigerus, Cenchrus biflorus, Fagonia critica, Aristida spp. Tribuluste rrestris, Boerhaviad iffusa, Gisekia* spp were also present at the studied sites. Among trees *Acacia tortilis* dominated in the grassland with density 20-80 tree ha^{-1} and IVI 3.05-20%. Halophyte like *Haloxylon* was present only at unprotected site while *Prospois cineraria*, *Calotropis procera* and *Prosopis juliflora* had rare distribution.

Methods

At each location one ha area was marked for sampling. Soil was sampled from accretion around grass clumps and in between accretions at 0-30 cm depth except the agriculture land at 15 days interval from 26th to 50th metrological week in the year 2013, synchronized with grass growth period. Pitfalls were placed in the interspaces of grass clumps. Berlese-Tullgren Funnel method was used for extraction of collembola and mites. Soil chemical parameters like pH, EC, Soil organic carbon (SOC), Labile Carbon (LC) dehydrogenase activity (DHA) and florescent diacetate activity (FDA) were examined.

Results and Discussion

From the study sites 15 Collembola, 29 Prostigmata, 17 Cryptostigmata, 10 Mesostigmata and 1 Metastigmata were identified and are deposited to Zoological Survey of India, Pune. All these microarthropods are first report from LS grassland of this region. Among the micro-arthropods, Collembola (75.46%) were the dominant group and its peak population was achieved in the 30th week while mites were abundant in 37th week. Micrarthropods were abundant near the grass tussocks, only a few individuals were recorded in between grass tufts. Higher enzymes concentration was found between 26th to 32nd metrological weeks. Microarthropods build up was synchronized with FDA and DHA activity (Fig. 2). However, collembola (df = 8) were strongly correlated with DHA in L1 (r = 0.63), L2 (r = 0.95), L3 (r = 0.84) and L4 (r = 0.96); in L5 mites were negatively correlation with FDA (r = 0.68).

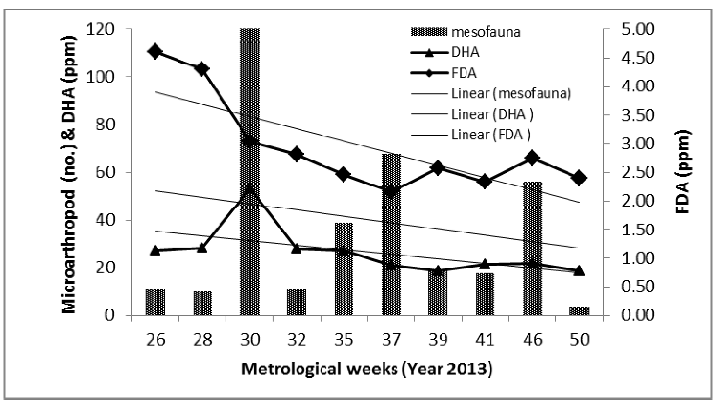
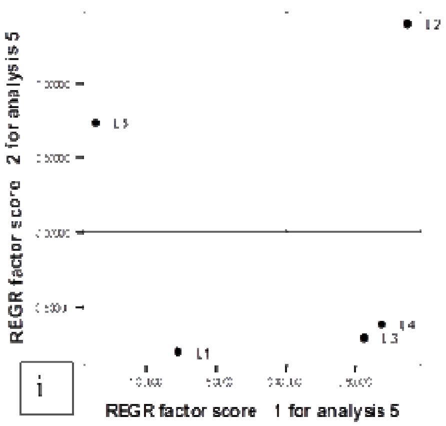


Figure 2. Microarthropods and soil enzymes for study period.

Factor analysis was applied to understand relationship of land uses with regard to microarthropods and various soil parameters. The factor l explained 66 per cent variation while factor 2 explained 20 per cent variation. The acari, collembola and most of the soil parameters have higher loading on factor 1 and are closely interrelated.

Many workers have used soil fauna community diversity and abundance as a whole to use them as indicator of ecosystem functioning (Straleen, 1998; Parisi *et al*., 2005). We also find that microarthropods especially collembolan have strong relation with LS grasslands of Thar Desert.



i

ii

Component Matrix[a]

	Component	
	1	2
SOC	-.748	.586
MBC	.859	.391
FDA	.880	.191
DHA	-.222	.899
LC	.824	.460
Coll	.701	-.423
Mite	-.867	.434
Other	.824	.548
Density	.879	-.134
Cover	.897	.099
Height	.968	.005

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Figure 3. Projection of land use (i) in relation to soil parameters (ii) Factor loading of soil parameters.

Conclusion and Implication

This work indicated that overgrazing and agriculture have reduced microarthropods abundance and diversity of the study sites. Simple protection measures like enclosures and regulated grazing have positive effect on soil fauna and this may help in restoration of LS grasslands.

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Relationship between Forage Mass and Canopy Height in Natural Grasslands: A Meta-Analytical Study

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Key words: Rangelands, sward height, herbage mass, Southern Campos.

Introduction

Natural grasslands of Pampa Biome are a very complex ecosystem where most part are composed by grasses (mainly C_4 metabolic cycle) and herbs (small shrubs and occasional trees) with a huge biodiversity (Boldrini et al., 2015). Furthermore, grazed areas are known as heterogeneous communities where, generally, there are two layers of strata: the lower and more grazed strata composed of prostrated species and the upper strata composed of tussocks. This implies that farmers have to manage a very diverse ecosystem for providing an adequate grazing environment for their animals as well as maintain the health of grazing lands.

An accurate measurement of available forage mass is fundamental in pasture management, mainly to define adequate stocking rates (Fehmi and Stevens, 2009). Nabinger et al. (2009) claim that is possible to triplicate animal production in natural grasslands of Pampa Biome with a standard measurement of biomass and its stocking rates adjustment. In measuring biomass of natural grassland, clipping methods are predominantly used. However, these methods are time-consuming, laborious and expensive. As such, it is important to find an alternative method to assess forage mass accurately as well as apply the technique in a large-scale such as in natural grasslands. Canopy height, a simple sampling method, has been broadly applied in cultivated pastures (Gastal and Lemaire, 2015) and therefore, the aim of this work was to evaluate the use of canopy height as a predictor to forage mass in natural grasslands of Pampa Biome.

Material and Methods

Dataset was organized from nine experiments (290 observations) performed in natural grasslands of Pampa Biome grazed with beef heifers, between 1998 and 2014. The criteria used to select studies for the dataset included those experiments that were conducted in the specified grasslands and used similar methodology to measure variables as forage mass (FM) and canopy height (CH). The FM (kg DM/ha) was evaluated in all experiments through a double-sampling technique with direct (above ground cuts of the forage) and indirect (visual estimative) evaluations. The CH (cm) was evaluated using a graduated stick (Sward Stick) where CH was measured at least three times in each FM point.

Data were summarized in MS Excel with the mean of each repetition from each experiment in each climatic season representing one observation. Then data were separated by climatic season resulting in 50 observations during winter, 68 observations during autumn, 84 observations during spring and 88 observations during summer. A regression analysis was performed between FM and CH for each climatic season. Significance of the linear regression equation and regression coefficient (R^2) was tested using ANOVA ($P < 0.05$). All statistical analyses were performed using software SAS 9.2 version.

Results and Discussion

During the spring season, a significant linear adjustment was observed between FM and CH (y = 202.38x + 24.621; $P < 0.0001$) with a determination coefficient (R^2) of 0.6297 and Pearson correlation coefficient was 0.79 (Figure 1). Similarly, a significant linear adjustment was observed between FM and CH for the summer [(y = 170x + 240.87; $P < 0.0001$) with a R^2 of 0.8064 and Pearson correlation coefficient of 0.90] and autumn season [(y = 91.102x + 968.35; $P < 0.0001$) but with a R^2 of 0.3734 and Pearson correlation coefficient was 0.61]. However, no relationship between FM and CH was observed for the winter season (y = 21.128x + 1129.4; $P = 0.42$) with a R^2 of 0.0353 and Pearson correlation coefficient of 0.12.

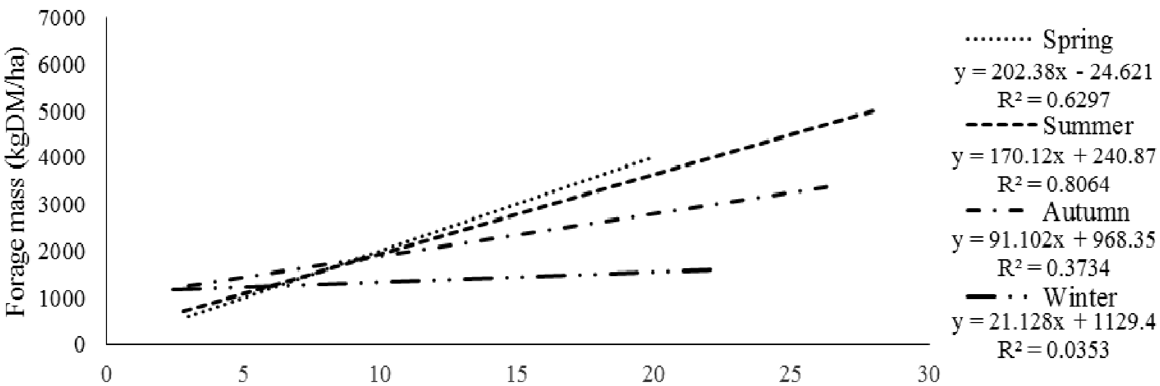

Figure 2. Regression analysis between forage mass (FM; kg DM/ha) and canopy height (CH; cm) in a meta-analysis about natural grasslands of Pampa Biome. [Significance of linear regression - Autumn ($P < 0.0001$); Spring ($P < 0.0001$); Summer ($P < 0.0001$); Winter ($P = 0.42$)]

The CH was not a good predictor of FM, at least, during autumn and winter. During these seasons, FM was more dependent on a fixed value (coefficient b) than canopy density (coefficient a), determined by CH in relation to FM. This fact could be explained by floristic composition of these grasslands, which mainly composed by C_4 grasses (Boldrini, 2015) with a growing seasonality between spring and summer. As such, when there is a significant forage growth (spring and summer), the relationship between FM and CH was more accurate (R^2 = 0.63 for spring and 0.81 for summer). On the other hand, during periods where there is a reduced and/or no growth (autumn and winter), FM was more dependent on the residual forage mass than depending on the canopy density. When the weather starts to become cold with a negative photoperiod, these plants reduce their capacity to grow, reduce soluble components and increase lignin content in their cells which increases their dry matter content. These botanical composition changes are reflected in the lack of relationship between CH and FM during winter ($P = 0.42$), demonstrating the impossibility to relate these variables during this period of the year.

Conclusions and Implications

Canopy height is an accurate predictor of forage mass in natural grasslands of Pampa Biome, mainly during the warm season (spring and summer) but not during the cool season (autumn and winter).

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Monitoring Technology for Semi-Arid Rangelands: The MARAS System

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Key words: Data base, soils, vegetation, biodiversity, patch structure.

Introduction

Long-term land monitoring technology is needed to track slow changes in arid lands and evaluate biodiversity, biological invasions, local extinctions and physical or chemical soil variations including carbon storage. Consistent data sets are lacking because researchers and government agencies use multiple techniques to evaluate the same variables. The MARAS monitoring system (acronym for Monitoring Arid and Semiarid Lands) is a set of standardized techniques that enable different research teams collaborate across wide geographical areas using a common open data-base (Oliva et al. 2011), and this ground data has been combined with remotely sensed information (Gaitán et al. 2013). The effort was partly financed with Gobal Environmental Funds and consists of a network of permanent sites that monitor Ecological Units in a 800.000 km-2 area in Argentina and Chile, that are now in 5-year reassessment process. The objective of this paper was to analyze data obtained in the first assessment in order to estimate errors at two scales: Site subsample variability was analyzed to determine expected errors of the means for the main variables using the fixed sampling effort that is prescribed in the MARAS manuals. At regional scale, between-monitor variability was analyzed in order to determine the minimum number of monitors that deliver an estimate the regional mean within an acceptable error. This analysis shows an estimate of precision of the evaluations and the power to evaluate changes in the future.

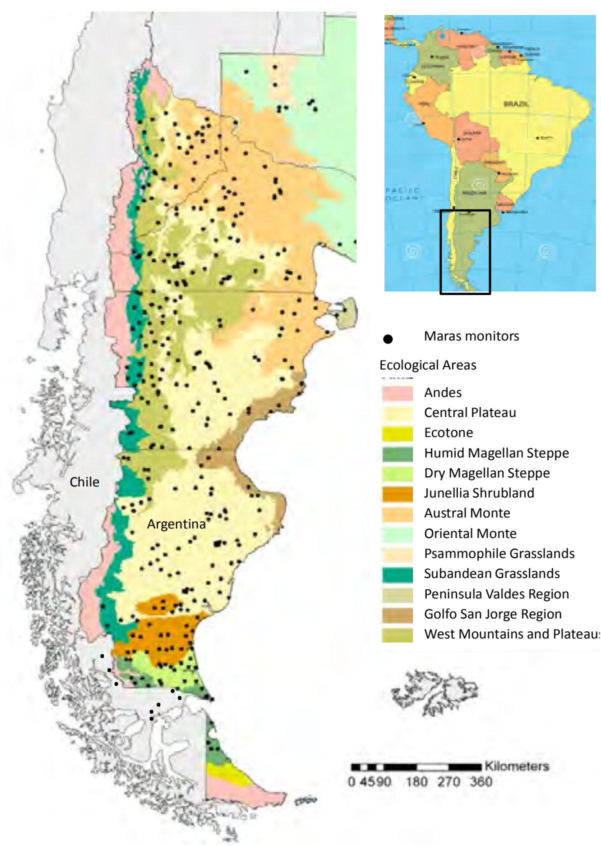

Figure 1. Location of the MARAS sites (black dots) and Ecological Areas of Patagonian region (December 2015).

Materials and Methods

Three hundred and fifty (350) ground-based monitors were set up between 2008 and 2014 in Patagonia, southern Argentina and Chile. Vegetation ranged from shrublands to grasslands and semi-deserts and has been classified in 13 Ecological Areas (Figure 1). Soil cover was sampled with two 50 m transects with a total of 500 points. 50-m long Canfield interception lines were used to recognize >5cm interpatches (areas that loose resources) and >10 cm patches (resource sink areas). Eleven LFA (Landscape Function Analysis) indicators were recorded in 10 bare soil patches and combined to asses: Soil stability, Infiltration and Nutrient cycling. Composite soil samples of patch and interpatch soils were obtained at 0-10 cm depth ant tested for Organic Matter, N, texture, pH and conductivity. Information was stored in a unified database that is accessible through web browsers. Error associated to site observation was estimated by evaluation of variability in 10 subsamples of 50 points in line intercept, variation between 50 interpatches and 10 LFA observations per site. Minimum number of transects required to sample an EA with an error of 5% was estimated using Koltrik and Higgins (2001):

$$n = \frac{(Z_{\alpha/2}\sigma)^2}{(E)^2}$$

Where:
n = number of transects needed. / $Z_{\alpha/2}$ = False-change Type I error rate 0.5 with a probability= 1.96 / σ = Standard deviation of the plots / E = Error in absolute terms.

Results and Discussion

At a plot scale the 500 intercept points provided estimations of vegetation cover within 4.4% absolute cover error. 50 patch-interpatch Canfield lines provided interpatch length estimations within a 6 cm error. 10 LFA Stability index observations provided estimations within 4% in a site. At a regional scale, the minimum number of monitors needed to estimate cover within 5%, richness within 2sp, Interpatch length within 20 cm and Land Function Indexes within 5% varies widely in different Ecological Areas (Table 1).

Table 1. Minimum sample estimation (n° of monitors) in order to estimate four variables (cover, richness, length of interpatches and stability) in the main Ecological Areas of Patagonia.

Ecological Aera	Total area (km^2x 1000)	Monitors installed	Minimum sample (N° monitors/region)			
			Vegetation cover	Species richness	Interpatch length	LFA Stability index
Mean error			5%	2 sp	20 cm	5%
Central District	2066	124	35	42	94	16
Humid Magellan Steppe	79	15	7	16	69	29
Dry Magellan Steppe	90	14	12	13	19	11
Junellia Shrubland	218	24	9	36	12	8
Austral Monte shrubland	1584	56	41	40	19	28
Subandean grasslands	384	24	33	104	54	18
Golfo San Jorge region	202	11	37	23	32	14
West Plateaus and Mountains	952	70	41	48	36	19
Total	5575	338	215	322	335	143

Conclusions and Implications

The sampling effort in each monitor (500 points, 50 m canfield lines and 10 LFA readings) provided site means for the main variables within 5% error. The number of monitors installed by December 2015 provided estimations for cover, diversity, patch size and land function indexes within acceptable errors (Table 1), but more monitors are needed in particularly variable regions such as Subandean Grasslands and Golfo San Jorge Region. Use of standarized methods and precise re-location of the transects will provide evaluations of change with a precision that has not been previously possible and may guide policy-making in view of climate change and natural catastrophes affecting these unique ecosystems.

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The Rangeland Vegetation Simulator: A User-Driven System for Quantifying Production, Succession, Disturbance and Fuels in Non-Forest Environments

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Key words: Modelling, remote sensing, fuels, rangelands

Introduction

Rangeland landscapes occupy roughly 662 million acres in the coterminous U.S. (Reeves and Mitchell 2011) and their vegetation responds quickly to climate and management, with high relative growth rates and inter-annual variability. Current national decision support systems in the U.S. such as the Interagency Fuels Treatment Decision Support System (IFT-DSS) require spatially explicit information describing production, fuels, grazing capacity and successional trajectory. However, no single system presently offers this information. In addition, issues of increasing national attention, such as preservation of lekking birds (e.g. greater sagegrouse (*Centrocercus urophasianus*), and greater prairie chicken (*Tympanuchus cupido*)), has prompted new management guidelines such as stubble height standards, but ecological tools for predicting this type of management outcome on rangelands are quite limited in their ability to predict these variables. Therefore a system is needed that quantifies these vegetation and fuel characteristics in sufficient detail to permit estimations of annual production, treatment success, grazing capacity, and fire behavior and effects. This situation inspired our project to develop a comprehensive program for simulating succession, productivity, and fuels in non-forest environments. This system is called the Rangeland Vegetation Simulator (RVS).

Materials and Methods

The RVS is a multithreaded, portable program written in C#. It also operates in a spatially explicit mode using a series of Python scripts through ArcGIS 10.X. A minimum of six inputs is required for simulating forage and fuels with the RVS (Table 1). The geospatial location is especially critical since it enables sampling of either the Biophysical Settings (BPS) geospatial data product (Rollins 2009) and their associated successional models, or state – transition models from Ecological Sites (Caudle et al. 2013) Growth and production of herbaceous species is governed by the site for which the simulation is being conducted, annual precipitation, and Normalized Difference Vegetation Index (NDVI) (Table 1). Growth and production of shrubs is controlled by allometric relationships and the site on which the shrubs are found. In a similar manner, quantifying fuel loadings of various fuel size classes is also accomplished using allometric equations for shrubs. For example, using height, cover, and species information, the loading of 0.64, 0.64 - 2.54, 2.54 - 7.62 and 7.62 - 20.32 cm. fuel size classes can be estimated using these equations. The RVS offers 46 allometric equations for quantifying and mapping biomass, production and fuels across the landscape. These fuel and production estimates are also influenced by management treatments including mechanical thinning, wildfire and herbivory. The RVS permits user-designed shrub overstory reduction as a treatment option and offers simulation of wildfire effects on shrub mortality and accompanying herbaceous response. Likewise the RVS simulates the effects of herbivory by both grazers and intermediate species (e.g. cattle vs. goats) on standing crop, stubble height, successional trajectory, shrub stature and associated fuel bed components.

Table 1. Minimal inputs needed to run RVS.

Data element	Use
Latitude and longitude	Enables sampling of 9 geospatial data layers
Vegetation composition	Ecological Site, production and fuels
Vegetation structure	Ecological Site State and Phase, production and fuels
Treatment & length	Treatments (Herbivory, Mechanical, Fire), length of simulation
Estimated climate	Spatially explicit climate and growing conditions

Results and Discussion

The RVS has a rich set of outputs for quantifying carrying capacity, fuels, fire behavior, and successional trajectories. The list of major summarized outputs is found in Table 2. Each of these outputs can be available in tabular or as a spatially explicit map.

Table 2. Simulation output resulting from climate, and proposed treatment (both pre and post treatment estimates available).

Outputs	Units
Species composition	% by species
Shrub density	Stems ha^{-1}
Shrub cover	%
Herbaceous cover	%
Herbaceous height	meters
Standing dead herbaceous	kg ha^{-1}
Shrub height	meters
Stubble height	meters
Fuel loading by size	kg ha^{-1} (0-0.64, 0.64-2.5, 2.5-7.6, 7.6-20 cm)
Surface Fire Behavior Fuel Model and Fuel Loading Model	Unitless
Succession class / state	Unitless
Annual production (for both herbs and shrubs)	kg ha^{-1}
Standing crop	(Live + dead herbaceous)
Utilization	[from herbivory] % (kg ha^{-1})

Conclusions and Implications

The RVS offers projections of future vegetation conditions thereby improving our ability to estimate the effects of management actions on future fuels, productivity and grazing capacity across 128 rangeland systems. The model is presently being used and tested across a variety of projects nationally including, 1) estimating sequestered carbon in shrubs, 2) 2015 fuel maps for more precise emission estimates, 3) Setting stocking rates across California and New Mexico (U.S.) rangelands, 4) development of a decision support system supporting stubble height requirements and estimates for sage grouse guidelines.

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Correlation Analysis between Vegetation Evaporation, Meteorological Factors and Community Characteristics in *Stipa breviflora* Desert Steppe

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Key words: Vegetation evaporation, evapotranspiration, meteorological factors, desert steppe.

Introduction

Desert Steppe is sensitive to climate change, which has been well-known. Meteorological factor is very important to natural grass in the region. The evapotranspiration is the significant factors for atmosphere hydrological cycle in grassland, which is hot topics in the study of eco-hydrology and ecological water requirement in arid areas with the dry tendency and the shortage of water resources (Rana, 2000; Lecina, 2003; Yang-jie, 2003; Zhang-min, 2014). The research of correlations between community characteristics and evaporation plays a significant role in understanding regional and global water balance and climate change. The comparison is more important for vegetation evaporation and meteorological factors or community characteristics in the grassland ecosystem. Our objectives were to investigate correlations between plant community characteristics and meteorological factors and to identify the major factor influencing factors in *Stip breviflora* Desert Steppe.

Materials and Methods

The experiment was carried out in *Stipa breviflora* Desert Steppe of Inner Mongolia from 2011 to 2013. (43º46′N and 116º59′ E). The experimental paddocks and blocks were grazing grassland began from 2004. The height, coverage and density of *Stipa breviflora* Griseb. *Artemisia frigida* Willd., *Cleistogenes songorica* Ohwi. and plant community were measured, which were repeated 10 times, in random quadrat (1 m × l m) from May to September of each year. The plants were cradled from random quadrat, and then measured the biomass, which were repeated 5 times. Vegetation evapotranspiration are measured by micro-evapotranspiration method (method of weighing the overall soil column) for 5 days in each month, repeated 3 times. The monthly evapotranspiration value（$mm \cdot m^{-2} \cdot m^{-1}$) was calculated by multiplying the average daily evapotranspiration value（$mm \cdot m^{-2} \cdot d^{-1}$) with the numbers of effective evapotranspiration days in the month (excluding rainy day). The accumulation evapotranspiration value was the sum of the monthly evapotranspiration value from May to September. The mean precipitation and temperature, evapotranspiration and duration of sunshine were collected from the small automatic weather instrument (Dynament Research of Automatic Weather Stations). Data were processed using Excel 2010 and SAS 9.0.

Results

The vegetation evapotranspiration was affected by the precipitation, average temperature and duration of sunshine (Table 1). The evapotranspiration had positive correlation with biomass and coverage of community and different plant population ($P < 0.01$), while negative correlation with density of them ($P < 0.05$). The impacts of evapotranspiration on population characteristics of *Cleistogenes* were notable, and the contributions of different meteorological factors to each characteristic differed significantly ($P<0.01$) (Table 2). The density of *Stipa* population had not correlation with evapotranspiration ($p>0.05$) because of possible lamina wrap when evapotranspiration increased with abundant density.

Table 1. Correlation between evapotranspiration and Meteorological factors under different grazing intensity.

Items	Evapotranspiration	Precipitation	Average temperature	Sunshine hours
Evapotranspiration	1			
Precipitation	0.65484※※※	1		
Average temperature	0.68323※※※	0.95488※※※	1	
Duration of sunshine	0.92244※※※	0.59831※※※	0.63247※※※	1

Table 2. Correlation between Plant population and community characteristics, evaporation and meteorological factor.

Category	Evapotranspiration			
	Stipa *breviflora Griseb.*	**Artemisia *frigida Willd.***	**Cleistogenes *songorica Ohwi.***	**Plant Community**
Biomass	0.77355※	0.74935※	0.73414※	0.88392※※
Density	-0.30751	-0.78415※	-0.95105※※※	-0.80884※※
Height	0.47927	0.69452	0.87909※※	-0.69047
Coverage	0.75569※	0.75675※	0.84766※※	0.91528※※

Note: *: P < 0.05, **: P < 0.01, ***: P < 0.001

Note: The micro evapotranspiration is a cylinder, which diameter for 226 mm, height for 250 mm, volume for 10000 cm3, 17 kg weight.

Conclusion

Variation of evapotranspiration was due to the complex effect of meteorological factors in *Stipa breviflora* Desert Steppe. *Cleistogenes* population and community characteristics has more correlation with vegetation evaporation than *Stipa* and *Artemisia* population on some extent.

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Areal Changes in Gully Erosion along the Burdekin River Frontage in North-Eastern Australia

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Key words: Gullies, aerial photos, savannah, GBR

Introduction

The effects of terrestrial sediment and nutrients on the Great Barrier Reef (GBR) in NE Australia are well documented (Furnas 2003). A study of yttrium concentrations in *Porites* coral in the northern Townsville-Whitsunday Management Zone of the GRB suggests that sediment deposition from the Burdekin River has increased by 40 to 50 percent since 1860 (Lewis *et. al*., 2007) when domestic livestock were first introduced to the Burdekin catchment. To estimate current sediment losses, Dight (2009) developed a catchment atlas for the Burdekin using the SedNet model. The modelling was ground truthed with ground cover traverses, stream gauging data and analysis of wet season runoff samples. Stream banks, gullies and hillslopes were identified as generating 23, 18 and 59 % respectively of sediment leaving the Upper Burdekin (30 % of the total Burdekin catchment). The upper Burdekin is generating more sediment from gully erosion than any of the other five subcatchments that make up the total Burdekin catchment (Dight 2009). Satellite imagery shows that a 177km length of the upper Burdekin River is heavily impacted by gully erosion. This paper quantifies the areal expansion of one of these gully networks.

Materials and Method

An area of extensive gullying near the confluence of the Burdekin and Clarke Rivers (19° 11’18”S, 145° 27’43”E) was selected. The area has a seasonally dry tropical climate with a median annual rainfall of 631mm. The gullied soils are deep, poorly structured alluvial tenosols (Rogers *et. al.,* 1999) with a sparse vegetation cover. The area of the gully network was measured using a time series of remotely sensed images (aerial photos captured in 1951, 1967, 1979, 1991 and 2002 and SPOT satellite imagery 2009.) The images were enlarged to a scale of 1:10,000 and the gullied area measured manually using a five millimetre grid.

Results and Discussion

The area of the gully network expanded from 21ha in 1951 to 25.5ha in 2009, an increase of 21.4% (Av 0.071ha/year or 0.31%/yr). The gullied area (A) for any year was calculated as:

$$A = 0.07085Y - 117.2 \quad (p<0.001, \text{ adjusted } R^2 = 93.6\%) \quad (1)$$

where Y is the calendar year. Although tenuous when used as a hind-cast, this formula indicates that gullies were present near the Burdekin-Clarke confluence in the 1840’s. This is supported by the diary of the explorer Ludwig Leichhardt (1847 p146) that mentions gullies in this area in 1845. These gullies therefore clearly existed prior to the introduction of domestic livestock in the 1860s. It also supports the fact that not all erosion is initiated by grazing domestic livestock.

Conclusion

The remotely sensed imagery indicates a relatively constant rate of gully erosion in the study area from 1951 to 2009. As this erosion commenced prior to the introduction of domestic livestock in the 1860s, some geomorphologically induced change in the behaviour of the Burdekin River in this area is considered to be the probable trigger. The extent of the gullying at the time of settlement was not recorded; therefore the subsequent impact of livestock grazing cannot be determined. Future work using more sophisticated remote sensing technologies will further ground truth the predictions of computer models such as SedNet and support targeted remedial actions to improve water quality in the Burdekin River catchment.

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The Dry-Weight-Rank Technique of Botanical Analysis: An Often Overlooked Technique

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Key words: Species yield, grassland, double sampling, vigour

Introduction

In grassland research, it is often desirable to determine grass yield. Where the grassland comprises a mixture of species, measurement of the yield of each species often provides valuable additional information, particularly where the component species differ in palatability, and respond differentially to disturbance. Measurement of the yield of component species of a grassland is tedious, time consuming and destructive, so is rarely done on a large scale. Some 50 years ago t'Mannetje & Haydock (1963) proposed the use of the dry-weight-rank (DWR) method for the non-destructive determination of the percentage mass of the herbage of each species present in mixed-species pastures. Barnes *et al*. (1982) and others suggested further modifications to increase accuracy, including using a double sampling technique to simultaneously weight the ranks for each quadrat on the basis of dry matter yield for each quadrat before summation of ranks. The technique has been tested and found to be suitable under a wide range of conditions after appropriate training (Barnes *et al*. 1982; Gillen & Smith 1986; Friedel *et al.* 1988).

Here the technique has been used to determine and demonstrate the impacts of sheep and cattle grazing on grassland, using selected data from Kirkman (2002).

Materials and Methods

Selected data from a grazing trial comparing impacts of sheep and cattle grazing (Kirkman 2002) are used to illustrate the potential of the DWR technique to determine impacts of grazing on grassland. The DWR technique (adapted from Barnes *et al.* 1982) was used to estimate regrowth of grass in a multispecies grassland in South Africa (mean annual rainfall 719 mm) during the season following grazing by sheep or cattle at similar stocking rates in order to determine the impacts of grazing on grass regrowth (or vigour) compared to ungrazed controls. Two hundred quadrats per treatment (replicated four times), were used to estimate regrowth. All measured plots were cut to 25 mm above ground level at the start for the growing season, so that regrowth measurements during the season had a common base.

Results and Discussion

Species were grouped into palatable, intermediate and unpalatable groups, and the yield of the groups in grazed grassland was compared to that of the ungrazed controls. Yields of individual species were also examined to determine differential impacts by sheep and cattle on palatable or unpalatable species.

Differences in vigour determined by the DWR technique were evident by the depressed vigour of the grazed treatments relative to the ungrazed controls, with the depression of palatable species vigour accentuated. Differences were evident between sheep and cattle impacts on vigour (Figure 1), with sheep having a greater depressive effect on palatable species than cattle. The impacts are reinforced when considering the effects of grazing on individual species vigour (Figure 2), where yield of *Themeda triandra* (a palatable grass) is differentially affected by sheep and cattle grazing. The selectivity of sheep grazing results in a greater vigour decline than under cattle grazing. The reverse is seen for *Aristida recta*, a highly unpalatable grass that is avoided by sheep and seldom grazed by cattle, where the vigour increases differentially after grazing.

Total yield **Palatable species yield**

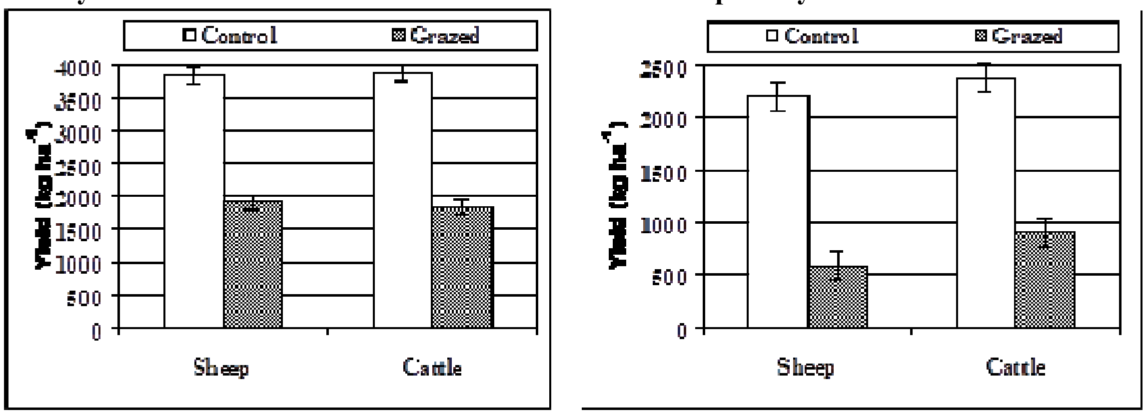

Figure 1: Effects of sheep and cattle grazing during the 1992/93 season on total yield and the yield of the palatable species of the control and grazed plots measured during December 1993. The error bars represent least significant differences (P<0.05).

***Themeda triandra* yield** ***Aristida recta* yield**

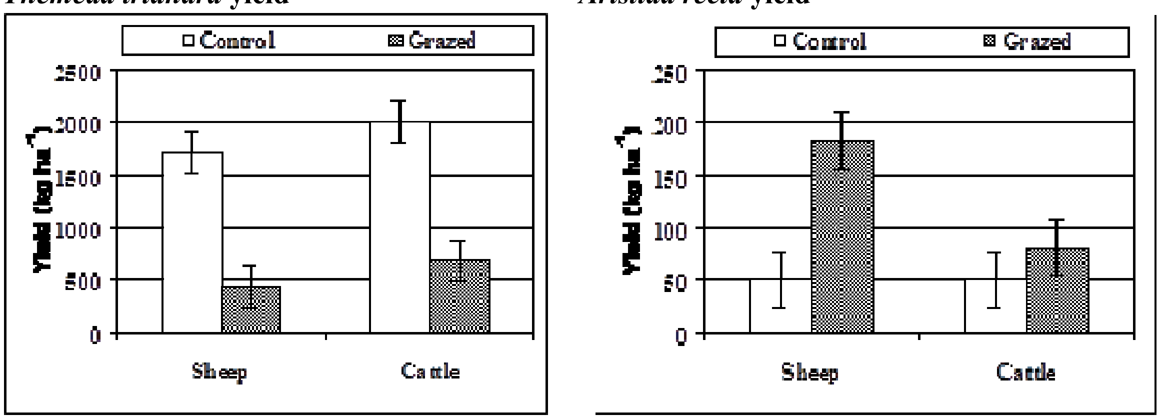

Figure 2. Effects of sheep and cattle grazing during the 1992/93 season on the yield of *Themeda triandra* and *Aristida recta* of the control and grazed plots measured during December 1993. The error bars represent the least significant differences (P<0.05).

Conclusions and Implications

Examination of the impacts of sheep and cattle grazing using the DWR technique has provided unique insight into the interaction between grass and grazers, highlighting the negative impacts on palatable species and the vigour increase shown by unpalatable species. The results showed highly significant impacts of grazing on grass regrowth or vigour during the following season, with sheep and cattle impacts reflecting the selectivity of their grazing habits. Differential effects on palatability classes and on individual species were clear, and provided new insight into impacts of grazing on grassland in South Africa.

The DWR technique provides a rapid means of estimating grass yield on a species basis, which has many different applications, including the study outlined here. This adds valuable insight and, as a short term measure of disturbance impact on grass species, may provide capacity to predict long term changes in species composition (Kirkman 2002). The speed of the estimation technique allows for comprehensive coverage of study sites in relation to more time-consuming destructive yield determination techniques. Further modification of the technique includes recording all species in all quadrats in addition to ranking the dominant species as required for the DWR technique. This allows additional measures to be calculated, such as species richness and frequency, in an efficient manner.

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Data-Driven Ranch Management: A Vision for Sustainable Ranching

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Key words: Sensors, technology, ranching

Introduction

The 21st century has ushered in an era of tiny, inexpensive electronics with impressive capabilities for sensing the environment. Also emerging are new technologies for communicating data to computer systems where new analytical tools can process the data. Many of these technologies were developed for mobile devices. Use of these technologies in ranching is in its infancy. Ranching is choosing how best to employ resources to achieve production that is economically, ecologically, and socially sustainable. Traditional research-based management sought to manage for the long-term average response of typical animals and ecological sites, often distilled to rules-of-thumb using calendar date triggers. Data-driven management enables ranchers to manage based on customized relationships that consider factors known to affect outcomes. Data-driven management is achieved by measuring, predicting, and adapting in near real-time. Many technological advances will be central to this vision including: unmanned aerial and ground vehicles with sensors, networked stationary sensors, and sensors deployed on, in, or near grazing animals. The connected sensors will communicate data to a computer where it is processed. Relevant scientific knowledge will inform the predictions required to provide actionable information or automated actions. Measured performance is feedback the system will use to make refinements to future predictions and draw attention to knowledge gaps.

The Data of Ranching

Resources

Accurate and timely measurements of relevant information—the data of ranching—are critical to the success of a data-driven ranch management system. These data include characterization of ranch resources including the land, water, vegetation, harvested feeds, supplements, animals, people, and facilities. Soil resources vary spatially, forage quality varies over time, and individual animals vary in their genetic makeup; therefore the data management system will need to store data with the relevant spatial, temporal, and individualistic dimensions. Public databases are available for many, more static aspects of land, water, and vegetation; and public satellite data are available for some spatially and temporally variable characteristics. Information needed on finer scales will be collected locally by sensors. These sensors will be deployed on stationary bases, on equipment and unmanned vehicles, and on animals.

Weather

Much change in the status of ranch resources is driven by weather. Weather affects, for example, the amount and quality of forage produced at a site, or an animal's nutrient demand or need for stress relief. Weather data is needed at appropriate spatial and temporal scales to be useful. Timing of weather events can impact the induced response. Public databases are available to query, but for some applications more timely and accurate data, measured locally, are needed to be useful for data-driven management. These local data can be obtained from a network of weather stations. Not only is the weather that has occurred important, but good weather forecasts are also critical for planning a course of action. These forecasts are available from public databases.

Markets

Biology meets economics when production input and output markets are considered. The markets vary spatially and temporally. Temporal variability in the markets may include changes that reflect change in weather, seasonal change, or change due to multi-year cycles. Changing market prices provide opportunities to choose a different mix of production inputs and outputs for profit. To properly consider these alternatives, timely market data are needed. Futures and options markets, as well as USDA-reported prices of livestock and crops, are available. Consistent reports of some other relevant input prices (fertilizer, equipment, etc.) may be lacking.

Analytics and Actionable Information

Ranches are complex systems with many interacting components, but there is much scientific knowledge about these components and their function that is currently underutilized. The analytics engine will begin to utilize this existing knowledge to process the data. The system will utilize feedback to make refinements for future predictions and highlight gaps in our scientific knowledge. The output from analytical processes for ranch managers will be actionable information and, in some cases, trigger automated actions such as opening a gate and allowing livestock to move into a new pasture.

Benefits

Potential benefits of data-driven management are numerous. Ranches may be operated more efficiently and cost-effectively, improving the rancher's standard of living and reducing food costs to the public. These systems do this through improved individual-animal management, decreased labor, and greater ability to balance production and sustainability objectives. Improved socio-economic status and the ability to work with technology may entice more young people to choose ranching. Increased knowledge of derived ecosystem services and improved predictions of the likely consequences of management options, will improve environmental sustainability. This "evidence-based" approach will also highlight knowledge gaps, focusing research where it is most needed. In general, data-driven management enables greater efficiency and focus on the most meaningful aspects of ranch management, resulting in fewer surprises.

Challenges

Certainly there are challenges to address. The cost of the sensor systems required, while decreasing rapidly, may still create "sticker shock" for many ranchers. Perhaps the larger cost is development of a centralized system to process data and conduct the analytics. Should this system be open and public, and share data across business enterprises? Or should it follow a proprietary model? If the system is not robust and user-friendly, users will quickly become frustrated and disillusioned. If users aren't comfortable with the privacy of data, they will refuse to use the system.

Summary

A data-driven, evidence-based approach to ranch management offers many potential benefits to improve sustainability of grassland agriculture. Technology developments such as sensors, communications, and analytics protocols would seem to be developing to the point to not just facilitate this kind of approach, but in some ways, make it a foregone conclusion. Organizations around the world are working on such approaches, and considerations of which approaches are most useful and best achieve sustainability objectives are warranted.

Camera Traps as a Tool to Estimate Grazing Intensity and Effects on Rangeland Health and Biodiversity

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Key words: Photographs, cattle, monitoring

Introduction

Rangelands cover up to 75% of the terrestrial surface and are critical habitat for many species and important reservoirs for biodiversity. Often, a conflict is perceived between livestock grazing and the maintenance of biodiversity. However, rangelands provide valuable ecosystem goods and services, including support for biodiversity and forage. Understanding the impacts of cattle on ecosystem goods and services is important for maintaining sustainable grazing practices. However, monitoring cattle impact across extensive systems can be difficult and expensive. Wildlife cameras are often used to monitor native wildlife (Burton et al. 2015) and also are a potential tool to monitor cattle in rangeland. The purpose of this study was to assess the potential to use wildlife cameras to develop measures of cattle activity and assess whether such measures were related to rangeland health.

Materials and Methods

In 2015 we deployed wildlife cameras at 25 native grassland sites grazed by cattle in Southern Alberta. We assessed rangeland health at each using the Alberta Rangeland Health Assessment (Adams et al. 2009). Four cameras were placed at each location in March of 2015 then retrieved in late summer; the cameras took photos whenever they detected motion (ABMI 2009). Photos were examined and any animal present in the photo was identified (ABMI 2015). The cameras include a date stamp so the time of animal activity is also recorded.

Results and Discussion

Over 625,000 photos were taken that had at least one cow in it, and the number of photos per site ranged from 6 to 70,685, with a mean of 26, 602 photos per site (Fig. 1). The number of photos of other species ranged from 347 to 16,370 per site and these captured from 7 to 18 identifiable species per site. Rangeland health scores ranged from 38 to 100, which represent an assessment of “unhealthy” to “healthy”. Thus, both sets of measures provide considerable range. Preliminary analysis shows that the number of photos of cattle did not correlate with range heath scores, photo-abundance of other species or the number of other species detected (Fig. 2). However, a number of important variables have yet to be considered including, the size of the pasture, type of plant community, duration that cattle were in the pasture, time of year cattle were present and the number of cattle.

Conclusions and Implications

Wildlife cameras present a potential tool for monitoring cattle activity and their impact on ecosystems. The cameras were reliable and required only deployment and retrieval in the field, but require substantial processing on a computer if many cameras are deployed. We did not find a relationship between the number of photos taken and associated range health scores or other species but a number of additional factors will be accounted for in future analysis.

Figure 1. Examples of photos taken with wildlife cameras at different rangeland locations: A) group of cattle near the camera, B) cow and Savannah Sparrow, and C) a herd of cattle.

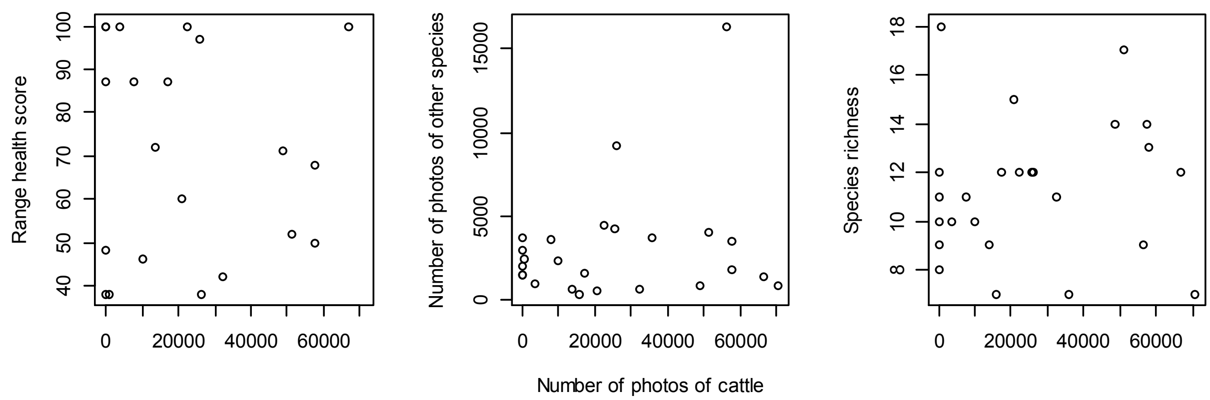

Figure 2. The number of photos taken of cattle by 4 wildlife cameras at study sites and A) their range health scores, B) number of photos of other species and C) species richness.

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Assessing Vegetation Productivity across Rangelands of Southeastern Arizona Using Machine Learning

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Key words: Grasslands, machine learning, remote sensing, climate, management

Introduction

Rangeland ecosystems support millions of people that depend directly on livestock-related activities (Gillson and Hoffman, 2007). From the 2012 U.S. Census of Agriculture, the United States occupies the first place as producer of beef and the second place as exporter in the World (USDA-ERS, 2014). Along with economic impact, rangelands require special attention in conservation efforts. Recent research on conservation has presented different methodologies from formal and informal monitoring procedures (Woods and Ruyle, 2015) to adaptive management (Havstad et al., 2007). Thus, one of the main challenges faced by ranchers, government agencies and stakeholders is the administration and conservation of the land. The U.S. Bureau of Land Management (BLM) has acknowledged that sustainable rangeland management will provide the foundation for ecosystems services such as food, fiber, and fuel production, climate regulation, watershed functions, wildlife habitat, recreation and biodiversity. The use of remote sensing technology has been proposed to assess different aspects of rangelands ecosystems, for vegetation change/state, phenology, watershed functioning or grazing effects (Veblen et al., 2014). Remote sensing provides an additional source of information both back in time and across space. Current remote sensing datasets are cheaper, more mature, and provide longer records at different spatial resolutions than had been available previously. The main goal of this research is to determine how climate, inherent productive capacity, and management combine to influence vegetation productivity of grazed areas at a regional scale to focus attention where production, given similar inputs, appears to fall short. We use gridded climate data and remote sensing as data sources and machine learning techniques to develop the model. Expertise from rangeland specialists along with limited field monitored data will provide the main inputs to validate the results.

Data and Methods

Study area

We conducted this study at a regional scale across southeastern Arizona, covering a surface area of approximately 48500 km^2. The study area is an initial proof-of-concept from a collaboration between USDA-ARS, Forest Service, and BLM with the purpose of developing a common framework that brings together the geospatial analyst and the range conservationist, to provide a deeper understanding on how climate and management practices interact to determine vegetation communities that meet management objectives of grazed public lands (Fig. 1).

Figure 21. Study area (green box).

Data

As a proxy for vegetation productivity, we used the maximum NDVI value per year for the 2002-2014 period using Landsat platforms. A 33-year normal precipitation record was obtained from PRISM (800m) and potential evapotranspiration (PET) from 4-km GRIDMET as the main sources to calculate SPEI (Standardized Precipitation-Evapotranspiration Index) drought index values. For solar radiation, the model (r.sun) from GRASS was used. The MTBS data base was used to identify pixels with fire events during the period of time. Pixels within 30m buffers of ponds (NHD) and roads (TIGER DB) were removed, and only those pixels falling within polygons classified as "grazed" areas from a Land use layer were used. Using terrain (USGS-NED/10m) features along with streams (NHD), we classified the landscape into bottoms, hills, and uplands.

Methods

To identify the factors controlling the productivity patterns we initially performed a simple linear regression model between our response variable, productivity (greenest pixel of the year), and the predictors: normal precipitation (over 33 years), annual SPEI, 3, 2 and 1 previous years of annual SPEI, and solar radiation which explained 39% of the variability ($R^2 = 0.39$). Next, we explored the machine learning approach of Random Forest, or RF (Breiman, 2001). This method is one of the most common techniques used in machine learning based on the theory of decision trees. Modeling with RF consists of training a model with data and validating on data the model has not "seen". After experimenting with the learning/modeling process we were able to explain 72% of the variability in the annual maximum NDVI ($R^2 = 0.72$) at the validation stage, which we used to predict the response values for the remaining data.

Results

Using RF we were able to identify the most important variables in estimating productivity for the study area. Figure 2a shows the average residuals from 2002-2014, where predicted annual values at the pixel level (30m) were used to calculate the annual residuals (Observed – Expected). This methodology is useful to identify those areas that were off the expected productivity values over time. Figure 2b shows residual pixels with values above or below ±1 standard deviation allowing the identification of outliers according to the expected values of productivity. We should be able to improve this relationship by adjusting for years with cloud cover at peak biomass, improving the GIS layers used to calculate the predictors, and improving the model structure.

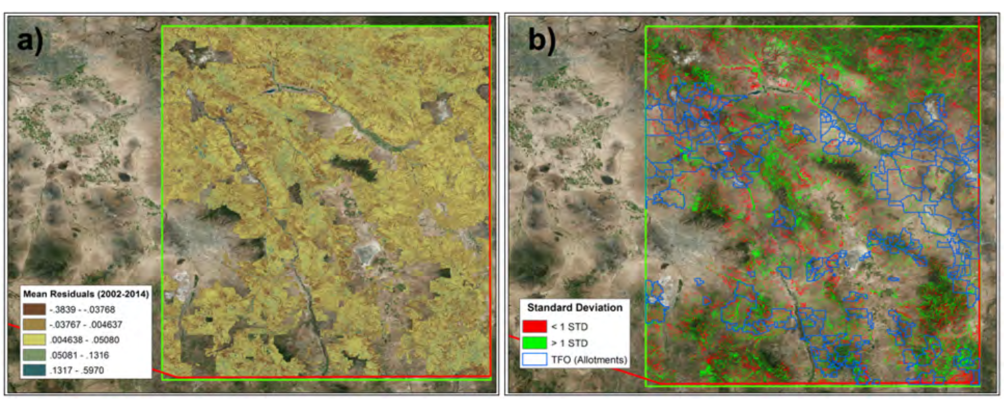

Figure 2. (a) Average residuals by pixel for 2002-2014 and (b) residual pixels with ±1 standard deviation.

Discussion and Conclusion

Research in rangeland ecosystems using remote sensing data has increased significantly. Using climate data/models, GIS data and management practice information, we produced a workflow to estimate productivity at a regional scale. Our processes generate tools that usable by experts on the field to continue validating the results obtained. Ranchers, stakeholders, government agencies can benefit from using this type of tools. In addition, the use of data-driven modeling techniques, such as machine learning, can help to keep up with the amount of data produced by current models and satellites. We identified those variables that have a greater impact in productivity and used that information to make spatio-temporal estimations. However, in a data-driven approach modeling, continuous model evaluation and improvement is required. Our continuing research will strongly rely on the support from experts in the field as part of an ongoing evaluation and dialogue.

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Remote Sensing Biomass Estimation from Permanent Monitoring Sites Located in Chihuahua, Mexico

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Key words: Grasslands, landsat, spectral data, linear regression.

Introduction

Grasslands provide valuable ecosystem services such as conservation of soil and water harvesting, among others (Zhao et al., 2014). However, these ecosystems are the most threatened on the planet (Sayre et al., 2012). Particularly, the loss of grasslands in Chihuahua, Mexico has reached worrying levels. The causes include overgrazing, land use change to agriculture, the global environmental change and others (El-Belgar and Madkour, 2012). In this sense, it is very important to be aware of the problem and rely on effective grassland biomass tools for the precise monitoring and quantification of such losses to implement management and protection strategies (Zhao et al., 2014). Available methods for biomass estimation include field studies, statistical models (Liu et al., 2007) and remote sensing. The essence of the remote sensing methods for this application is the establishment of a regression model between biomass measurements and reflectance. In this study, the spatial and temporal production of biomass from two permanent monitoring sites of natural grasslands in the state of Chihuahua were determined through remote sensing to discuss about their dynamics and implications.

Materials and Methods

Two permanent monitoring sites (PMS) of grasslands were employed for this study; the PMS Teseachi (SPMT) is located in the central coordinates 28.893 (N), -107.447 (W) and the PMS El Sitio (PMSS) located at the coordinates 27.588 (N), -106.275 (W). Each PMS consisted of nine sampling stations. Each station covered a surface area of 1.0 ha, where four biomass samples, each of 1 m^2, were taken. Six scenes of the study areas were acquired from the Landsat ETM and OLI sensors (pixel size = 30 m x 30 m). The images dates were from October of the years 2012, 2013 and 2014, which coincide to the peak of biomass production and to the dates were samples were taken. Since the vegetation from the two PMS consisted mostly on grasses, and biomass was at its peak of production, the influence of litter or senescent vegetation on the spectral data was not significant. Data were extracted from the bands 1-5 and 7 for the ETM Landsat sensor and from the bands 2-7 for the OLI sensor. The values of the bands were then converted into reflectance with the software plugin module developed by Cogendo (2003). Linear regressions between reflectance values from each band and biomass production were calculated. The regression that gave the highest coefficient of determination was chosen for each year. For the models with a high coefficient of determination, values of biomass production were mapped to for the land nearby the PMS.

Results and Discussion

The relationship between biomass and spectral data was established by correlation analysis. Particularly, the band 7 was strongly correlated to biomass production in the area of the PMST. Meanwhile, the band 5 had a strong correlation with biomass production for the PMSS (Table 1). A strong correlation between biomass and spectral data resulted for the PMST in 2012 and 2013 (R^2=0.72 and R^2=0.76) and for PMSS in 2014 (R^2=0.78). The variability in the biomass distribution, appreciated in Fig. 1, could be due to the climatic conditions of the site.

Table 1. Models for biomass estimation.

Site	Year	Model	Statistical parameters		
			R^2	S_{xy}	*p - value*
PMST	2012	y = 948 – 3846 (b7)	0.72	48.65	0.004
	2013	y = 731 – 2470 (b7)	0.76	48.79	0.002
	2014	y = 577 – 1705 (b5)	0.56	40.9	0.019
PMSS	2012	NA	NA	NA	NA
	2013	y = 521 – 7093 (b2)	0.49	30.45	0.034
	2014	y = -2272 + 9748 (b5)	0.78	88.04	0.001

NA = Poor correlation, PMST=Permanent Monitoring Site Teseachi, PMSS=Permanent Monitoring Site El Sitio, R^2=Coefficient of Determination, b2, b5, b7=spectral bands, $S_{x,y}$= Desv. Est. and *p-value*=Level of significance.

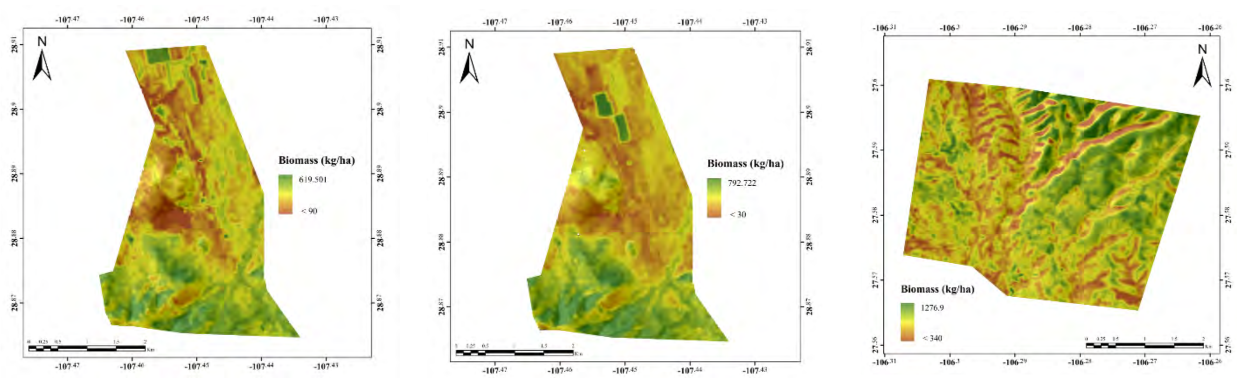

Figure 1. Spatial distribution of biomass. Biomass distribution in in Teseachi 2012 (left), Biomass distribution in in Teseachi 2013 (center), Biomass distribution in El Sitio 2014 (right).

Conclusions and Implications

A strong relationship between spectral data and biomass production was found. Biomass production for the PMST decreased form 2012 to 2013. This result highlight the need for implementation of strategies to conserve the potential of biomass production of the site. This approach represents an alternative for the development of predictive models for biomass production and distribution by using spectral data from remote sensing. There are still efforts to perform to improve the accuracy of the models for some of the years studied. Future research could include data of precipitation, temperature and vegetation indices.

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Grazing Land Degradation Study in Mongolia Using Advanced GIS-Based Modelling Technique

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Key words: Grazing, pasture, land degradation, GIS, modelling

Introduction

Mongolia is situated at the Central Asian Highland and the country's main type of land use is grazing land for semi-nomadic livestock husbandry. The availability of pasture is determined by rainfall, and access to fodder is determined by the availability of water during summer and of snow during winter. The country has harsh continental climate and adverse climatic conditions often influence the agricultural crop production and animal husbandry. Especially, when there is drought, the fodder production is too low to feed all animals. As a result, extensive overgrazing occurs. Moreover, due to tremendous increase of livestock, natural vegetation is being consumed with such intensity and speed that more yearly species are demolished and annual species cannot flower and produce seed for reproduction (Amarsaikhan, 2013).

For conservation and improvement of the degrading pasture and grazing lands of Mongolia, extensive research studies should be conducted using advanced spatial techniques. One of such techniques could be a GIS-based water balance modelling method. It determines the root zone water balance on a timely basis and can predict spatial differences in water availability and estimate recharge to the groundwater. As the output, different changes and patterns would be obtained and interpreted in terms of land degradation (Amarsaikhan et al., 2008; Amarsaikhan, 2011).

The aim of this research is to demonstrate how an advanced spatial modelling technique can be used for a grazing land degradation study in Mongolia. For this purpose, a GIS-based water balance modelling technique has been applied compiling data sets from multiple sources.

Test Site and Method

As a test site, Bayan soum, located in about 130 km toward the southeast of Ulaanbaatar, the capital city of Mongolia, has been selected. It has an area of 4736 sq.km. The land use is mainly grazing and the northern part has a better grass cover than the southern edge. There are many small catchments, especially in the south and east that lead to local depressions. The test site and a soil map of the study area are shown in Fig. 1a,b.

Figure 1. (a) 2009 MODIS image indicating the test site; (b) Soil map of the Bayan soum area.

The model is based on one-layer root zone water balance, with as incoming flux direct rainfall and through fall under the canopy with and as outgoing fluxes plant transpiration and soil evaporation on the upper boundary and percolation downward out of the root zone. The outgoing fluxes are strongly determined by the moisture content of the soil. Plant cover also plays a role, which is derived from a series of RS images. The model can calculate a runoff fraction for every rainfall based on the available storage, and the runoff can infiltrate down slope (Amarsaikhan et al., 2008; Amarsaikhan, 2011).

There are three data sets such as meteorological, terrain and vegetation used for the model. Meteorological data set contains a table with daily rainfall, a table with average daily values of incoming radiation, relative humidity, temperature, wind speed, and a map with the position of the meteorological station. Terrain data set contains DEM, a map with hydrological units based on soil texture, a table with the soil hydrological characteristics, and a map of the initial soil moisture content. Vegetation data set contains a series of multi-temporal MODIS NDVI images of plant cover.

Results and Discussion

The water use in itself is not a direct indicator, only in relation to the results of other years. For instance, 2009 appears to be a wet year while other years are drier, which may then indicate the relative status of a year and eventually the appearance of trends. The water use equals the actual transpiration if the cover of 2009 MODIS images is a good measure for plant development. In the simulated season the water use in the area varies from 40 to 60 mm depending on the different soils, rainfall input and plant cover. The water stress is related to the ratio of actual evapotranspiration and potential evapotranspiration (ETa/ETp). Fig. 2a shows that the frequency of the rainfall prevents all out drought and keeps the evaporation deficit limited between 0.6 and 0.4. Fig. 2b shows a soil moisture deficit map at the end of the season.

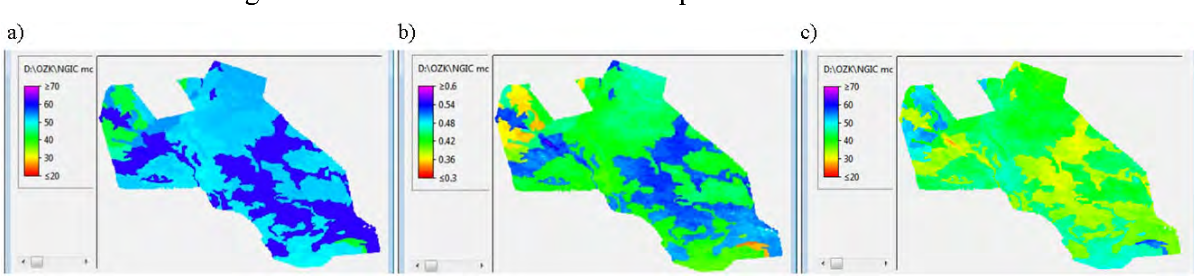

Figure 2. (a) The total estimated water use, (b) Average seasonal water stress, (c) GW recharge map at the end of the season. The more permeable soils have more recharge (about 50 mm).

The amount of water leaving the root zone can be seen as an indicator for groundwater recharge. The model produces a map with the total recharge. The average of the area is 42 mm of recharge with variations in the area between 50-60 in the NW to <30 mm in the SE. The reason for this pattern is primarily an assumed decrease in rainfall towards the SW (Fig. 2c).

Conclusion

The aim of this research was to apply a GIS-based water balance modelling technique for the grazing land degradation study in Mongolia. As the test site, Bayan soum area located in the central part of the country was selected. Overall, the research indicated that modern techniques based on GIS could be successfully for different land degradation studies, including grazing lands.

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Spatial and Temporal Patterns of Radiation Use Efficiency in Semi-Arid Shrublands of La Rioja (Argentina)

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Key Words: semiarid rangeland, aboveground net primary production, radiation use efficiency, absorbed photosynthetically active radiation, plant functional types

Introduction

Aboveground net primary production (ANPP) is an integrative indicator of ecosystem functioning. Sensors onboard satellites provide spectral information to estimate ANPP in real time, at low cost and with full area coverage. Monteith's model (1972) provides the conceptual basis to estimate ANPP from fraction of absorbed photosynthetically active radiation (fAPAR), the incoming photosynthetically active radiation (PARi) and the radiation use efficiency (RUE) of the canopy:

$$ANPP = PARi \times fAPAR \times RUE,$$

We analyzed the control of spatial and temporal patterns on RUE, integrating ANPP data obtained from a field network located in a semiarid region of Argentina and APAR estimated from Normalized Difference Vegetation Index (NDVI) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data.

Materials and Methods

The study was carried out in the Arid Chaco region (~100000 km^2), in North-western Argentina (La Rioja province), between 28ºS - 32ºS latitude and 65ºW - 67ºW longitude. The climate is subtropical, with mean annual temperatures ranging from 17ºC to 20ºC, and an east-west precipitation gradient from 500 mm/year to 250 mm/year. Most annual precipitation (85%) occurs during the warm season between November and April. The area is covered by a subtropical xerophytic shrubland (Morello et al. 1985), with scattered trees, mainly *Aspidosperma quebracho-blanco* and *Prosopis spp*. Most common shrubs correspond to the *Larrea,* and *Mimozyganthus* genera. The herbaceous stratum is composed principally of C_4 perennial grasses of the *Trichloris, Chloris, Pappophorum, Aristida,* and *Setaria* genera. We selected 26 study areas (13 range sites x 2 paired range condition). The ANPP herbaceous (ANPPH) and woody (ANPPW) annually (April) was estimated from 2009 to 2015. ANPPH was estimated by biomass harvesting. We estimated ANPPW using linear model [ANPPW= (0,8566*woody aerial cover) + 12,948]. ANPPW linear model was generated by linear regression using a previous data set of ANPPW (obtained by live biomass harvesting and woody (shrubs + trees) aerial cover (Blanco, L., unpublished data). Simultaneously, we estimated aerial cover of plant functional types (trees, shrubs, perennial tallgrass, perennial shortgrass and forbs). We calculated APAR (absorbed photosynthetically active radiation) as the product of fAPAR and PARi. The fAPAR was estimated using a non-linear function of NDVI (Piñeiro et al. 2006). We obtained NDVI values from the MODIS imagery. Finally, we estimated RUE [= (ANPPH + ANPPW) / APAR] where APAR is the sum of the APAR from 01 November to 30 April. ANPPH, ANPPW, ANPP (ANPPH + ANPPW), APAR and RUE values, were compared between range sites and range conditions by ANOVA (n = 7 years). We performed multiple linear regression analysis (n = 182 = 13 range sites x 2 range condition x 7 years) between RUE (dependent variable) and aerial cover of plant functional types (independent variables).

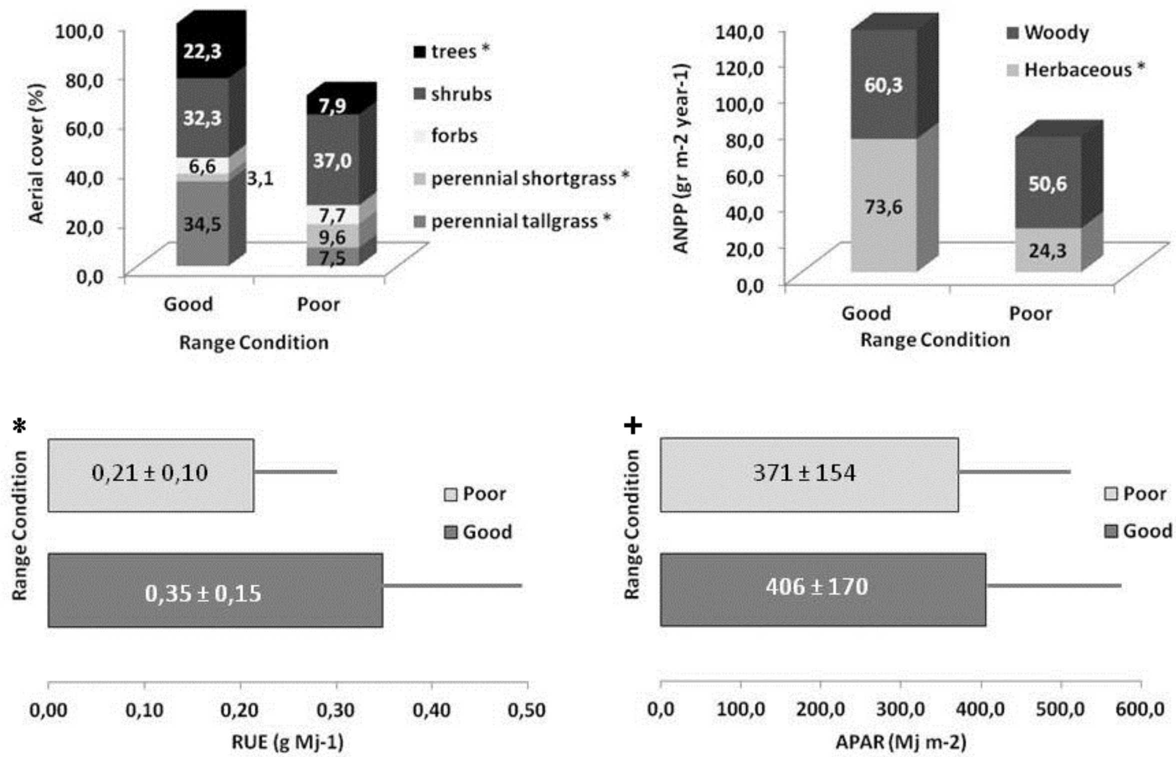

Figure 1. Aerial cover (%) of the plant functional types (left top panel), herbaceous and woody aboveground primary production (ANPP, g m^{-2} year^{-1}, right top panel), radiation use efficiency (RUE, g MJ^{-1}, left bottom panel) and absorbed photosynthetically active radiation (APAR, MJ m^{-2}, right bottom panel) in good and poor range condition. *indicates significant differences between range condition ($p<0,01$), + indicates significant differences between range condition ($p<0,05$).

Results

ANPP, APAR, RUE and plant functional types cover were different between range sites ($p<0.01$). The aerial cover of trees, perennial shortgrass and perennial tallgrass, ANPPH, RUE and APAR were different between range conditions (Figure 1). However, APAR was less sensitive than ANPP to changes in range conditions. Apparently, changes in tallgrass aerial cover were the main determinant of spatial and temporal variations of RUE (Table 1).

Table 1. Contribution of spatial and temporal plant functional types patterns to radiation use efficiency (RUE) variability. Results of the multiple linear regression analysis [n = 182 (13 range sites x 2 range conditions x 7 years)] between aerial cover (%) of plant functional types (independent variables) and RUE (MJ m^{-2}, dependent variable).

Source	F value	P value
Perennial tallgrass	73,72	0,0001
Shrubs	2,92	0,0895
Trees	1,99	0,1599
Perennial shortgrass	1,70	0,1934
Forbs	0,27	0,6030

Discussion

Strong differences observed between range sites in ANPP, APAR, RUE and aerial cover of plant functional types, could reflect differences in soil types. ANPP, APAR, RUE and aerial cover of plant functional types showed large differences between years, perhaps in response to interannual variations in rainfall. ANPP differences between range conditions were more evident than the observed differences in APAR. This could be attributed to the replacement of species among plant functional types or within each functional type, as well as spatial scale differences between ANPP estimations (m) and APAR estimations (ha). On the one hand, tallgrass was the plant functional type most affected by the change in range condition (from good to poor), and on the other the plant functional type most influential in the spatial and temporal variations of RUE, determining RUE differences between range conditions.

Conclusions and Management Implications

RUE showed spatial variations between range sites and range conditions, associated primarily with changes in the proportion of plant functional types. ANPP estimates based on remote sensing to adjust the stocking rate should take into account the proportion of plant functional types of each range site and range condition.

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Ecological Risk Assessment of the Alpine Grassland in the Eastern Tibetan Plateau Based on Remote Sensing Technology

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Key words: Alpine grassland, ecological risk, remote sensing, Tibetan plateau

Introduction

Grassland ecological risk assessment is an important part of the research on land ecosystems safety, and it will reveal the possible damage degree to the grassland ecosystems in future. However there are little studies in this field, though it is so important (Fernandez et al., 2005; Landis, 2004).

The study area, Gannan Tibetan autonomous prefecture is located in the northeast of Qinghai-Tibet Plateau and the southwest of Gansu province (100°46～104°44′E, 33°06～36°10′N, 2800m-4806m, typically inland plateau climate). Being the most important livestock husbandry bases of the east Tibetan plateau, the total area of state is 3.83×10^6 hm^2. The grassland types include alpine shrub meadow, alpine meadow, warm meadow steppe, and warm and marsh grassland (Fig. 1).

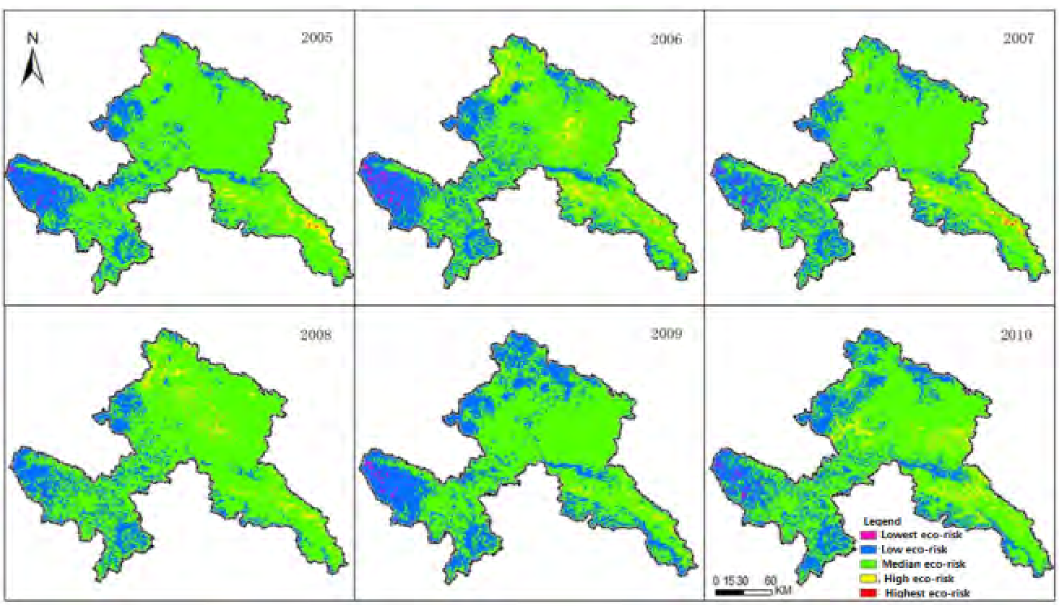

Figure 1. Comprehensive evaluation alpine grassland ecological risk.

Materials and Methods

Four types of data were used in this study: remote sensing image data, ground sample data, Gannan basic geographic & meteorological information datum data and government statistics data. A total of 56 Landsat TM and 72MOD09Q1 images from July to September for 6 years (2000-2010) were used. The classification system of the United Nations Environment Programme (UNEP) was used for classifying those TM images into various surface landscape types every year. The Geographical location and elevation information of the 570 sampling sites was also recorded. The Gannan basic geographic and meteorological information datum data include in the Gannan Tibetan autonomous prefecture government administrative zoning map, the grassland type map, temperature and precipitation data.

Ecological risk factors and evaluation methods

Five major sources of risk were considered: extreme change of climate, soil erosion, rodent damage, overloaded grazing and urbanization degree.

(1) Calculating composite drought index (*CI*) is used to express the impact of extreme weather on the grassland eco-risk. (2)The USLE (United States Universal Soil Loss Equation) was used to do quantitative calculation to soil erosion of Gannan region. (3) For enhanced vegetation index (EVI) using overlay analysis, while the grass and soil type indexes were calculated based on a quantitative share of the area. After numerical normalization, EVI after treatment, grassland type index and soil type index, elevation, slope, and aspect all were done the overlay analysis to calculate the Gannan 2005 to 2010 rodent damage impact strength values. (4) Overloading grazing stocking rate is the ratio of actual and theoretical stocking rate, at the end of the year, the actual number of livestock animal is the actual carrying capacity. Therefore, by inversion vegetation index from MOD09Q1 data, aboveground biomass was reversed calculating and then integrated the actual edible forage ratio, the theoretical number of livestock animal was calculated. (5)From three aspects of the non-agricultural population, the rate of urban sprawl and the total economic output value of AFAF (agriculture, forestry, animal husbandry and fishery), a comprehensive evaluation of urbanization level to grassland ecological risk was done.

Comprehensive evaluation to alpine grassland ecological risk

With PCA (Principal component analysis) method, the weight of each risk source was determined, and resulting in integrated risk intensity [3]. Each year, between risk intensity values for each risk source is no significant correlation. In these 6 years, the cumulative contribution rate of the first 2 principal components of all the risks sources more than 85%. Comprehensive principal components factor F is that:

$$F = \frac{\lambda_1}{\lambda_1 + \lambda_2} F_1 + \frac{\lambda_2}{\lambda_1 + \lambda_2} F_2 \quad (1),$$

Where $F1$ was the first principal component corresponding coefficient, F_2 was the second principal component corresponding coefficient, $\lambda 1$ was the characteristic value of the 1st principal component and λ_2 was the characteristic value of the 2nd principal component. Then, the values of comprehensive principal components factor of different risk sources were calculated as the results of Fig.1. The comprehensive eco-risk intensity is calculated as that,

$$\mathrm{Q} = \sum_{i=1}^{5} k_i x_i p_i \quad (2),$$

Where x_i is the i-th value of the intensity of the eco-risk, k_i is the i-th risk weight value in Table 1, and p is the probability of occurrence of the various sources of risk.

Table 1. The evaluation grade of ecological risk.

Values of eco-risk	Grade
[0,0.2]	Lowest eco-risk
[0.2,0.4]	Low eco-risk
[0.4,0.6]	Median eco-risk
[0.6,0.8]	High eco-risk
[0.8,1]	Highest eco-risk

Results and Summary

The results (Table 1) show that the ecological risk status of Gannan includes five levels in 2005, 2006, 2007, 2009 and 2010. The lower level is mainly located in northwest of Maqu. And higher level is spread over periphery of Lintan and Zhouqu County from 2005 to 2010. And that of Hezuo City is a little lower that of Zhouqu County, and the risk intensity of Zhuoni County is the lowest of all the counties, moreover, the risk strength of this three counties was trending up but not changed a lot; however, the ecological risk intensity of Diebu County extremely rised through first level to the fifth level among 9 years; the risk strength of Luqu County also increased a lot but not as that of Diebu; among all the counties, risk intensity has a large irregular change because of snowstorm. The prediction result indicates that risk intensity of Lintan County is the largest; the intensity of Zhouqu County is a little lower than Lintan; that of Zhuoni County is the lowest and that of Maqu county, Luqu County, Diebu County and Xiahe County is medium; the intensity of Hezuo City is a little larger than the four counties above. The results would provide a theoretical basis for the effective management of natural alpine grassland.

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Oceanic Nino Index Driven Variability in Vegetation Index Values in Arid and Semi-arid Ecosystems of Central Asia

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Key words: Central Asia, Oceanic Nino Index, La Niña, El Niño

Introduction

The irregular patterns of precipitation and drought anomalies are affecting Central Asian drylands and our preliminary studies have shown that El Niño–Southern Oscillation (ENSO) phases directly linked to vegetation responses in Central Asian ecosystems. Central Asia countries (Tajikistan, Kazakhstan, Uzbekistan, Kyrgyzstan and Turkmenistan) have a sharp continental climate (*i.e.,* located far away from any ocean), but ENSO phases have been demonstrated to be linked to land surface responses in Central Asia (Syed et al., 2006; Giorgi, 2006; Kariyeva, 2010). The rising occurrence of drought events and following soil salinization are serious threats that have major impacts on land-use and land-cover (LULC) patterns in agricultural regions of Central Asia. Warm ENSO phases have been shown to result in an intensified precipitation signal, while cold ENSO phases result in drier conditions in the region (Barlow et al., 2002, Syed et al., 2006; Kariyeva, 2010). Also, Lioubimtseva et al. (2013) found that increase and decrease of vegetation productivity with warm and cold ENSO phases respectively affected in non-agricultural areas of Turkmenistan. The objective of our study is an assessment ENSO impacts to the vegetation patterns and their relationships between drought persistent and NDVI anomalies in Central Asia.

Materials and Methods

The relationship between temporal (1982-2011) dynamics of ENSO events and Normalized Difference Vegetation Indices (NDVI) spatial patterns for arid and semi-arid zones of Central Asia was investigated. Specifically, a linear relationships between very strong El Niño (VSE) anomalies and NDVI for 1982-1983 and 1997- 1998 as globally observed drought anomaly periods, as well as very strong La Niña (SL) period and NDVI for 1988-1989, which was considered as a wet period. Periodical oscillations Oceanic Niño Index (ONI) was identified using the El Niño 3.4 indices. Data were extracted from 1982-1983 and 1997-1998 as very strong El Niño (EN, positive ONI: warm period) phases and 1988-1989 as a La Niña (LN, negative ONI: cool phase) periods. Then NDVI values were resampled bi-weekly to match the temporal resolution of ONI index. For the ENSO and NDVI analyses, departures or anomalies were calculated by subtracting the base period of monthly means from 1981-2010. Warm and cold episodes (Fig.1) were calculated based on a threshold of +/- 0.5^{o}C using the ONI index based on 30-year base periods with every five years updates. For historical purposes, cold and warm episodes were defined when the threshold was met for a minimum of five consecutive over-lapping seasons. The threshold was further broken down into strong (1.5 to 1.9) and very strong (≥ 2.0) events. Bi-weekly NDVI 3g time-series data were used to calculate three-month average vegetation value to match the temporal resolution of ONI index.

Results and Discussions

The outcomes from our study demonstrated an inverse relationship between EN and NDVI, where vegetation response decreased with larger positive ONI value; and a direct relationship between LN and NDVI, where vegetation response increased with smaller negative ONI value (Fig. 1). Furthermore, there was an inverse relationship between El Niño and NDVI, decreased vegetation response with larger positive ONI value; and direct relationship between La Niña and NDVI, increased vegetation response with smaller negative ONI value.

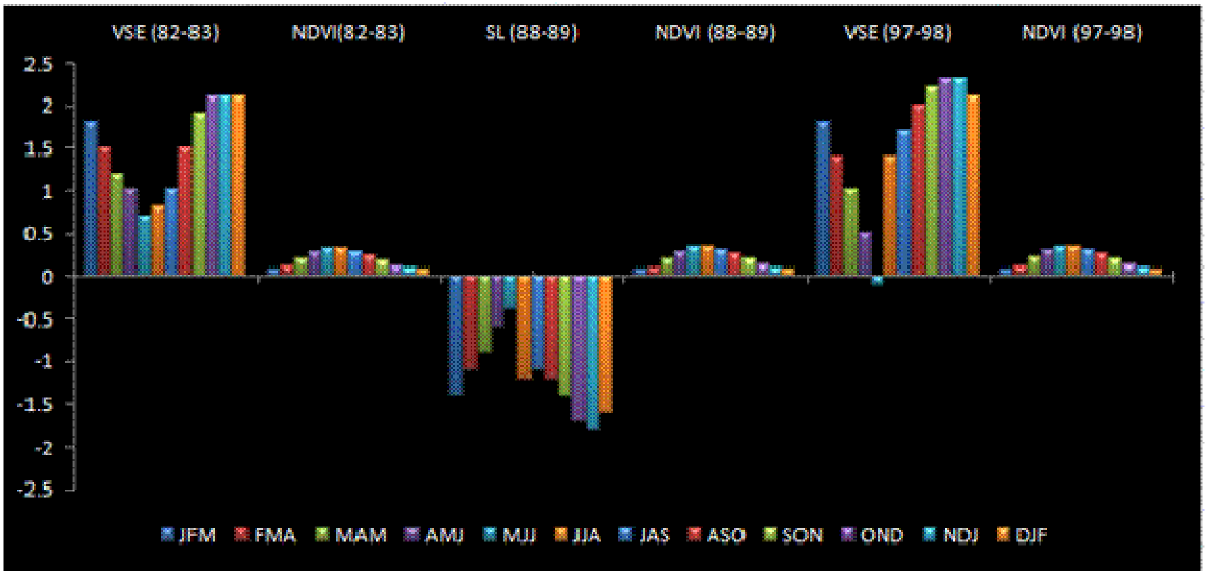

Figure 1. Trends of ENSO phases detected anomalous patterns of precipitation and drought conditions with following years: 1982-1983; 1997-1998 (VSE) & 1988-1989 (SL) phases among five countries of Central Asia. Vegetation productivity with warm and cold ENSO phases and their intensities with running 3-month mean ONI values. Legends described with beginning of the month with following composition of last three month (*e.g.,* JFM-January, February, March).

These results demonstrate that understanding of non-anthropogenic drivers of variability in land surface vegetation signals is beneficial for efficient rangeland/grassland management in precipitation-driven ecosystems of Central Asian rangelands.

Conclusions and Implications

For the Central Asian region, longstanding land use practices and water management challenges are unique and do not align well. Drylands of the region are prone to frequent seasonal droughts and complex terrain both hinders ground and satellite based remote sensing observational modeling and challenges the applicability of conventional sub-grid process parametrizations. This study demonstrates potential applications of the large-scaled datasets to assess and measure relationships between global climate patterns and regional scale vegetation responses to support land and water use and management in this drought-prone region.

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7.2 Technology in social and psychological data acquisition and modeling

Cartography of Pastoral Vegetation Communities in North African Arid Saline Rangelands: The Case of Tunisia

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Key words: Arid bioclimate, cartography, pastoral vegetation, Tunisia

Introduction

Saline soils are highly abundant in arid bioclimates due to drought conditions and less precipitations. About 30% of the world's land area is covered by Arid and semi-arid bioclimates (Saco et al 2007). North African countries have encountered problems relating to high salinity, which may have more impact on areas used for agriculture. These phenomena could be exacerbated as a result of global change. Increasing external pressure in arid systems through climate change will lead to desertification (Kefi et al 2007). In this study, we focused on the cartography of saline soils in arid bioclimates in Tunisia. Today, it is very important to locate saline soils through digital mapping in order to save this information because it may be useful for next generation of scientists.

Objectives

The aim of this study is to map saline soils including pastoral vegetation in Tunisia. In addition our objective is to locate all saline sites in arid bioclimates in Tunisia for subsequent field work. Moreover, the precise cartography exploited allows us to identify the location of pastoral communities in those rangelands ecosystems.

Methods and Materials

The map of saline soils in Tunisia was established using a database provided by the Tunisian Ministry of Agriculture. This information was processed with ARC GIS 10.2. The first step was to estimate the area of saline soils in five different bioclimates. Total area was calculated by superimposing two layers referring to bioclimate and saline soil regions. Area values were displayed with a histogram, and we understood that the arid bioclimates contain the maximum amount of saline soils. As a result, we created a new map for saline soils in arid bioclimates in Tunisia. In this phase, we sorted salinity into three classes according to the electric conductivity value previously reported in the database. The three classes of salinity on the map of saline soils in arid bioclimates in Tunisia are high, medium, and low salinity. Next, we focused only on high salinity areas, because vegetation faces a high degree of salinity stress in those ecosystems. We estimated the areas of highly saline soils located on the map in order to choose those that cover more than 1500 km^2. Finally, to perform the field work, we located 16 sites in the high arid and the low arid bioclimates, which were divided in two equal groups of 8 sites. In our previous study, we discovered that a pastoral rangeland in saline ecosystems is divided in 5 sectors according to the level of salinity and vegetation typology. Consequently, a field trial was conducted at Sabkhat Boujmel for the acquisition of geographic data to make precise cartography delineating the different sectors in terms of plant species and level of salinity by means of a Global Positioning System (GPS) Trimble Geo

XM with an average accuracy of 3m and Geographical Information System (GIS) ArcGIS 10.2. The transfer and processing of GPS data were performed by recovering data from the GPS, with an I/O interface and a cable connecting the GPS and a PC. Microsoft Active Sync and GPS Pathfinder Office software were used to transfer the geographic data.This GPS receiver was preset in the projected coordinate system WGS_1984_UTM_Zone-32N.
UTM: Universal Transverse Mercator
WGS: World Geodetic System

Results and Discussion

We established a model of five habitats of halophytes in all the stations investigated. This model is described in Figure 1, which shows the distribution of 4 groups of species.

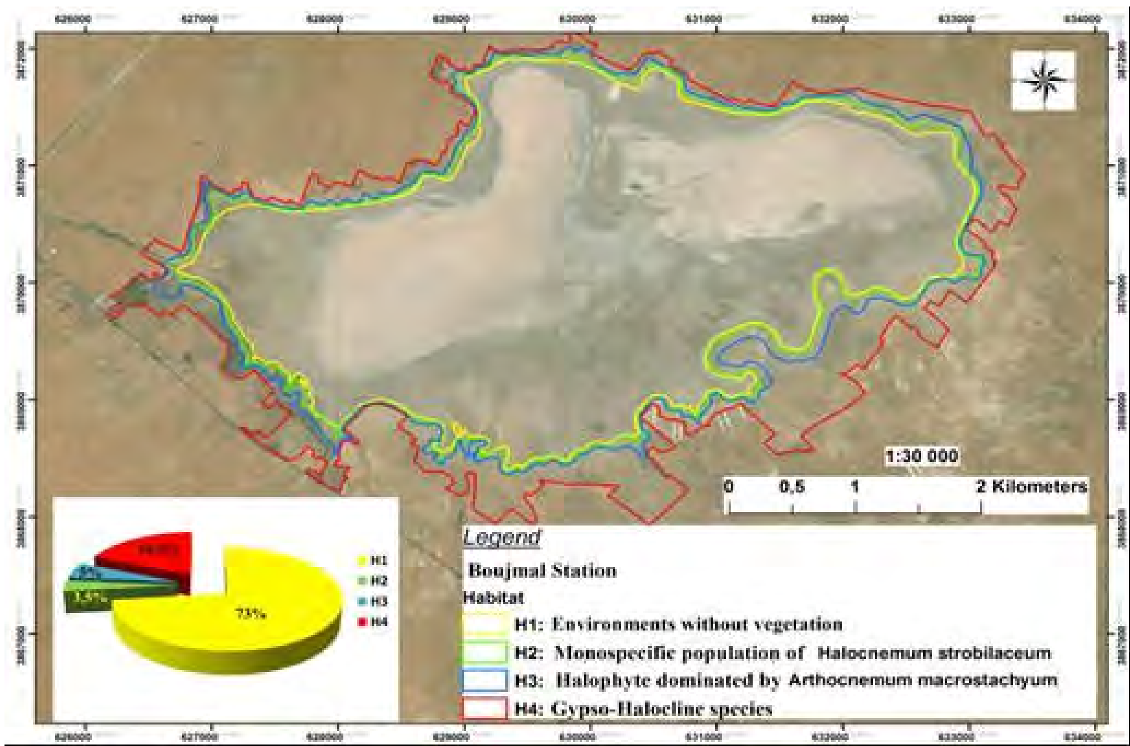

Figure 1. Habitats of halophytes. The First habitat (H1) is considered to be a hydromorphic environment. This area does not contain any species because salinity in this area is very significant. In the second habitat (H2), we found a monospecific population of *Halocnemum strobilaceum*. This species is the most salt-tolerant halophyte in this ecosystem. The third Habitat (H3) consists of a group of halophytes such as *Salsola tetrandra*, and *Suaeda fruticosa*. Those species are almost dominated by *Arthrocnemum macrostachyum*. The forth habitat (H4) supports a group of Gypso-Halocline species such as *Lygeum spartum*, *Nitraria retusa,* and *Zygophyllum album*. The last Habitat (H5), which does not appear on the map, includes a cultivated area.

Conclusion

Salt affected soils threaten biodiversity by damaging natural vegetation. In addition, salinization exacerbates desertification and the loss of soil properties. It is therefore important to find new solutions in order to avoid salinization effects and to save non-saline areas from this problem.

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Exploring Dynamics of Evapotranspiration in a Semi-Arid Grassland of South Africa

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Key words: Rangelands, land cover change, evapotranspiration, remote sensing

Introduction

The influence of land use change on hydrological fluxes has been a subject of long term debate (Zhou et al., 2015). In a context of global environmental changes, it is imperative to understand dynamics in water use of different land cover types in grasslands. Woody thickening has been identified as one phenomenon that changes landscape evapotranspiration (ET) resulting in reduced runoff. The ratio of ET to precipitation (ET/precipitation) is an important index to discern the influence of land use dynamics on ET. In South Africa, invasive alien plants such as *Acacia mearnsii*, together with increases in dryland cultivation and human settlements are the main drivers of land use change. In a context of climate change and increasing water scarcity, it is prudent to understand the consequences of land cover changes on ET experienced in the grasslands of South Africa. Determining landscape ET is a daunting task and consequently, a number of approaches to measure or model ET have been developed (Liou and Kar, 2014). ET measurement methods tend to be point samples and are subject to instrument error. In heterogeneous areas point estimates are inadequate, and at best can be used to parameterize and validate spatially explicit models. Water use of different land cover types in a catchment may not be known particularly in ungauged catchments. Consequently, remote sensing technology has become vital in providing ET values on a continuous basis at high temporal and spatial resolution in such environments. Products such as MOD16 (Mu et al., 2011) provide an opportunity to evaluate spatial and temporal variation in water use. The present study sought to determine variations in catchment scale ET attributable to land cover change. Therefore an earth observation approach in the form of the global MOD16 ET product was deemed suitable for the study.

Material and Methods

Study area

Quaternary catchment S50E of the Kei River in South Africa was selected for the study. The area represents a natural grassland ecosystem under communal tenure where main economic activities are livestock and crop production cultivation. Mean annual rainfall is about 600 mm and average pan evaporation is 1742 mm. The altitude ranges from 1010 m to 1700 m.

Methods

Available land cover maps for the study area were evaluated to determine trajectories in land cover change. An extract of the 2000 National Land cover (NLC) map and the 2014 map that was developed specifically for the study area by a parallel study were used. Subsequently, the MOD16 ET product was used to derive ET for different land cover types in the quaternary catchment. Rainfall data for the hydrological years was obtained from an automatic weather station located in the study area. Using the zonal spatial analyst tool in ArcGIS version® 10.2, mean annual ET for 2000 and 2014 were computed for each land cover class. In order to evaluate the impact of land use change, the ET/precipitation ratios for the years 2000 and 2014 were computed.

Results and Discussion

As expected, the reduction in plantations and wetland cover and increase in indigenous forest, thicket bushlands, bush clumps, high fynbos class resulted in decrease and increase in ET, respectively. However, it was surprising that reduction in grassland and water bodies covers were accompanied by an increase in ET and ET/ precipitation. For grasslands the ET/precipitation ratio increased by 37.8%, while that of water bodies increased by 30.5% (Table 1). This may be due to increasing temperatures, as monthly minimum temperature increased by between 0.03-0.15 $^{\circ}$C, while monthly maximum temperature increased by between 0.01- 0.14 $^{\circ}$C for most months. MacKellar et al. (2014) found that throughout South Africa there was a significant increase in temperature between 1960 and 2010. With respect to water bodies, the ET/ precipitation increased by 30.5%. Despite a 13% increase in land under cultivation and reduction in annual rainfall, annual ET remained unchanged. However, the ET/ precipitation ratio increased by 11.7%. The marginal increase in woody vegetation had a major increase in the ET/precipitation (15.4%). The increase in built up areas was also accompanied by an increase in ET/precipitation (26.5%). The results confirm that built up areas are not a desert but contribute significantly to water fluxes as observed by Ramamurthy and Bou-Zeid (2014). Wetlands and bare rock or soil classes drastically declined by 2014 and their relative contribution to total catchment ET were insignificant (-) and hence were not included in Table 1 for 2014.

Table1. Land cover changes and ET/ precipitation ratio in quaternary catchment S50 E (2000-2014).

Land use	2000		2014	
	Percentage cover	ET / Precipitation	Percentage cover	ET / Precipitation
Grassland	75.72	0.72	56.63	1
Plantation	3.94	1.15	1.80	1
Indigenous forest, thicket bushlands, bush clumps, high fynbos	5.43	0.94	10.76	1.09
Bare/rock	0.32	0.72	0.22	-
Cultivated, permanent, commercial, irrigated	4.98	0.82	18.10	0.91
Urban / Built-up (residential, formal township)	5.78	0.75	9.46	0.95
Water bodies	3.59	0.52	2.91	0.68
Wetlands	0.25	0.81	0.13	-

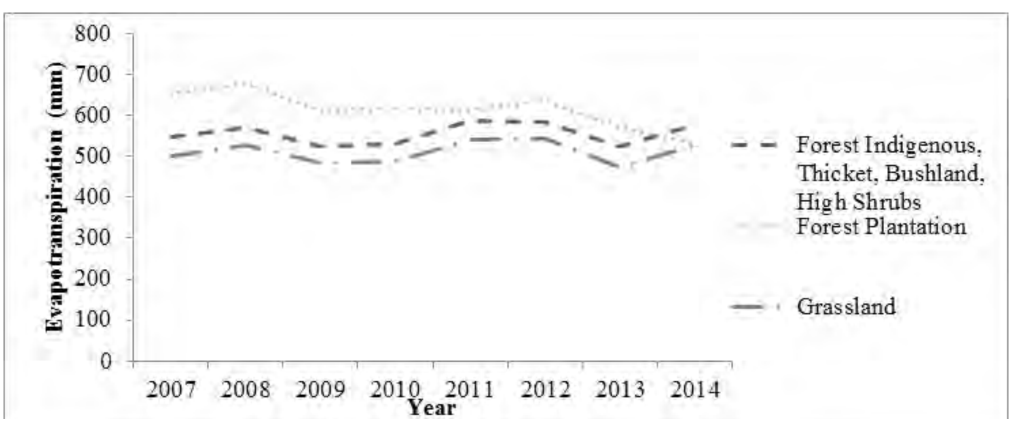

Figure 1. Variation in ET over time.

It is noteworthy that most of the land cover types had higher ET/ precipitation. This is not surprising as woody vegetation is able to utilize ground water. It should be observed that most of the woody encroachment observed in the study area is related to the invasion by *A. mearnsii*. However, it was surprising that grasslands had ET/ precipitation similar to woody vegetation in 2014. Fig 1 confirmed that woody vegetation generally had higher ET compared to grasslands, suggesting that woody encroachment may have serious hydrologic consequences in rangelands.

Conclusions and Implications

Although, there was reduction in the plantation land use, woody thickening did take place in the study area resulting in a higher ET/precipitation ratio. Dramatic land cover change in some cases does not result in a corresponding change in ET as reduction in grassland cover surprisingly yielded an increase in ET and in ET/ precipitation. Land cover change influences ET and this may have serious hydrologic consequences in rangeland.

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Detecting and Mapping the Last Frontiers of Savanna Grasslands of the Western High Plateau of Cameroon

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Key words: Detection, mapping spatial distribution, savanna grassland, sub Saharan Africa, land use change

Introduction

Over the past three decades remote sensing, geographic information system (GIS), and landscape ecology have been gradually integrated to estimate degrading Savanna grasslands by researchers across the Sub Saharan Africa. The Western High plateau (above 1,500m) is covered by "prairie" and grass savanna vegetation that constitute very rich pasture for grazing. The plateaus receive abundant precipitation and have undergone multiple anthropogenic influences. Some of the most valuable grazing lands in Cameroon with rich pasture that includes grass associations of *Hyparrhenia spp, Sporobolus africanus, Pennisetum clandestinum and Paspalum spp*. Expanding human and animal population as well as agricultural needs, have led to overgrazing, expansion of invasive weed, conversion of rangelands to farmland, deforestation, and land use conflicts between resident farmers and grazers. Change in landscape is thus accounted for by human activities or natural phenomena. In either case, it is important to have quantitative data that records the direction, magnitude, and spatial pattern of change so that rational land use strategies can be formulated and implemented and root causes of degradation addressed. Landsat multispectral scenes, acquired periodically through time, are uniquely important for change detection because of the duration of coverage (continuous since the 1970s) and because the scanner systems are sensitive to variation in vegetative coverage and soil moisture. Our main objective is to detect and map the last frontiers and remaining patches of Savanna Grasslands of the western high plateau of Cameroon that are persistently under perturbation. We also want to identify locations with the most extreme changes on the rangelands area.

Materials and Methods

The study utilizes Landsat multispectral scenes change detection since the 1970s and Google images for mapping feature extraction. Landsat scenes between 1973 and 2012 were used for targeted vegetation detection with the Spectral Angle Mapper (SAM) algorithm in ENVI. Locations with the greatest loss of vegetative cover were identified and mapped as zones experiencing extreme changes on the rangelands. These target detection zones are particularly above 1,500m elevation where abundant precipitation and multiple anthropogenic agropastoral influences have significantly transformed the agrarian landscape. Ten Landsat scenes from 1973 to 2012 were processed and required one scene to fully cover the geographical extent; this scene is orbital Path-200/Row-56 for MSS, and Path-186/Row-56 for TM and ETM+. The image acquisition dates were selected to correspond as much as possible to both the dry season and the rainy season in one year. Data were processed using ENVI 4.8, Erdas Imagine 8.9, ArcGIS 10.1 (ESRI, 2010), Microsoft Office Excel, and Adobe Illustrator. ENVI was used to classify the land cover and land use for the different Landsat images. First the Landsat scenes were loaded into ENVI and spatially subsetted to eliminate areas outside the study area. The raw digital numbers (DN) of each Landsat scene were converted to radiance values. The radiance digital numbers were then converted to exoatmospheric reflectance (top of the atmosphere (TOA) reflectance).

The scenes were then processed through ENVI Spectral >Thor Work flow Target Detection algorithm using bands 2, 3 and 4. The Target Detection tool is design to go through the process of finding targets in hyperspectral or multispectral imagery, and in this case our target is the Savanna Grassland area. The Target Detection classification is particularly important for this study because it identifies and locates land cover types that are known a priori through a combination of personal experience, interpretation of aerial photography, map analysis and fieldwork (Jensen, 2005).

Results and Discussion

Using ten Landsat scenes, the classification identification and labeling was principally based on the experiences of the author, the observed vegetation, agro-pastoral landscape from the satellite images, and comparable studies. Using such subjective bases, the Savanna Grassland class was created. However, due to existing confounding factors during image processing such as cloud cover and reflection problems from the satellite images, and inconsistency in the data acquisition anniversary dates, only three good images that had none of these uncertainties were used for change detection analysis. These images are the 1978 rainy season, the 1988 dry season, the 2002 rainy season and 2010 rainy season images (Table 1).

Table 1. Changes observed in the Savanna Grasslands of the Western Highlands of Bamenda

Landsat Sensor	Total Area (Sq. Km)	Resolution (Meters)	Date	Pixels (Cell Size)	Area/Pixel	Total Area covered (Sq. Km)	% Area cover
MSS	4660.4	57	1973	635607	36229599	3622.96	77.74
TM	4660.4	57	1988	222590	12687630	1268.763	27.22
TM	4660.4	57	2002	107925	6151725	615.1725	13.20
ETM+	4660.4	24	2012	100074	2401776	240.1776	5.15

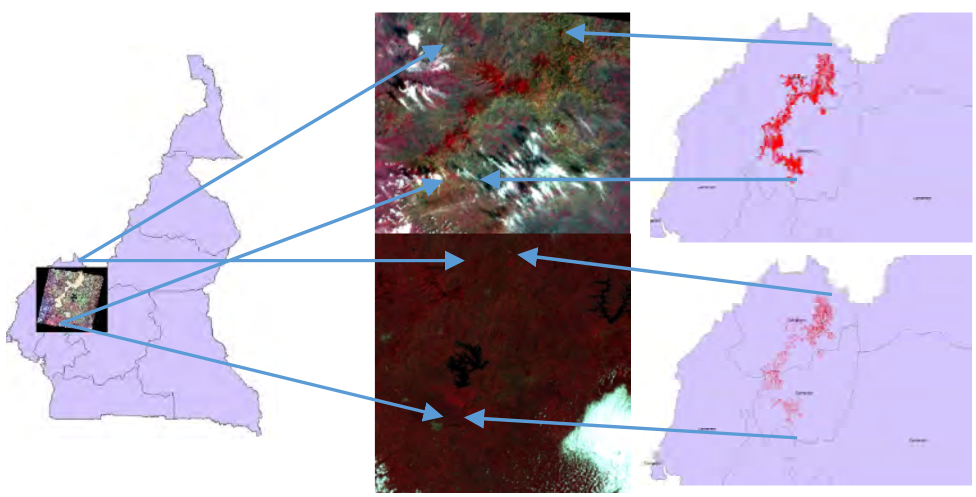

Figure 1. Total area covered by Savanna Grasslands in 1973 (above) and 2002 (Below) Landsat MSS and ETM+ Image respectively for the Bamenda grazing area in Cameroon

Conclusions

The agro-pastoral landscape, from 1973 has change considerably following the agrarian reforms. There has also been an increase in farming area and settlement significantly transforming the agrarian landscape from 77.74 % in 1973 to 5 % in 2012. The Savanna grasslands here are therefore largely influenced by agricultural reforms that focused for the most part on agricultural vulgarization under the then green revolution in the Cameroon third Five-year development plan (1971-76), whereby, most of these grazing areas were turned to farmlands.

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Rangeland Data Acquisition: Lessons Learned from Mobile Tool Development

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Key words: Rangeland health, mobile, technological data capture

Introduction

Rangelands in British Columbia (B.C.) consist of natural landscapes of dense coniferous forests, open coniferous forests maintained by fires, dry valley bottoms with bunch grasses, and deciduous forests with mixed prairie and alpine environments. Reliable access to palatable plants on Crown lands supports the beef and guide/outfitters industries. Under the B.C. Forests and Range Practices Act (FRPA), evaluating the impact of range practices on the quality and quantity of livestock grazing is a key priority. Multiple use of the diverse and large landscape necessitates systematic organization and collection of spatial data on ecosystem health to facilitate monitoring by the Range Branch and District field staff (Agrologists). The monitoring and tracking of rangeland health using a mobile device (handheld computer) linked to a Global Positioning System (GPS) enhances field data collection and analysis. This presentation describes lessons learned from 12+ years of using mobile tools to collect field data.

Materials and Methods

The use of mobile technologies has been a key element of the Range program's collection of standardized field data since the early 2000s. Prior to this period, paper forms were used to collect health assessment data that support decision-making for resource allocation, planning and ecosystem management. The protocols for data collection were established during the 10 years prior to moving to a digital technology and are based in rangeland science (Fraser, 2007; National, 1994). Thus, moving to mobile tools involved a focus primarily on the technology and its limitations/opportunities, and did not become confounded with discussions around procedural development. Field data collection involves: recording how extensive grazing is; measuring bare soil, plant vigor, and community structure; identifying the location of range improvements; detailing the extent of weeds; determining how many animals a particular pasture will support; navigating in the field; linking digital pictures with the appropriate inspection form; and recording additional written and audio notes. Total cost for equipment for one Agrologist, including device and protective casing, ranges from $500 to $1200 (CDN).

The majority of B.C.'s rangelands are located 'off the grid', thus requiring the use of technology that would support off-line or disconnected editing. Until 2010, the monitoring and tracking of rangeland health was completed using ArcPad on handheld computers linked to a GPS. Technology changes have initiated changing platforms to Apple's iPads. From 2011 to present we have adapted our field data collection to form-based apps (e.g. Filemaker), photography apps (e.g. Theodolite), and mapping apps (e.g. ArcGIS Collector, PDFMaps). We have been receiving feedback from users and also have enumerated how many Health forms are completed each year. These approaches have provided us with metrics to measure the degree of success of the program.

Results and Discussion

In our pre-digital days, a day in the field typically required carrying: a large paper map for navigation, clipboards, a camera, a GPS, and water-resistant paper forms to record observations. One mobile device, with its many apps, replaces what for years has been a backpack full of equipment and books, including a camera, GPS, set of maps, field guides, legislative summaries, other reference materials, etc.

Adoption of digital technologies has notably reduced the time taken to collect data, complete analysis, and write reports. With 'paper-only', each day spent in the field required three additional days to analyze data and generate reports (a 1:3 ratio). It was not uncommon for a one-week field excursion to generate a box full of forms, which required almost a month of work to type the information into a spreadsheet, analyze and summarize. Our initial implementation of digital technology created immediate efficiencies. As the time to retype notes on paper forms was eliminated, and much analysis was supported by the addition of scripts and functions, time spent on overall data related tasks was reduced by more than 75 percent.

Further benefits were realized; for example, a visual summary of the extent of a monitoring regime improved the cost-effectiveness of subsequent field trips. Other benefits of using mobile technology include improved navigation. One employee reported that: "using the technology boosts my navigation abilities, making me feel more confident when spending time in the field."

Any initiative that relies on digital technology is required to adapt as technology changes, which happens at sometimes dizzying speeds. For example, we started our digital data collection efforts using Hewlett-Packard iPaqs and running ESRI's ArcPad mapping software and although this proved successful it ceased to be an option for us in 2010 as the hardware was superseded by newer technologies. In 2010 we moved to Apple iPads and actually lost some of the efficiencies gained because we did not immediately have a suitable app for collecting data. In 2011, we were able to create data collection forms in form-based software and these had a greater appeal to the Agrologists collecting data than any previous form. This was reflected in the first year of using the new forms when we received an increase of 300% in completed data forms from 2x the number of individual users who had used the previous technology. We support development 'in-house' by our own staff, and this means that we can make changes in a timely manner and can continue even when no budget exists for external contracting.

Conclusions and Implications

Key learnings can be summarized from our 12+ years of using mobile data collection tools to support Rangeland health monitoring. A technological solution that supports field operational business must:

- Capture spatial data using a device's GPS sensor
- Run 'off-line' as data are never collected within cell coverage
- Export to various dbase formats
- Export to PDF report and other required reporting formats
- Interact with other apps and formats (e.g. photography, KML etc.)
- Be based on attractive and easy-to-use interfaces
- Be relatively easy to make edits to, independent of external contractors ($ efficiency and guarantees longevity in times of no budget)

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Estimating Vegetation Biophysical and Biochemical Properties Using Remote Sensing and Modeling in a Semi-Arid Grassland

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Key words: semi-arid grassland, remote sensing, radiation transfer modeling, leaf area index, chlorophyll content

Introduction

Remote sensing data have been widely used in previous studies to estimate grassland biophysical and biochemical properties, such as leaf area index (LAI) and chlorophyll content (Dusseux et al., 2015) , primarily through establishing linear relationships between remote sensing data and vegetation properties. However, such linear relationships are generally influenced by sampling size and lack of transferability. In contrast, radiation transfer models (RTMs), developed based on physical laws, are more robust and have shown more advantages than the linear regression models (Darvishzadeh et al., 2008). Over the years, many leaf and canopy-level RTMs have been developed for vegetation studies. For instance, PROSPECT is a key leaf-level RTM for simulating leaf spectrum using leaf properties (Feret et al., 2008). PROSAIL model, a coupled model of the PROSPECT and SAIL canopy models, is a canopy-level RTM to simulate canopy reflectance using vegetation canopy properties. These RTMs can be inverted to estimate vegetation properties using vegetation spectral data. The inversion of RTMs to estimate vegetation properties has been highly successful for forest and agriculture ecosystems, but somewhat less successful for grassland ecosystems. An exhaustive experiment demonstrated that PROSPECT cannot simulate spectra of non-photosynthetic leaves (e.g., senesced and decayed leaves), which dominate semi-arid mixed grasslands. This is expected because the PROSPECT model was calibrated using a green leaf dataset. Since the PROSAIL was integrated using PROSPECT model, it has also performed poorly at simulating the reflectance of grassland canopies.

This research aims to re-calibrate the PROSPECT model for simulating the spectra of non-photosynthetic leaves. The re-calibrated PROSPECT model will then be integrated into the PROSAIL model to improve its performance in estimating grassland canopy-level LAI and chlorophyll content.

Materials and Methods

The latest PROSPECT version, PROSPECT 5, uses 6 parameters (i.e. leaf thickness, chlorophyll content, carotenoid content, brown pigments content, water content, and dry matter content) to describe the physical structure and chemical components of green leaves. These chemical components have different absorption coefficients, quantified using a green leaf dataset. Given senesced and green leaves have different physical structures and chemical components, a new set of parameters needs to be considered for sensed leaves in the PROSPECT model. For instance, there is almost no chlorophyll or carotenoid in senesced leaves, however, senesced leaves do have new chemical components, such as humic acid. For senesced leaves, the chemical parameters we considered in this study are humic acid, brown pigments, water, and dry matter. The content of these components, as well as leaf thickness, were applied in re-calibrating the PROSPECT model. After re-calibration, PROSPECT was integrated into a canopy-level model to investigate vegetation properties at canopy level.

Sample collection, process, and measurement

To complete the re-calibrating process, we collected leaf samples of 33 monocot species (e.g., grasses, forbs, and crops) at five senescence stages (e.g., from freshly dead to fully decayed, Figure 1) in fall and winter of 2014. An integrating sphere was used to measure the reflectance and transmittance of all leaf samples. The leaf samples were then processed to measure the humic acid content, water content, and dry matter content, following the protocol of Van Soest et al. (1991) and Swift et al. (1996).

Figure 1. Leaf samples at different senescence and decay stages.

PROSPECT model calibration and integration into PROSAIL

Based on the procedure proposed by Feret et al. (2008), the re-calibration of PROSPECT was divided into two steps: i) calibrating the leaf thickness for each sample, and ii) determining the specific absorption coefficients for each chemical component and quantifying the refraction index. Half of our leaf samples were used to calibrate the model, and the other half were used for validation. The calibrated PROSPECT model was then integrated into PROSAIL to investigate canopy-level vegetation properties.

Preliminary Results and Discussion

Leaves at different senescence and decay stages exhibited distinct reflectance and transmittance, partially attributed to the differences in chemical components of leaves at different stages (e.g., humic acid content increases as decay progresses). Re-calibrated PROSPECT was capable to simulate spectra of non-photosynthetic leaves. After integrating re-calibrated PROSPECT into PROSAIL, the updated PROSAIL performed better at simulating grassland canopy reflectance, and its inversion improved canopy LAI and chlorophyll content estimation for the semi-arid mixed grasslands.

Conclusions and Implications

The PROSPECT model was re-calibrated using a new dataset that quantifies chemical components of senesced leaves to improve its performance for studying semi-arid mixed grassland. After integrating this model into the canopy-level model PROSAIL, it can be applied for simulating canopy reflectance and estimating canopy LAI and chlorophyll content. Our next step is to apply the modified PROSAIL model to estimate grassland LAI and chlorophyll content using hyperspectral imagery (e.g., CASI).

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A Prototype Application of State and Transition Simulation Modelling in Support of Grassland Management

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Key words: Modelling, state-and-transition, fuels, Ecological Sites, Great Plains

Introduction

The Great Plains grasslands of North America provide a multitude of ecosystem services including clean water, forage, habitat, recreation, and pollination of native and agricultural plants. A general lack of quantitative information regarding the effects of varied management strategies on these spatially heterogeneous landscapes complicates our understanding of the processes within them. Given the paucity of studies in the western Great Plains, it is difficult to quantify the interaction of environmental (e.g. drought) influences and managerial strategies, such as grazing intensity and seasonality or fire frequency and behavior. This presents unique challenges to managers seeking to understand, explain, and justify desired management strategies.

In response to this need, we have developed a decision support system based on ecological models for predicting the impact of climate on fuelbed properties on Great Plains grasslands. The system is comprised of two distinct tools which act in concert to produce state-of-the-art ecosystem modelling capabilities. First, the Rangeland Vegetation Simulator (RVS), deterministically estimates growth, succession, and fuels and second, the State-and-Transition Simulation Model (ST-SIM) enables stochastic modelling of ecological processes such as plant community development and response to climate.

This new decision support system (DSS) enables managers to determine the most appropriate strategies for reducing fuel loads and fostering ecological resiliency. The DSS represents a multiyear international effort, and this document describes a prototype application on the Great Plains estimating ecosystem response by focusing on two important elements including: 1) estimating future fuelbed properties and 2) quantifying feedbacks between fire cycle, climate and species assemblages and structure.

Materials and Methods

Here we demonstrate the application of the decision support system by applying it to the Loamy Plains Ecological Site on the central Great Plains in north central Colorado. The Loamy Plains Ecological Site was chosen to prototype this system and identify uses and limitations of its application on the Great Plains. The climate within this region is characterized by a mean average annual precipitation of 305 – 406 mm, with the amount received in any given year varying widely, from less than 200 mm to more than 500 mm. The region also experiences average winds of 9 mph annually, with peak winds in the spring. Average growing season length is 142 days, with the frost-free period extending from mid-May to late-September. Mean monthly minimum temperatures vary from -11.0 °C (Dec) to 13.0 °C (July), and mean maximum monthly temperatures vary from 7.3 °C (Jan) to 34.4 °C (July).

The dominant plant species on this Ecological Site (in terms of their basal area and contribution to ANPP) are two C_4 shortgrasses *(Bouteloua gracilis*, *Bouteloua dactyloides*). Other less abundant but important plant species include C_3 perennial graminoids (*Pascopyrum smithii, Hesperostipa comata*, *Elymus elymoides*, and *Carex* spp.), a C_3 annual grass (*Vulpia octoflora*), C_4 bunchgrasses (*Aristida longiseta,* *Sporobolus cryptandrus, Bouteloua curtipendula*), plains pricklypear cactus (*Opuntia polyacantha*), and subshrubs (*Gutierrezia sarothrae, Eriogonum effusum, Artemisia frigida*) (Lauenroth and Burke 2008).

Management actions evaluated using the decision support system included a gradient of grazing intensities from low, moderate and high for the region equivalent to 0.08, 0.10, and 0.15 Animal Unit Months (AUM's) per ha per year. These management schemes were tested across a simulation period of 15 years (2000 to 2014). During each year, community response in terms of annual production, vegetation cover and height, composition and fuelbed properties were quantified. Annual production, standing crop, and vegetation were validated against data collected on vegetation structure on the Loamy Plains Ecological Site by the Agricultural Research Service in Cheyenne Wyoming.

Results and Discussion

The calibrated model closely matched observations of annual production (Fig. 1) and emulated the temporal variation in climate observed during the study period (Figure 1). The heavy grazing scenario increased the area of a sodgrass state dominated by *Bouteloua dactyloides* by about 30% while simultaneously decreasing annual production by approximately 18%. In addition, the heavy grazing scenario reduced overall fuel loadings by about 40%, thereby commensurately decreasing potential flame length and spread rate. In contrast, the moderate and light grazing scenarios did not increase the abundance of the sodgrass state but did enable steadily increasing coverage by cool season (C_3) graminoids.

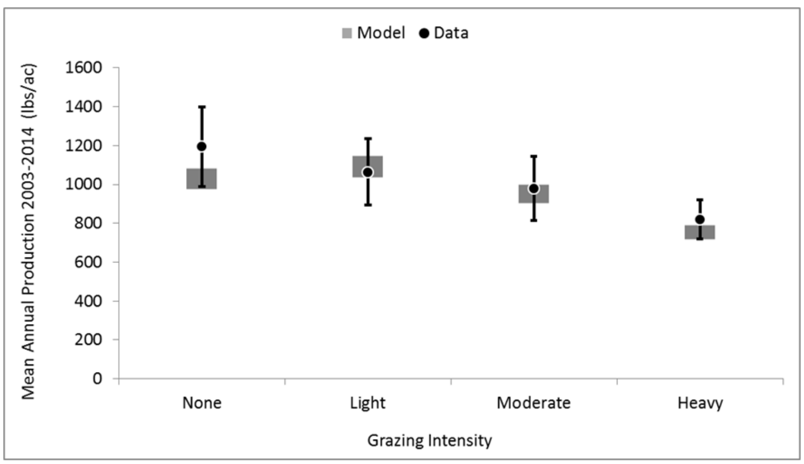

Figure 1. Predicted and observed annual production for the Loamy Plains Ecological Site across four grazing scenarios.

Conclusions and Implications

The RVS/ST-SIM decision support system prototyped on the Loamy Plains Ecological Site indicates significant potential to improve management outcomes. The grazing strategies examined provide a range of outcomes influencing annual production, fuelbed properties and species assemblages. Results demonstrate the inherent resiliency of this shortgrass steppe to moderate levels of herbivory. Application of this combined model to quantify likely management outcomes will become increasingly important in the future for species conservation as demands for sustainable goods and services continue to increase and feedbacks on natural systems become more complicated. Future research will involve adding multiple management strategies simultaneously (e.g. wildfire, off-road vehicle use, increased competition from non-native feral horses and burros). Our goal is to produce recommendations for future management strategies which will increase the probability achieving desired landscape conditions.

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Adaptive Grazing Management for Multiple Ecosystem Goods and Services: Does it Enhance Effective Decision-Making?

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Key words: Social-ecological system, grassland birds, livestock production, shortgrass steppe, decision-making

Introduction

The shortgrass steppe of Eastern Colorado, USA is a complex social-ecological system where multiple production-conservation management objectives converge. The concerns of rangeland stakeholders include the desire to support diverse native plant communities, economically viable cattle ranches, and grassland bird habitat. Conventional rangeland experiments, however have traditionally excluded the critical decision-making aspects of grazing management.

The Adaptive Grazing Management (AGM) Experiment is a 10-year project to foster partnerships and data-driven rangeland management through active engagement of stakeholders in the research process. The project adopts the collaborative adaptive management (CAM) framework, which aims to connect multiple forms of knowledge via structured decision-making where the outcomes of management decisions are used to inform future actions (Allen and Gunderson 2011; Smedstad and Gosnell 2013). Within this framework, social learning is a key concept as it involves a change in understanding for individuals and groups (Cundill et al. 2012).

In the AGM Experiment, 11 stakeholders (ranchers, state and federal land managers, and non-governmental conservation organizations) adaptively manage 10, 129.5 ha pastures and ~220 yearling cattle for livestock production, wildlife, and vegetation objectives. Decisions are consensus-based. Stakeholders prioritize desired ecosystem services, and determine criteria for livestock movement among pastures. They evaluate monitoring data from adaptively managed pastures as well as 10 paired traditionally managed pastures (continuous season-long) with the same moderate stocking rate. The objectives of this paper are to identify how the AGM stakeholder group 1) negotiated management objectives for multiple ecosystem services, 2) experienced social learning, and 3) perceived the effectiveness of the CAM process in using new information to adjust management (close the adaptive management loop).

Materials and Methods

Participatory qualitative methodology increases power-sharing between scientists and stakeholders. This approach challenges conventional researcher/participant hierarchies and explores research questions in depth and within specific social contexts (Bell 2014). Three years of quarterly AGM stakeholder meetings and semi-structured interviews with individual stakeholders were transcribed and thematically coded in RQDA. The resultant themes around major issues and uncertainties in the AGM project and CAM process were examined by the stakeholders via a participatory focus group discussion. We synthesized focus group findings and submitted them to the stakeholders for verification.

Results and Discussion

The CAM process allowed the group to recognize and attempt to reconcile trade-offs between multiple objectives over space and time. Perceived conflict between stakeholder interests early in the project gave way to the recognition of a common goal for sustainable management. Monitoring from the first 2 years of grazing showed progress in adaptively managed pastures toward vegetation and wildlife objectives while cattle weight gain lagged behind traditionally managed pastures. Stakeholders said a longer time frame is needed to find the "sweet spot" they believe exists where all 3 objectives align to the greatest extent possible. As a result, the group increased their focus on fine-tuning vegetation and cattle behavior triggers for cattle movement between pastures based on experimental, expert, and local knowledge. Stakeholder input improved monitoring and data presentation, process archiving, and decision-making rules. Specific stakeholders took on knowledge-broker roles, translating between types of knowledge as evidenced by meeting discussions. Stakeholders valued the CAM process as a way to build trust and respect among group members and foster adaptive decision-making. Qualitative analysis of interviews revealed a belief that adaptive management relies on construction of an institutional memory that includes group norms such as a willingness to learn, experimentation, and a greater understanding of each other's world views. Stakeholders perceived that their participation in the AGM Experiment would positively influence their rangeland management roles outside of the project.

Conclusions and Implications

In this study, the CAM process provided opportunities for stakeholders to negotiate multiple management objectives, create spaces for social learning, and close the adaptive management loop. Progress toward vegetation and bird habitat objectives but a decrease in livestock production relative to traditionally managed pastures in the first 2 grazing seasons indicates a clear learning curve for the stakeholder group. Long-term commitment from stakeholders and scientists is key to building norms of trust and respect, which in turn foster social learning that enables adaptive management for multiple ecosystem services. Early experiences suggest that social learning is a key process for successful adaptive grazing management.

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7.3 Technology in animal movement data acquisition and modeling

The Drivers of Cattle-Grazing Behaviour in South-Eastern Australian Heterogeneous (Non-Uniform) Paddocks: The Effect of Pasture Biomass

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Key words: Global Navigation Satellite System (GNSS), grazing behaviour, livestock, pasture, remote monitoring

Introduction

Numerous pasture attributes impact cattle forage preferences, but amongst the more important are pasture quantity and quality. Understanding cattle grazing preferences and the effect on liveweight gain, and the interactions between pasture availability, quality and grazing behaviour has substantial production and profitability implications. Traditionally, farmers gained information on pasture quantity, quality and cattle behaviour by subjective visual assessment. Attempts at quantification of cattle grazing behaviour in relation to pasture characteristics has rarely been undertaken by producers or researchers due to the time consuming and laborious nature of the task. Data obtained, therefore, are generally lag data — that is, not instantaneous — which would provide farmers with the best information for decision-making (Edirisinghe et al., 2011). The potential to obtain frequent, accurate and economic pasture quantity and quality measurements without an increase in labour or disruption of normal animal behaviours is crucial to help producers manage their pastures more precisely. This is increasingly important in Australia as producers try to minimise the cost of supplementary feeding and rely on pasture to maintain profitability. Therefore, aim of this study was to see the effect of pasture biomass and the wearing of Global Navigation Satellite System (GNSS) collars on cattle behaviour.

Materials and Methods

The experiment was conducted at The University of Sydney, Greendale NSW, Australia (33°56'19.18"S, 150°40'33.32"E), over 15 days (30 January to 13 February 2015), and was approved by The University of Sydney Animal Ethics Committee. Behaviour observations were conducted on 20 Charolais cows at 5 minute intervals using a scan sampling technique. Cows were identified using numbers painted on their side and 12 behaviours were recorded in Noldus Pocket Observer (Noldus Information Technology, The Netherlands). These behaviours included standing stationary, grazing, walking, running, drinking, standing ruminating, lying ruminating, resting, social, self-directed, other and out of view. Observations occurred daily from pre-dawn to post-dusk at the following sessions: 06:00-08:00 h, 09:00-10:00 h, 11:00-12:00 h, 14:00-15:00 h, 16:00-17:00 h, and 18:00-20:00 h throughout the 15 day trial period. Cattle were placed into an 8.9ha native Australian grasslands paddock consisting primarily of Kangaroo grass (*Themeda australis*) and Paspalum (*Paspalum dilatatum*) for the duration of the trial. Spatio-temporal data derived from UNEtracker II GNSS devices (Trotter et al., 2010) attached via neck-collars to 10 randomly selected cows were used to determine which areas cattle are spending time, providing information on animal location and movement. Normalised Difference Vegetation Index (NDVI) readings were generated every 4-6 days using a CropCircle ACS-470 system (Holland Scientific). The CropCircle uses information gained from the visible and near-infrared bands of the light spectrum to provide an NDVI value and an estimate of pasture biomass. Statistical analysis using a Reduced Maximum Likelihood model (REML) in R was undertaken to compare behavioural differences between collared (CD) and non collared (NC) cows.

Results and Discussion

Pasture availability and NDVI declined linearly with day ($R^2 = 0.99$), while cows increased time grazing (the searching and consumption of food), presumably to compensate for the declining availability of feed as they attempted to meet their nutritional requirements. Figure 1 highlights the interaction between grazing behaviour, pasture availability and NDVI. Grazing behaviour did not differ ($P>0.05$) between cattle wearing compared to not wearing GNSS collar units. Daily differences seen between collared and non collared cows can be attributed to variation between individuals. If producers were able to detect changes early on, they could implement management decisions such as rotating cattle onto a new paddock before pasture was depleted, leading to a potential increase in production and improved pasture management practices.

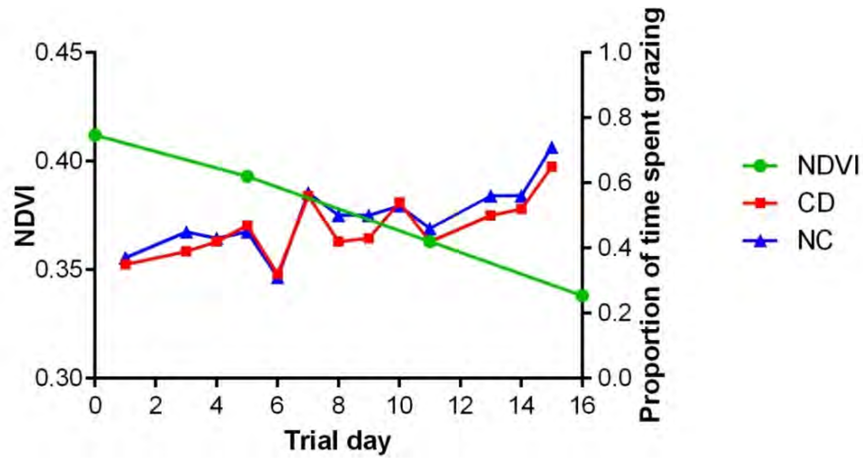

Figure 1. The proportion of time spent grazing by Charolais beef cows versus average NDVI across the paddock (●) over the duration of the trial (15 d). No difference in the proportion of time spent grazing was found between collared (■) and non-collared (▲) cows.

Conclusions

Cattle increased time spent grazing as pasture availability declined. By adopting new technologies into farming practices, producers will be better equipped to make management decisions, as well as potentially improving the level of livestock monitoring. Research is currently underway into pasture quality aspects of heterogeneous paddocks in order to determine how the quality (fibre, sugar, protein content etc.) of pasture affect spatial distribution of grazing cattle, their preference for pasture species and production attributes.

Acknowledgements

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Use of a UAV-Mounted Video Camera to Assess Feeding Behavior of Raramuri Criollo Cows

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Key words: Drones, diet selection, foraging behavior, cattle.

Introduction

The use of unmanned aerial vehicles (UAVs or drones) in science and engineering has increased dramatically in recent years (Harris 2013). Although US government regulations currently constrain the use of this tool for research (Vincent et al. 2015), it is likely that in the near future UAVs will become the preferred remote sensing platform for applications that inform sustainable rangeland management (Rango et al. 2011). The objective of this study was to determine whether UAV video monitoring could be used to predict intake of discrete food items of rangeland beef cows exposed to a controlled foraging environment.

Materials and Methods

We conducted a series of arena tests with 35 non-nursing adult rangeland-raised Raramuri Criollo cows weighing approximately 360 kg at the USDA-ARS Jornada Experiment Range in New Mexico, USA. Animal handling protocols were approved by NMSU IACUC (Protocol 2015-012). Video footage of all arena tests was acquired with a 3D Robotics Y6 Multi-copter (3D Robotics, Berkeley, CA) fitted with a 2 axis Brushless Gimbal with a BaseCam open source controller and a GoPro Hero 3 Silver Digital Camera (GoPro, San Mateo, CA) shooting 30 FPS at 1080i.

Pilot tests were first conducted to determine whether the sound of the UAV altered the feeding behavior of cows. Twelve feed containers were arranged in an open semicircle in a 405 m^2 rectangular arena devoid of vegetation. Bowls were numbered and placed approximately 1m apart. Each bowl contained either alfalfa hay (AH, 200g), Sudangrass hay (SH, 200 g), or cottonseed cake (CC, 50g). Four bowls of each food type were alternated (CC, AH, SH) using the same sequence in all tests. Pairs of either UAV-adapted or UAV-naïve cows were exposed to the experiment arena for 12 min. In all tests, the UAV was flown at an altitude of 25 ± 2 m above ground level, and typically hovered over the arena and was returned to home base as soon as cows were removed from the arena. Immediately after each trial, food orts from each bowl were collected and bagged separately and each bowl was replenished with the appropriate type and amount of food. All orts were weighed later that day.

Two months later, we conducted experiment tests with a different group of 15 adult non-lactating cows to determine whether UAV video monitoring could be used to predict intake of known amounts of discrete food items. Given the results obtained during pilot tests, no adaptation to the UAV sound was conducted prior to experiment tests. Arena layout and amount and types of food offered were identical to the pilot tests. Cows were led into the arena individually in random order and were allowed to feed from bowls for approximately 4 min. Test length was determined by UAV battery life, which typically supplied power for 5 to 6 min flights. Each test was filmed with the UAV deployed from a nearby location, again at an altitude of 25 ± 2 m. Food orts collection and weighing was conducted as described above.

All video files were downloaded and later processed to extract 2 sec. interval still images. A total of 4,893 images were inspected. Number of images indicating length of visits to bowls with AH, SH, and CC during each arena test were added and expressed as a frequency (%) by dividing number of visits to bowls containing a given food item by the total number of still images extracted from the video footage of a given test. Frequency data gathered in the pilot tests were analyzed with a t-test to determine if UAV-naïve and UAV-adapted animals exhibited different feeding frequencies. Data from the experiment tests were subjected to Linear Correlation analyses to determine the relationship between video-derived feeding frequency of individual cows and amount of food consumed per bowl (g*bowl visited^{-1} or rank). All analyses were conducted in SAS 9.3 (SAS Institute, Cary, NC). Differences between means or relationships between variables were considered statistically detectable at $P \leq 0.05$.

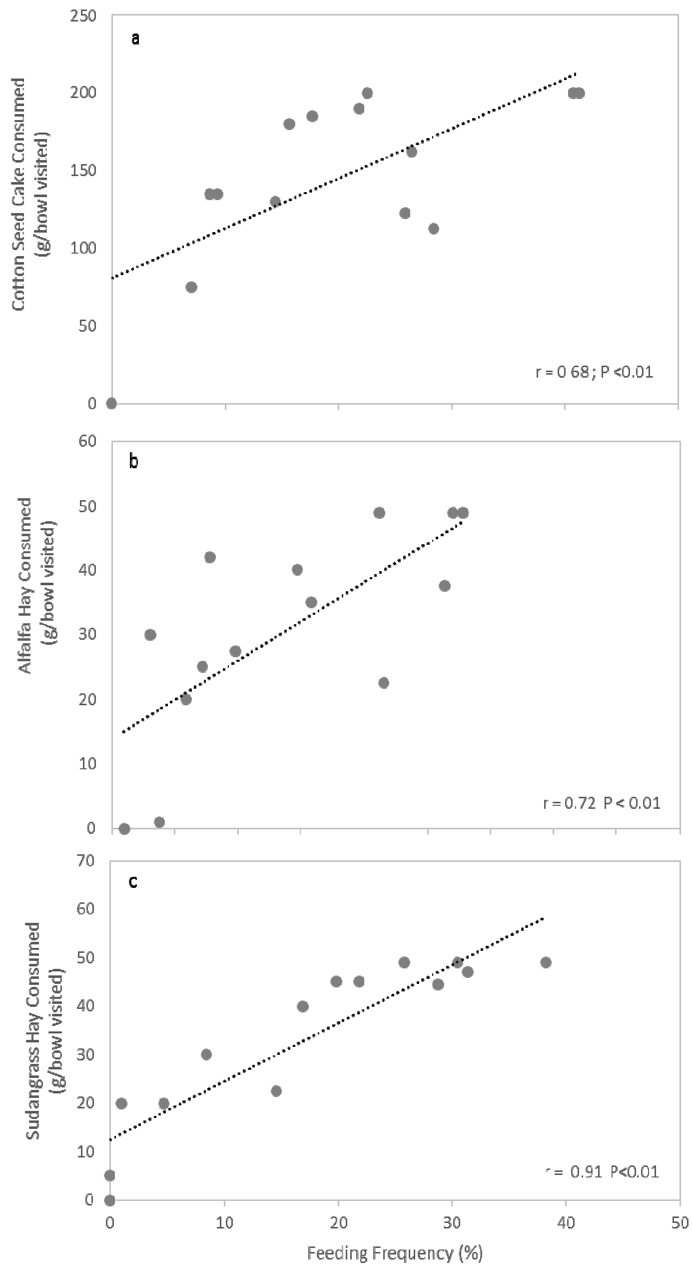

Figure 1: Relationships between feeding frequency (%) of 14 indi-vidual cows and: grams of cottonseed cake (a), alfalfa hay (b), and Sudan-grass hay (c) consumed per bowl visited during 4 minute arena tests with non-nursing mature Criollo cows.

Results and Discussion

Pilot tests showed no difference in feeding behavior of UAV-naïve and UAV-adapted cows, suggesting that this monitoring technique could provide an adequate non-invasive means of descri-bing behavior of non-adapted rangeland beef cows. Experiment tests showed strong positive correlations between feeding frequency observations derived from UAV video footage analysis and the amount of food consumed per bowl visited by cows (Fig. 1). This relationship was strongest for Sudan grass hay (r 0.91; P< 0.01) and weakest for cotton seed cake (r 0.68; P< 0.01).

Implications

Further development of UAV power sources to provide greater flight autonomy will be needed to use this tool in rangeland environ-ments. Because UAV image acquisition is spatially explicit, the integration of video from improved UAVs coupled with wireless transmission of acoustic signals from microphones fitted on grazing animals could provide unpre-cedented opportunities for integrating the study of diet and habitat selection of free-ranging livestock.

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The Digital Homestead Assists Rangeland Managers to Make Timely and Informed Decisions

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Key words: Wireless sensor network, beef cattle, outback, big data

Introduction

In 2013 the beef industry was worth $7.4 billion to the Australian economy. For those 10% of Australians who live outside the major cities, information and communication technologies are trickling into the small towns and homesteads of rural Australia. Data and information are key to sustainable businesses including agriculture enterprises and information will be increasingly important for economic and environmental sustainability, animal health and welfare and preserving the right to farm. Producers that can provide evidence of the way their products are produced may command a premium price in a modern society.

Materials and Methods

We developed a prototype digital dashboard (Digital Homestead) with the capacity to filter and integrate data collected electronically from the property, such as walk-over-weight (WoW) data, with off-farm information, such as market prices, to assist in making the right decisions at the right time.

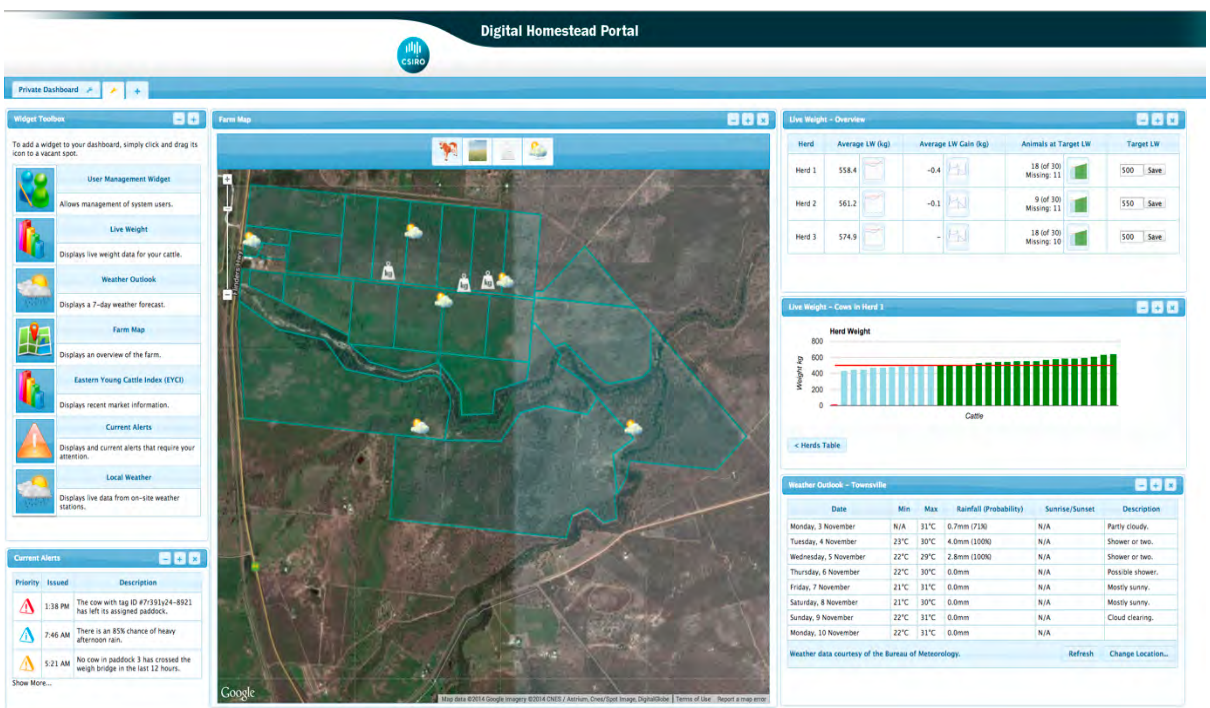

Figure 22. Screen capture of Digital Homestead dashboard.

Initial trials were conducted at CSIRO's Lansdown Research Station (19.66^{o}S, 146.84^{o}E) and subsequently evaluated on a commercial scale at the Spyglass Research Station (19.50^{o}S, 145.71^{o}E). Sensors deployed on the properties measured air temperature, rainfall, wind speed, wind direction, humidity, soil moisture, tank levels, cattle location, cattle activity and cattle live weight. A browser-based data dashboard, combined on-farm with external data sources such as market and weather information. Producer engagement was used to optimise the content and look of the dashboard and a workshop and field day were held to demonstrate the utility of the Digital Homestead.

Results and Discussion

An example of data collected from sensors at CSIRO's Lansdown Research Station together with feeds from relevant external websites is shown in Figure 1. Information could be drilled down to evaluate temporal trends, and used in a predictive capacity to run *what-if* scenarios. Figure 2 shows the weight change of a group of cattle over 12 months of grazing. The choice of sensors is dictated by the needs of a particular property and in a subsequent deployment at Spyglass a sub-set of sensors were deployed but across a more extensive landscape. The current prototype is intended for on-farm application and tailored to the northern cattle industry. However, because the system is modular it can be readily repurposed for other commodities and adapted to integrate data across the value chain.

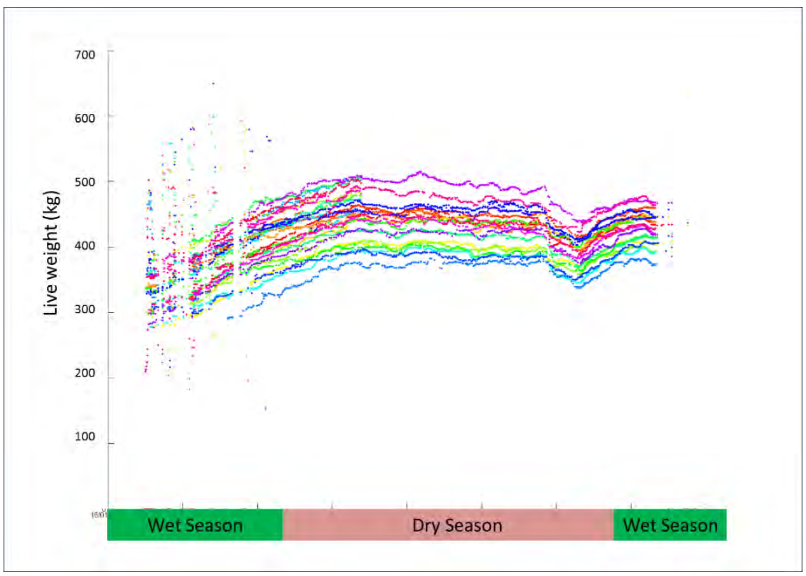

Figure 2. Weight change of growing steers over a 12-month period recorded using the Digital Homestead.

Conclusions and Implications

This project demonstrated the feasibility of the Digital Homestead and highlighted issues including the robustness of sensors in extreme environments and the limitations of transferring large amounts of data across extensive landscapes. Nevertheless we have demonstrated that such a system could service Australia's 15,000 beef businesses and be integrated into other agricultural enterprises including dairy and sheep industries. Australian beef producers are required to tag cattle with a National Livestock Information System (NLIS) passive ear tag and the digital homestead system builds around this existing technology. The Digital Homestead was developed in collaboration with industry including the technology providers that service this industry to address interoperability issues. Information is the key to ensuring sustainable businesses in the future and there are likely benefits from the system that are yet to be realised, for example, around provenance. It is suggested that technology broker networks will service farmers by providing the hardware and software to access an open-source dashboard similar to that developed in this project. Their data is transformed into accurate and timely information and presented in a user friendly format on computer, tablet or mobile phone. No existing technology providers have a system to integrate disparate data streams like the Digital Homestead.

The Effects of Seed Ingestion by Livestock, Dung Fertilization, Trampling, Grass Competition and Fire on Seedling Establishment of Two Woody Plant Species

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Key words: Dung nutrients, seed scarification, survival, tree-grass seedling competition, woody plant encroachment

Introduction

The increasing rate of woody plant encroachment in grasslands or savannas remains a challenge to livestock farmers. The causes and control measures of woody plant encroachment are of common interest, especially where it negatively affects the objectives of an agricultural enterprise. Seedling emergence and seedling establishment are crucial processes (early stages of the life cycle) in plant population dynamics because they usually influence the distribution and abundance of plant species. The appearance of a radicle marks the end of seed germination (the emergence and development from the seed embryo) and the beginning of seedling establishment, a period that ends when the seedling has exhausted the food reserves stored in the seed. Despite the widespread occurrence of woody plant encroachment, its dynamics are not entirely understood, particularly processes that lead to woody plant encroachment and dominance (Sharam et al. 2006). The objectives of this study were to determine the effects of gut passage (goats, cattle), dung (nutrients), fire, grass competition and trampling on establishment of *Acacia nilotica* and *Dichrostachys cinerea* seedlings

Materials and Methods

The study was done at the Agricultural Research Council's Roodeplaat Experimental Farm, Gauteng province, South Africa (28°19′E, 25°35′S). The vegetation type of Roodeplaat is classified as Marikana Thornveld by Mucina & Rutherford (2006). The experimental design consisted of 1 × 1 m plots, with 50 seeds per plot planted at 1 cm depth in the soil. All plots were separated by a 1 m buffer zone. The seedling emergence trial consisted of a completely randomized design with five factors replicated three times per treatment. These factors are: 1) passage through goats or cattle or unpassed/untreated seeds (i.e. not ingested), 2) dung and control (no dung), 3) grass competition and mowed grass, 4) fire and control (no fire), and 5) trampling and control (no trampling). Fifty *D. cinerea* seeds and 50 *A. nilotica* seeds retrieved from goats and unpassed/untreated seeds were planted per plot (50 *D. cinerea*, 50 *A. nilotica* and 50 unpassed/untreated seeds of each species were planted in separate plots) in three replicates with 16 combinations (96 plots and 4800 seeds). Another 50 *D. cinerea* seeds and 50 *A. nilotica* seeds retrieved from cattle and untreated seeds were planted per plot in three replicates with 16 combinations (96 plots and 4800 seeds). A total of 14400 seeds were planted in 192 plots for goats, 192 plots for cattle and 192 plots for controls (untreated seeds by passage through the gut of goats or cattle). Seedling emergence and establishment were monitored over three seasons (winter, spring and summer; i.e. from May 2012 to January 2013).

Results and Discussion

The interaction of animal species, grass and fire had an effect on seedling recruitment ($P < 0.0052$). Seeds retrieved from goats and planted with no grass and with fire (6.81% ± 0.33) had a significant effect on seedling recruitment than seeds retrieved from goats and planted with grass and no fire (2.98% ± 0.33; Figure 1). The use of fire to remove the above-ground grass had the most important effect on seedling emergence and seedling recruitment, most probably because of less dense grass cover and therefore reduced competition between tree seedlings and grasses (Campbell and Clarke, 2006). Significantly more *D. cinerea* and *A. nilotica* seeds germinated following seed ingestion by goats (3.59% ± 0.16) than cattle (1.93% ± 0.09) and control or untreated seeds (1.69% ± 0.11). Longer retention of seeds ingested by large bodied-animals, e.g. cattle, may result in substantial damage to the seeds (Rohner and Ward, 1999), which may cause significantly lower seedling emergence after cattle ingestion than from goats.

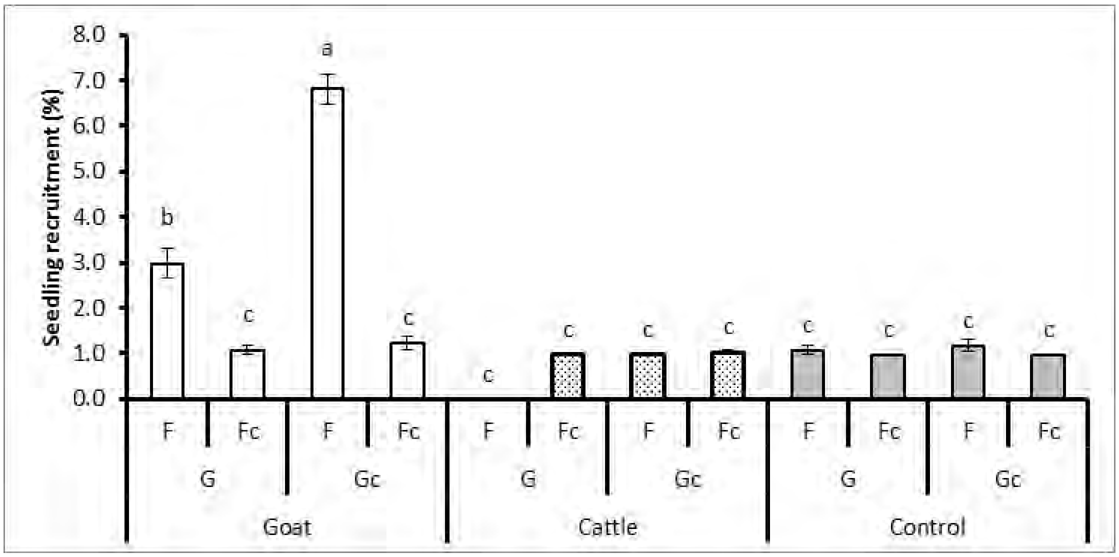

Figure 1. The treatment combination effects of animal species (goats, cattle), unpassed/untreated seeds (i.e. not ingested), grass (G) (and mowed grass (Gc)), fire (F) (and no fire (Fc)) on seedling recruitment during the dry season. Bars represent standard errors (S.E). Same letters on the bars mean that P > 0.05. A LSD *post hoc* test was used.

Conclusion and Implications

Regardless of the relatively low seedling emergence and recruitment, this study shows that the direct or indirect effects of gut passage, grass competition and precipitation were important in the recruitment of *D. cinerea* and *A. nilotica* seedlings, and may consequently contribute to woody plant encroachment. Overall, we showed in this experiment that the passage of seeds through the guts of different animals is not really a significant issue for woody plant encroachment. However, it was clear that interactions of various other factors (such as fire) and their direct and indirect effects may lead to woody plant encroachment.

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Alternative Breeding Scenarios for Abergelle Goat Breed Suited to Arid Climate in Ethiopia

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Key words: Genetic gain, goat, inbreeding, ZPLAN+

Introduction

The economic significance of goats in Ethiopia include small initial investment requirement, high survival rate during drought conditions, higher off-take and complementary feeding habit (ESGPP, 2009). These invite improving goat production and productivity in the country via designing appropriate community based breeding program (CBBP). Recent works on simulation study of pure breeding program of goat has presented various alternatives to the conventional CBBP of goats in Ethiopia (Temesgen et al., unpublished). In their works, the authors indicated that consideration of both dam line selection and systematic expansion of the one tier CBBP to two tier resulted in both higher predicted annual genetic gains and discounted profitability than the conventional one. However, the advantage of considering dam line selection on top of two tiers breeding program was not investigated. By its nature, the two tier CBBP could have two anticipated advantages: address emerging demands of the goat keepers to participate in the program and reduce high risk of inbreeding. Therefore, the objective of this work was to compare consideration of dam line selection in two tier CBBP of Abergelle (AB) goat to the dam line selection in one tier breeding program.

Materials and Methods

Description of the study area and breed

The simulation study on AB was made basing two villages namely, *Dingur* and *Blaku*. Detailed descriptions of the study areas are found on Alubel (2015) and detailed description of Abergelle goat breed is found in ESGPP (2009).

Breeding scenarios

Dam line selection in one tier (dam line) and dam line selection in two tier (two tier) CBBP were compared. Description of the scenarios are available in Temesgen et al. (unpublished). Six month weight (6mw) survival to six months (SUR) and average daily milk yield (ADM) were the identified selection criteria. All input parameters were prepared following the menu driven modeling software known as ZPLAN+ (https://service.vit.de/zplanplus/).

Results and Discussion

Annual genetic gain

Predicted annual genetic gains (PAGGs) in 6mw, ADM and SURV are given in Table 1 for AB from the two scenarios. The PAGGs of the selection criteria from two tier were higher than the PAGGs from dam line selection. The increments of PAGGs from two tier were about 50% in ADG and SURV and about 4% in 6mw over dam line selection. Higher PAGGs from two tier CBBP were associated with the shorter generation intervals. The shorter generation interval in this scenario, in turn, is associated with intensive use of early selected bucks compared to the other scenario.

Discounted breeding costs and profits

Discounted breeding costs and profits (EURO) together with the monetary genetic gain for both scenarios are given in Figure 1 for AB goat breed in Ethiopia.

Table 1. Predicted annual genetic gains in six month weight (Δ6mw), average daily milk yield (ΔADM) and survival to six months (ΔSURV) of Abergelle goat breed from the two scenarios.

Scenarios	Δ6mw (kg)	ΔADM (ml)	ΔSURV (%)	GI (year)	SI
Dam line selection	0.213	0.617	0.008	2.86	0.696
Two tier CBBP	0.222	3.695	0.048	2.610	0.619

GI= generation interval; SI=selection intensity.

The total return is higher in dam line selection compared to two tier CBBP. On the other hand discounted variable costs per animal were smaller in two tier CBBP compared to dam line selection. The smaller discounted variable costs in two tier CBBP is associated with larger number of animals in this scenario compared to the dam line selection since variable costs tend to decrease with increased number of breeding animal in a given breeding program. Even though both breeding scenarios were profitable, profitability from dam line selection was higher than that from two tier CBBP. Monetary genetic gain (mGG) is a measure of the average superiority of the progenies of the selected animals (Mirkena et al., 2012). And the mGG is obtained as the sum of the products of genetic gain in a component breeding objective trait and its corresponding economic value (Gizaw et al., 2014). The mGG was higher for two tier CBBP than dam line selection which was associated with the higher genetic gains of breeding objective traits in the in two tier CBBP where the economic values of the breeding objective traits remain constant.

Figure 1. Discounted total return (Total return), variable cost (total cost), profit and monetary genetic gain from different scenarios in Abergelle goat breed in Ethiopia.

Conclusions and Implications

In our present work, we suggest consideration of dam line selection on top of systematic expansion of one tier breeding program to two tiers. Therefore, community based breeding program of Abergelle goat in the arid agro-pastural production system should be two tier, where the dam line selection, say 20% culling, would be the implicit activity.

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A Framework for Separating Genetic and Environmental Influences on Cattle Performance on Open-Range Pasture

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Key words: Cattle, foraging behaviour, residual feed intake

Introduction

Residual feed intake (RFI) is a heritable trait that can be used to measure feed efficiency in cattle and serve as a tool for managing costs in beef operations (Basarab et al., 2003). However, measures of RFI have most commonly been evaluated under drylot conditions, where animals are on a standardized diet and foraging behaviour is minimal (Richardson & Herd, 2004). In rangelands, evidence suggests cattle are highly selective while foraging, a phenomenon that applies across multiple spatial scales ranging from individual feeding stations to plant communities (Senft et al., 1987; Bailey et al., 1996). There is also marked temporal variation in forage quantity and quality throughout the grazing season. Our study is exploring the utility of RFI by relating molecular breeding values (MBVs) for RFI to cattle performance, and using GPS collars and leg mounted pedometers to determine if there are relationships between cattle habitat selection and activity budgets with associated MBVs for RFI.

Materials and Methods

This work is being conducted at the University of Alberta Mattheis Research Ranch, north of Brooks, Alberta in the Mixedgrass Prairie. A subset of 27 commercial cows, estimated to have high and low RFI based on divergent MBV's, were bred in 2014 to bulls with corresponding estimated breeding values for RFI (including their own RFI records) to create a crop of 2015 calves divergent for RFI. These cows were evaluated in the summer of 2015 for industry-relevant production metrics such as calf growth, cow rebreeding interval, cow weight gain and ultrasound fat thickness. We collected calf birth and weaning weights. Cows were weighed and ultrasounded for back fat thickness at pasture turnout in early June and again at weaning in October. Cows were also assessed for rebreeding in fall.

The 27 cows were fitted with Lotek 3300LR GPS collars and AfiAct II pedometers from June to October 2015 to track their habitat selection and movement during the grazing season. We hypothesize that cows with low MBV's for RFI (efficient) would utilize areas associated with greater quality forage for longer periods and spend less time moving outside of travel to food or water sources, compared to cows with high MBV's for RFI (inefficient). Further, we expect these behaviours to be reflected in the production metric success (greater weight gain, calf success and growth, successful rebreeding) of these animals, with the efficient animals out-performing the inefficient.

Activity data from the 27 animals will be pooled and analyzed by RFI category. Analysis will be stratified into the early growing season (June-August) and dormant season (September-October). Three a-priori mechanisms that contribute to the variability in cattle use of the landscape were hypothesized with biologically relevant measurement variables within each category identified (see Figure 1).

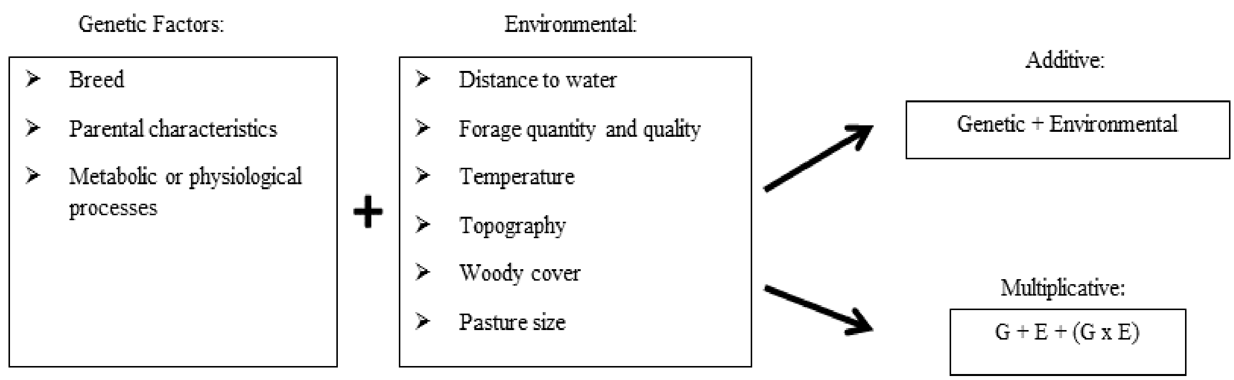

Figure 23. Conceptual representation of the factors contributing to the variability in cattle use of the landscape (and subsequent success as measured through production)

Expected Results and Discussion

Occupancy for each animal within an RFI category will be completed as per Nielson & Sawyer (2013) and the values obtained compared to assess differences in use between RFI categories. Factors with significant values ($P<0.05$) will be included in our model selection process, and beta values used to create resource selection functions (RSF's). RSF's will ultimately be used to create habitat use models within ArcGIS for animals from each RFI category. Information collected on cattle production metrics will be analyzed in conjunction with the behaviour data and will help to confirm or reject our hypotheses, and will provide an evaluation of the ability of RSFs to explain production metrics.

Conclusions and Implications

Determining whether selection for RFI in beef cattle has consequences (positive or negative) on the use and production of open-range landscapes may be a key step towards changing the management of rangelands via alternative beef cow selection criteria. Alternatively, the lack of differences in foraging behaviour, landscape use, and cow/calf performance between animals with contrasting MBV's for RFI may signal that selection for RFI within a breeding program will not affect rangeland use or cow/calf performance under open-range grazing.

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Rainy Season Herding Patterns of Agro-Pastoral Livestock Smallholders in Southwestern Mali: A Preliminary GPS-Based Assessment

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Key words: Grazing behavior, sheep, cattle, Region of Sikasso

Introduction

Smallholder livestock production in Mali's rain-fed agro-pastoral systems is strongly limited by deficient levels of ruminant feeding (Cibils et al. 2015). Crop cycles frequently dictate access to common grazing resources giving way to the *smallholder's paradox*. During the rainy season when quality and quantity of forages are highest, access to common grazing lands is extremely restricted because smallholders seek to minimize the risk of crop damage liability. Conversely, during the dry season, when forages are dormant and scarce, mobility and grazing access is unrestricted. Herders (often children) can further constrain ruminant foraging choices when deciding *where* and *for how long* animals graze. The objective of this pilot study was to characterize movement and activity patterns of herded GPS-collared ruminants during the season with highest movement/access constraints.

Materials and Methods

Six animals were fitted with a Garmin ETrex Legend GPS receiver connected to a double D cell battery pack, placed in a watertight box mounted on a polyethylene strap. Three small adult ruminants (a doe, a ewe, and a ram) and three large adult ruminants (two oxen and a cow) belonging to farmers in a village located close to Koutiala, region of Sikasso, Mali, were tracked for a week in September 2015. GPS receivers were configured to log animal locations at 1 min intervals. All GPS receivers were WAAS enabled insuring fix location precision of ≤ 3 m. At end of the week, collars were retrieved, and data were downloaded for mapping and analysis.

Location data were projected in UTM 19 N zone coordinate system and were explored in Google Earth™ and MS Excel. We calculated time at which tracked animals left and returned to the village in the mornings and evenings; total time of each daily herding circuit (h); and distance traveled in a day (km). GPS points were classified into presumed activity classes based on known movement velocities of common animal activities (resting, grazing, and traveling). Small ruminants were presumed resting, grazing, or traveling if their velocity was < 0.5 m/min, between 0.5 and 5 m/min, or > 5 m/min, respectively. For large ruminants, velocities of < 1 m/min, between 1 and 20 m/min, or > 20 m/min were presumed to indicate resting, grazing, or traveling, respectively. Means and standard errors for all parameters were calculated in MS Excel. Pearson Correlation Coefficients were calculated using PROC CORR in SAS 9.3 (SAS Institute, NC) to determine the relationship between estimated time spent grazing while being herded and both distance of the herding route and daily herding time. Correlations were declared statistically detectable at $P \leq 0.05$.

Results

Two collars malfunctioned, so we analyzed data retrieved from four of the six GPS collars (two large and two small ruminants) which yielded 29,010 GPS locations. Large ruminants left the village approximately 3 h earlier and returned almost 1 h later than their small ruminant counterparts. Large ruminants spent 4 additional h in the field and traveled about 4 additional km each day compared to small ruminant counterparts. Large ruminants grazed for over 7 of the 12.6 h they remained in the field each day whereas small ruminants grazed for less than 3 of the 8.8 h of their daily herding route (Table 1).

Table 1. Characterization of smallholder herding patterns during the rainy season in an agro-pastoral village close to Koutiala, Mali. (Means ± SEM)

		Large Ruminants	Small Ruminants
Individuals tracked		2	2
Tracking period (days)		5.5 ± 0.5	4.5 ± 0.5
Total GPS fixes		16,106	12,904
Daily Herding	Began	6:22 AM	9:21 AM
	Ended	7:01 PM	6:10 PM
Daily Herding Time (h)		12.66 ± 0.10	8.81 ± 0.23
Daily Distance Traveled (km)		11.76 ± 0.60	7.95 ± 0.14
Activity During Daily Herding	Grazing (h)	7.36 ± 0.59	2.75 ± 0.16
	Resting (h)	1.56 ± 0.08	1.41 ± 0.33
	Traveling (h)	3.76 ± 0.42	4.76 ± 0.25

Increased distance of daily herding routes was associated with detectably less time spent grazing by large (P=0.02) but not small (P=0.17) ruminants (Fig, 1). Longer daily herding time was associated with significantly more time spent grazing for small but not large ruminants (Fig. 1).

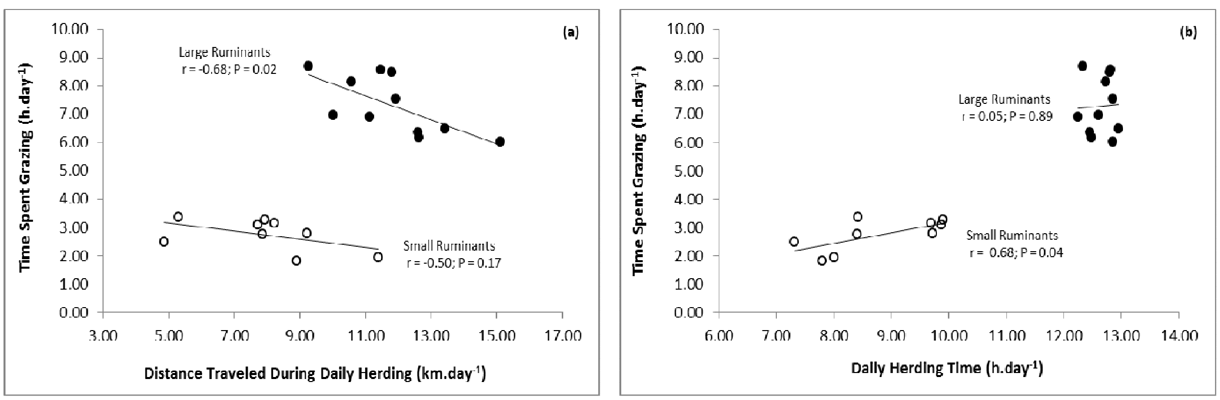

Figure 1. Hours per d spent grazing by large and small ruminants in relation to distance traveled during daily herding (a) and duration of daily herding (b) during the rainy season in village close to Koutiala, Mali (number of points corresponds days*animals).

Discussion and Implications

Estimates of time spent grazing by large ruminants in this study are comparable to what Arnold and Dudzinsky (1978) described for free ranging cattle (7–12 h d^{-1}) but considerably less than what these authors observed in free ranging sheep and goats (6–10 h d^{-1}). Our estimates suggest that during the rainy season, large and small ruminants from the herds we monitored were possibly able to harvest about 90% and < 50% of their daily dry matter requirements, respectively, while being herded on common rangelands adjacent to the village.

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7.4 Technology in education and extension

Developing Web Applications to Aid Grazier Decision-Making

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Key words: Allocation, applications**,** forage, pasture, mobile phone

Introduction

A fundamental part of improving feeding of range-fed livestock is the appropriate allocation of forage or pasture to meet animal requirements. Many technologies have been designed to measure feed for grazing livestock, including both in situ (Thomson et al., 2001) and remote sensing options (Dennis et al., 2015). Tools to allocate that feed to meet the intake of the grazing animal are available, using office-based computer packages. However, the decision to allocate feed and the grazing duration is often made by the grazier in the field without access to these measurements or tools. This paper describes a web application that is fully downloadable to mobile smart phones and available off-line to enable graziers to check that their in-field feed allocations meet their projected production targets.

Materials and Methods

Two simple calculators were developed to provide an answer to a range of questions asked by the grazier. The first application (app) addressed the question 'how much do I need to feed my animals?' A feed allowance calculator, DEERFeed Intake, was developed for red deer farmers. The application (app) uses live weight, live weight gain, gender and physiological status to calculate feed requirements for both weaners and hinds, using equations from Nicol and Brookes (2007). It estimates the maintenance and growth requirements for weaners, and the maintenance, growth, pregnancy and lactation requirements for hinds.

A second calculator to help the grazier allocate the pasture or forage to meet those requirements, DEERFeed Allocation, was also developed. The questions that could be answered included: how many animals will that amount of forage provide feed for; how much area must I allocate for this mob; what will the intake allowance be if I have this much forage available; how much forage do I need on offer to meet my feeding targets; how much forage will be left behind if the animals eat their allocation; how many days can I leave this group in this paddock? All of these questions relate specifically to the pasture or forage available *in situ* in the paddock. These questions are all inter-related and require the same information.

The equations needed to answer these questions were formulated and then built into an HTML5 coded web app. These were designed to be fully downloadable onto any device with a web browser, such as a smart phone, tablet, laptop or desktop computer.

Results and Discussion

Figure 1 provides an example of the screens that require input when determining feed intake and allocating feed. The two apps, intake.deerfeed.co.nz and allocation.deerfeed.co.nz, are available at a single website deerfeed.co.nz and are linked together with a cover page and embedded links with each app. The intake app calculates the feed requirements while the allocation app provides a tool for allocation of the grazing resource. The allocation app allocates the *in situ* available forage, rather than accounting for any supplementary feed that may be provided. Both apps assume that the user understands concepts of amount of feed on offer and grazing residuals. Thus the apps are for graziers with significant knowledge in grazing management and feed requirements of livestock. Future apps to calculate sheep and beef requirements are under development.

Figure 1. Screenshots of the intake (left) and allocation (right) apps, deerfeed.co.nz.

The ability to download the whole app (as a web site) provides the utility of being able to subsequently use the application without any internet connection. The grazier then has the ability to make decisions in the paddock. The use of HTML5 as a base language also means that the apps are universally available on all mobile operating platforms, as only an internet browser is needed. This then means that the apps remain current regardless of changes in the operating systems of the user's mobile phone.

The downside with this approach is that the app then must have a dedicated website and an on-going home for support and hosting. There is also the requirement for slightly more instruction for downloading and use as users are less familiar with the web app approach than the purchase of an app from a distributor.

Finally the app requires that the grazier is a relative expert in grazing management, understanding the terminology and the implications of pre- and post-grazing feed resources. It may provide educational elements from trial and error once the grazier begins to observe the effects of implementation.

Conclusions and Implications

The development of an accessible web app provides an easy to use tool for graziers to improve their feed allocation to meet productivity targets. Being able to work off line gives a portable tool for all decision-makers from manager to stockmen to improve the precision of their decisions.

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Saskatchewan Ministry of Agriculture: Technology in Education and Extension

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Introduction

This presentation will feature 16 methods of agriculture education and extension used by Saskatchewan Agriculture to promote improved management and new ideas on range and forage management.

Materials and Methods

The following are various methods of technology transfer used by Saskatchewan Rangeland and Forage Extension personnel. Publications, web videos, webinars, project reports, research reports, program information and upcoming events are available to all interested individuals and can be found at: http://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers

Publications *(Winter Swath Grazing, Winter Bale Grazing, Portable Windbreaks, Mole Hill Levelers)*
The swath grazing and bale grazing publications assembled the relevant and important details about these practices. They include information that assists the manager to decide whether or not to adopt the practice, and pertinent details about managing the practice. The information was collected from producers already using these methods, and from professionals knowledgeable about the subject areas covered.

The portable windbreak and mole hill leveler publications were assembled as a collection of all the designs and features that were currently in use. The majority of the windbreaks and levelers were producer designed and built. Producers are almost always quite receptive to ideas and equipment their peers are developing.

Web Videos *(Alfalfa Weevils, Crop Residue Collection for Field Grazing)*
These videos are less than five minutes, but relatively thorough with details. The information is clear, concise and easy to understand. The visual component of procedures, diagnosis and equipment function is powerful for uptake and retention of information.

Demonstration Projects *(Root Project, Yellowfeed, Annual Cereal Demo)*
The root project clearly captured and displayed the effects of different grazing treatments. The physical differences in root mass are easily noticed. The yellowfeed project measured and documented the effect of glyphosate on annual cereals when drying for stored forage. Advantages and disadvantages of the practice were noted and reported. In summary, there were no negative effects on yield or forage quality. The results gave industry the confidence to quickly adopt this practice as a forage drying option when weather conditions are not favorable for drying in the windrow.

Stay Connected
Stay Connected is an electronic weekly email to keep producers and other interested persons informed of relevant topics, issues and upcoming events. Subscribers need to provide their email address. Stay Connected is a nimble information source for producers that changes weekly. For example, during the alfalfa weevil hatch, we keep producers up to date on hatch progression, numbers and feeding activity. Producers are then attentive as to when they need to monitor their own fields.

Webinars
Webinars are presentations that are broadcast through the computer. Any individual can register and view them from the convenience of their home computer. If they miss the initial transmission, they can view it later at their convenience. Webinars are usually 30-60 minutes long.

Provincial Pasture Tour
Each year the Ministry, along with several industry partners, hosts a one-day pasture tour in a selected region of the province. Progressive ranch operations that use recommended and proven pasture management methods are featured. Participants travel from site to site on a charter bus with plenty of opportunity to interact with the site manager, other producers and professionals. They can view, judge and ask questions for themselves how various forage production ideas and methods might apply and benefit their own operation.

Ranch and pasture pictures are taken through the season, and a "Virtual Ranch Tour" presentation is developed for each site visit. The host ranch delivers the presentation indoors if the field tour is not possible due to inclement weather.

Environmental Farm Plans
The Saskatchewan Environmental Farm Plan program is a self-learning workbook that assists producers to assess environmental risk on their farms and ranches. Once completed, producers can apply to the Farm Stewardship Program for funds to assist implementing practices that are beneficial for the environment. One example is seeding perennial forage on annual cropland that is saline or erodible.

Producer Seminars/Meetings/Conferences
Producer learning events are often scheduled during winter months when some producers have a greater ability to attend in person. Relevant topics are presented that keep producers informed for improved business management decisions.

Agriview
Agriview is a monthly publication mailed to every farm and ranch in Saskatchewan. It features information on crops, soils, economics, livestock, research, upcoming events and programs and services.

CTV FarmGate
Each week, television films and broadcasts a three minute interview with a Saskatchewan Agriculture Specialist. The topics are wide ranging and timely for the season.

Radio
Each week, radio tapes and airs a three minute interview with a Saskatchewan Agriculture Specialist. The topics are wide ranging and timely for the season.

Field Surveys
Fields are scouted early and regular to detect the initial stages and extent of insect populations and disease problems. Producers are kept informed through emails, Stay Connected and/or Radio, depending upon the urgency of the situation. They can then begin monitoring their own fields with a greater level of confidence. In recent years, the most recurring and urgent situation has been alfalfa weevil.

One on One
Producers consult with Specialists about their own operations by phone, text, farm calls, office visits or email. Specialists gather information about and consider the unique aspects of an operation before offering options for situations.

Diagnostic School

Producers have the opportunity to attend diagnostic field schools where insects, weeds and diseases are displayed and monitoring techniques are shown.

Federal Community Pasture Transfer to Patrons

Develop grazing plans with patrons to ensure continued good range health. Develop plans and protocol for monitoring and controlling invasive weeds.

Twitter

Social media tools such as Twitter are used to provide relevant "tweets" of information to producers so they can make timely decisions. Examples include insect or disease developments, information from workshops or events, and pertinent research or demonstration results.

Results and Discussion

Collectively these methods are effective for agriculture education and extension, and well received by producers. Producers routinely look for new and proven practices to implement and improve their operations. These methods are effective at drawing their attention to a subject, with the ultimate goal of having them learn and adopt improved management practices.

Conclusion and Implications

The education and extension method(s) chosen must be suitable for the situation. For timely topics (short term insect outbreak) the information needs to be instant, nimble and widespread. For ranch management strategies (implementing winter swath grazing program) the information needs to be in a form that can be referenced, as there are many details to co-ordinate to ensure implementation is successful.

Manitoba Beef & Forage Initiatives Inc.: A New Public/Private Collaborative Model for Supporting Beef and Forage Research

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Key words: Research, extension, beef, forage, demonstration

Introduction

At Manitoba Beef & Forage Initiatives Inc. (MBFI) we are building the future from the ground up; starting at the level of the soil and working our way upwards. In other words, we are a new beef and forage research and demonstration farm near Brandon, Manitoba with the goal of using research to benefit valuable ecosystems, improve producer profitability and build social awareness around the beef and forage industries.

Manitoba's Climate Change and Green Economy Action Plan (MAFRD, 2015) released in December of 2015 recognised that "acting on climate change is an economic and environmental imperative in Manitoba." In this document it specifically highlights promoting perennial forage crops as one of their strategies to increase the environmental benefit of the Agriculture sector. Additionally, a recent publication highlighted a significant reduction in greenhouse gas emissions over the last 30 years in a large part due to increased efficiencies in beef cattle production. In order to continue on this track of reduced environmental impact, it is important that we continue to find new ways of increasing production efficiencies (Legesse, 2015). It is clear that to meet social requirements beef producers will have to be cognizant of their impact on the environment and continue to communicate with the public while sustaining the profitability of their farms. For these reasons, MBFI's focus is on applied research that producers can use to improve the efficiency and environmental soundness of their operations. The beef and forage industries not only provide a source of nutritious food but they also enhance soil health, sustain biodiversity, increase carbon sequestration, reduce soil erosion and protect watersheds. The plan is for MBFI to become a resource for researchers, producers, and the public to communicate regarding these great benefits that this industry provides.

Materials and Methods

The Initiative is in its initial year of operation but has been in development for a number of years. It takes a group of very determined individuals to create an initiative with this kind of vision and with such diverse partners. In this case the core partners are Manitoba Food and Rural Development (MAFRD), Manitoba Beef Producers (MBP), Manitoba Forage and Grassland Association (MFGA), and Ducks Unlimited Canada (DU).

A few of the initial development steps were to secure an agreement for the land that would be used for the farm; to organise a steering committee of core partners; to organise a research advisory committee comprised of collaborators and producers and to secure the start-up funding for the project. After 2 years of negotiations, planning and development an announcement of the agreement between MBFI and the Provincial and Federal governments through Growing Forward 2 for $3.1 million dollars on Feb 5, 2015. Since then it has been a flurry of activity on the three sites that MBFI utilizes.

A number of dedicated MAFRD staff have been seeking out researchers to begin research trials on the sites and many have their own applied research projects ongoing at the site. Throughout the summer and fall of 2015 crops were planted, staff were hired, cattle were custom grazed, a research herd was purchased, a cattle handling facility was constructed, and twenty plus submissions for research projects were received and are being planned for the coming season.

Some of the research projects started this summer utilizing approximately 1300 acres of wetland, cropland and pasture. For all of these long term projects this year was the initial year so although data was collected there are few significant results to report. The list of projects include:

1. Assessing riparian health to determine management techniques that can be used to increase their health score.
2. Planned grazing methods that test the hypothesis that intensive grazing improves soil, forage and animal health.
3. The ability of energy dense annual forages to grow in our climate, the palatability of the forages and the effect they have on cattle performance.
4. Measuring the impact of grazing on the abundance of cicer milkvetch in a stand also started this summer.
5. Using low cost methods to increase land productivity and reduce weed populations on marginal pasture lands was started.
6. Measuring the economic efficiency of using different trap types to reduce the rodent population in research fields.

Results and Discussion

The results of this summer's research work has been the gathering of extensive baseline information and general observations from each project. The summer students also gained valuable knowledge from training days and by working with the researchers on their projects.

One of the main results from this first year of work has been the valuable partnerships, outside of the core partners, that have been developed and continue to be solidified. These include partnerships with academia (University of Manitoba, University of Winnipeg, Brandon University, and Assiniboine Community College), corporations (McDonalds, bioTrack), non-profit organisations (Manitoba Zero Tillage Research Association, Western Beef Development Centre) and government (Agriculture and Agri-Food Canada). Already there has been significant interest to include MBFI in events, tours and incorporated it into class curriculums. Funding contributions from companies like McDonald's are very important and will ensure the continued success of MBFI.

Conclusions and Implications

The team at MBFI is anticipating that this will be a sought out venue for workshops, events, student training, research projects and many other activities. The Manitoba Beef & Forage Inc. has already brought many organisations together including government, industry and academia. MBFI will also be available as a resource for the public to go for balanced information on beef and forage production.

We are and will continue to build the future from the ground up.

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Extension Priorities Guide Ranch Stewardship Mapping Curriculum

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Key words: Extension, GIS, grassland, rangeland, sustainability

Introduction

Cooperative Extension has a long history of helping producers address their current needs and emerging public issues; often through training in the use technologies which are not yet widely adopted. Sustainability of beef cattle production is a prominent concern of scientists, consumers, retail corporations and producers. Extension programs addressing sustainability issues, such as stocking rates, water, and soil should be expanded (Steiner et al., 2014). Geographic information system (GIS) mapping is becoming a widely available technology. Web mapping applications and geospatial pdf maps have good potential for helping cattle ranchers identify, implement and document their sustainability improvement efforts (Boyer, 2016). Objectives of this project are to better understand Extension education priorities of beef cattle owners and the broader public, and then develop digital mapping resources relevant to current needs of cow/calf producers, as well as to long-term sustainability of cow/calf production. Age, gender and relevance to production practices may be important successful program delivery (Noble, 2015).

A program prioritization survey (PPS) conducted by Kansas Extension will guide development and delivery of the ranch stewardship mapping curriculum. Research questions asked in this study are how do beef cattle owners prioritized education programs on 1) animal wellbeing, 2) livestock environmental regulation, 3) rangeland/grassland management, 4) woodlands/tree planting, 5) water quality and quantity, 6) invasive species, 7) soil fertility and erosion, and 8) wildlife management; and how do these priorities differ from those of non-beef cattle owners? It is hypothesized that grassland management is the top priority of owners, that they consider it and invasive species more important than do non-owners; and that they consider woodlands/tree planting, and environmental regulation to be lower priority than do non-owners. Another research question is what are gender, generational, and regional differences in the priorities of beef cattle owners? It is hypothesized that women owners consider education needs related to environmental regulation and animal wellbeing to be a higher priority than do male owners.

Materials and Methods

Eleven program focus teams developed six survey questions each for the PPS. Survey respondents ranked the six questions for each program in order from highest (1) to lowest (6) priority. Respondents also answered demographic questions. Eight questions from two program areas (livestock production and natural resources) and four demographic categories (gender, age, county and beef cattle ownership) are used in this study. Ages were classified into four generations, and counties were classified into 3 precipitation regions for this study. The survey was administered online and in hard copy form to local residents for a period of approximately four months. Complete responses for the livestock and natural resource questions were provided by 2,240 respondents; of those, 688 (31%) were beef cattle owners. Priority scores were compared using Kruskal-Wallis (K-W) non-parametric analysis. Pairwise post hoc tests were used to determine differences of independent variables having more than two groups.

Results and Discussion

Owners and non-owners of beef cattle both scored animal wellbeing (median 2) as a high priority and environmental regulation (median 5) as a low priority for Extension livestock education. However, K-W tests comparing mean ranks show that they are both a higher priority for non-owners. Top median priority scores for natural resource education from non-owners were 3 each for grass, soil, water and trees. The same from owners were 2, 3, 3 and 4 respectively. As hypothesized for natural resource education, owners scored grassland management as their top priority (median 2), and scored it as a higher priority than did non-owners (median 3). Also as hypothesized, owners scored woodlands/tree planting as a lower priority (median 4) than did non-owners (median 3). These directional differences in median scores are consistent with that of mean ranks determined using K-W test. Median scores on invasive species were 4 for both owners and non-owners. However, the K-W test comparing mean ranks of invasive species scores indicates that it is a higher priority for owners. All K-W test results reported above were significant at a level of $p<.001$.

Priorities of beef cattle owners (Fig. 1) help identify more immediately relevant program topics for the curriculum. Gender, generational or regional differences of owners could possibly be used to help direct how it is delivered. As hypothesized, females scored animal wellbeing as a higher priority (median 2) than did males (median 3). This directional difference in gender median scores is consistent with that of mean ranks comparison of the K-W tests. There was no significant difference in mean ranks of gender scores for environmental regulation with median scores of 5 for both males and females. Additionally, female owners ranked water (median 3) as higher education priorities than males (median 4). Owners from the wettest region of Kansas identified invasive species as higher education priority (median 3) than did owners from the driest region (median 4). These directional differences in median scores are consistent with region mean ranks comparison of the K-W test. All K-W tests results reported above were significant at a level of $p<.05$.

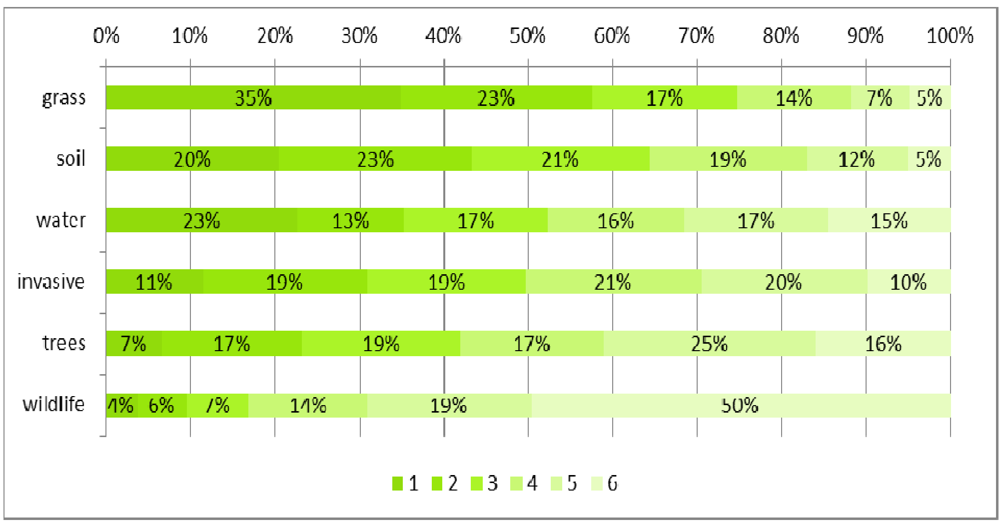

Figure 24. Beef cattle owner natural resource priority score frequencies.

Conclusions and Implications

A ranch stewardship mapping curriculum will be developed to provide cow/calf producers tools to help identify, implement and document sustainability improvement efforts. These tools should be relevant to their priorities (animal wellbeing, grass, soil, water) and yet responsive to differing public priorities (trees and environmental regulation). Tools will specifically help in determining stocking rates, and in strategic management of livestock concentration areas such as livestock shelter, water resources, and supplemental feed sites. Management of these factors is important to production, animal wellbeing, and the impact livestock have on soil, water, and riparian woodlands. The stewardship curriculum will include web mapping applications, geospatial pdf maps, GIS data layers, spreadsheets, and user guide bulletins and videos. It will be marketed initially to women in Kansas, possibly emphasizing water and/or animal wellbeing aspects of grassland management. Much of the content however, will be available for ranchers across the Great Plains.

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From Farmers to Farmers and from Researchers to the Public at Large: Films for Communicating Best Practices and Research Findings

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Key words: Alpine summer farming, best practices, documentary film, farmer to farmer, Youtube.

Introduction

In Switzerland as a mountain country, elevated grasslands and pastures are an important feature of the cultural landscape. In many locations, the traditional extensive management is changing due to environmental impacts (climate change), technological changes (breeding progress, new farm machinery for steep grasslands, irrigation), socio-economic processes (low farm income, reduced attractiveness of farming as a profession) (Herzog et al., 2016).

In an inter- and transdisciplinary research program, we investigated the future prospects of alpine summer farming (www.alpfutur.ch). The program consisted of 22 disciplinary projects, which were co-ordinated towards an overall synthesis (Lauber et al., 2014; Seidl et al., 2015). In order to communicate our results beyond the scientific community, we initiated the production of films.

Materials and Methods

The film project "Farmer to farmer" aimed at demonstrating best practices of pasture management for the prevention of abandonment and the preservation of mountain meadow biodiversity. Together with a multi stakeholder discussion group, the author Patricia Fry identified three summer farms which had successfully implemented such best practices. After interviewing the farm managers and their team members a film concept was derived. The films show the protagonists explain their approach and methods in an authentic way (Fry, forthcoming).

The film project "Summertime" summarizes the major outcomes of the research program to the public at large. The author Pascale Gmür accompanied the research process over several years with the camera. She identified 3 storylines which – in combination – explain the complexity of the summer farming activity, the challenges it faces and research findings which allow addressing those challenges.

Results and Discussion

Farmer to farmer

Three films of 15 minutes each were produced, in which the farmers explain their practices in their own words (Fig. 1). The films have subtitles in German, French, Italian and English. The film DVD is distributed by one of the Swiss mountain farming schools and the films are regularly used in training courses for practitioners. They are available for download on YouTube:

"Farmer to Farmer - Non-intensive farming is worth it"
https://www.youtube.com/watch?v=2gpn3O9l5g0, 7,300 views in German after 2 years.
"Farmer to Farmer - Independent team manages a large summer dairy farm":

https://www.youtube.com/watch?v=9a5aDI2ruQM, 56,000 views in German after 2 years.
"Farmer to Farmer - Innovative pasture maintenance with dairy goats"
https://www.youtube.com/watch?v=dmPaoYKXlKo, 22,000 views in German after 2 years.

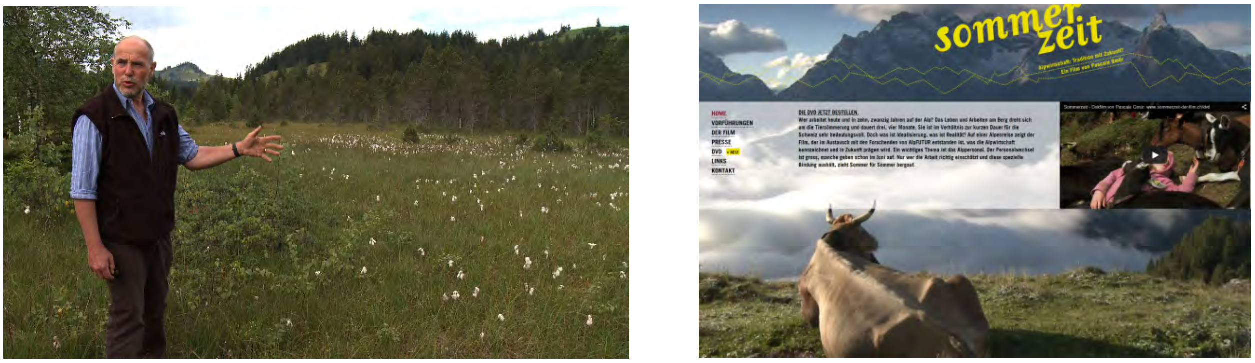

Figure 1. Still from the Youtube movie "Farmer to farmer" (left) and leaflet announcing the documentary film "Summertime" (right).

Summertime

The film "Summertime – Alpine summer farming: a forward-looking tradition?" (78 minutes with subtitles in German, French and English; Fig. 1) is a documentary movie which addresses the general public. It explains the complexity and the diversity of summer farming systems by portraying people involved in this activity. The camera accompanies three scientists who do research on pasture management, on the working conditions for herders and on historical practices and buildings of the summer farming area. In addition, the film portrays ten herders, cheese makers and families who work on a summer farm. The film was first shown in a cinema in the city of Zurich in 2013. Since then it has regularly played in cinemas, in specialized festivals, at agricultural faculties of Universities and farm schools. It is available as a DVD from http://www.sommerzeit-der-film.ch. When it is shown, the author is often present and available for a public discussion after the screening.

Conclusions and Implications

Communication in a multilingual country such as Switzerland (four national languages) is challenging because the information needs to be translated. The three films "Farmer to farmer" are appreciated by practitioners and extension workers. This is illustrated by their actual utilization at farm schools and by the elevated number of downloads on Youtube. The longer documentary film "Summertime" is appreciated by both, city dwellers who still identify with traditional mountain farming practices as part of their national identity, and by rural communities who appreciate the consideration of their daily reality by modern research and communication techniques.

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Precision Pastoral Management System: Automated 'Big Data' Analysis for Pastoral Properties

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Key words: Technology, decision support systems, precision agriculture

Introduction

The beef industry of Australia continues to search for technology that can increase production and reduce operating costs. Beef producers in Australia's rangelands manage an average of 7000 head of cattle over 2000 km^2 with 6.6 labour units (MLA 2015). To date, collecting and analysing objective data on pasture and cattle performance is done by few beef producers. Hamilton and Banney (2011) reported that 76% of northern Australian beef producers complete no written forage budget. Undertaking regular monitoring of cattle and rangeland pasture is currently expensive, time consuming and requires skills and knowledge that are not readily available in the remote parts of the country. A tool is needed that can provide accurate, objective data on rangeland cattle and pasture production. The Precision Pastoral Management Tools (PPMT) project has spent the past five years developing a cloud-based software system, the Precision Pastoral Management System (PPMS), to address these needs. The PPMS can remotely monitor and analyse cattle and pasture production without any labour or skill inputs from beef producers.

Materials and Methods

A review was undertaken of 60 mapping and modelling technology products, with 34 shortlisted and four selected for inclusion in the PPMS. The four technology products selected were the Google Earth mapping platform, the Queensland Government's pasture modelling program GRASP, Landgate's NDVI program Pastures from Space and Precision Pastoral's RLMS (automated weighing and drafting unit). The PPMS prototype was built to receive automatic and manual data from third party providers. This prototype was reviewed by beef producers, and their feedback was incorporated into the 2013 version of the PPMS. The PPMS 2013 version was applied to five commercial cattle stations in 2013 and 2014 for research and development.

The project has undertaken quantitative and qualitative research methods, driven by an action learning process. The quantitative research concentrated on validating the pasture data products used in the PPMS. The qualitative research focused on reviewing if and how the data have been used by the beef producers and documenting improvements that could be made. The qualitative research has involved semi-structured interviews held with each of the station managers at the start, middle and end of the research phase. The research is ongoing; therefore preliminary data are reported in this paper from Glenflorrie Station, run by the Grey family.

Results and Discussion

Quantitative research has focused on validating the NDVI values and correlating them with observations from cattle station paddocks. The correlation between observed green cover in the paddock against measured NDVI found that r^2=0.7909. This regression provides beef producers with the confidence that the NDVI trends accurately reflect the condition of the pasture.

Five existing stations have been using the PPMS since 2013. Based on the interviews conducted in the first year of using the PPMS, all beef producers were hesitant to use the data to make decisions as they were still evaluating the accuracy of the system. Glenflorrie Station in Western Australia is the only station to have completed its research phase.

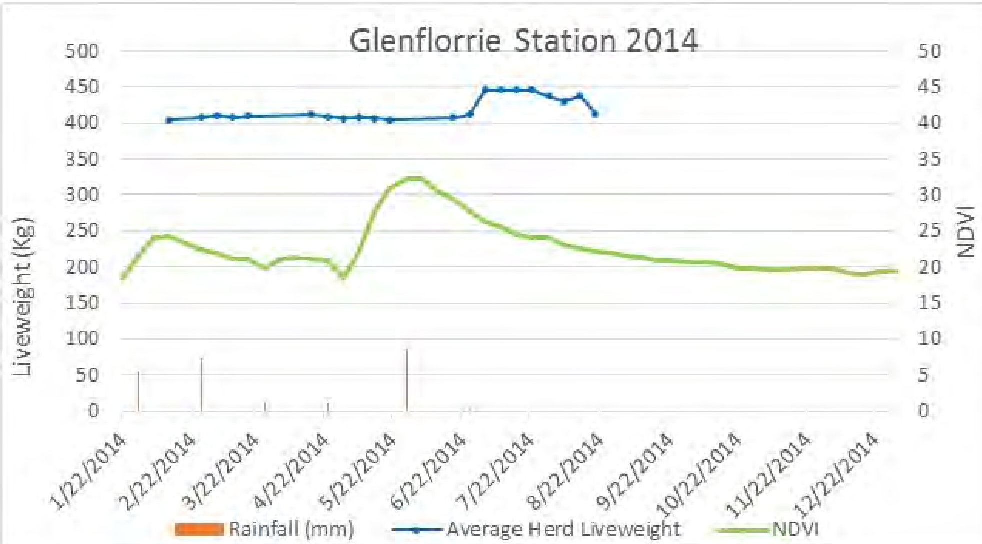

Figure 1. Data output from the PPMS at Glenflorrie Station in 2014, including average herd liveweight, NDVI and rainfall

The use of the PPMS at Glenflorrie Station has provided significant learnings for the Grey family. In 2014, the PPMS identified pasture quality declining from the 11 June and cattle losing weight from the 30 July (see Fig. 1). The pasture quality decline was 3 months earlier than Murray Grey expected and the cattle weight decline was five weeks earlier. Mr Grey described the experience: "The PPMS was indicating that the paddock was done in July, but I thought that the paddock would hold the cattle until September. Looking at the feed from the road it seemed that paddock would be right. Once I rode through the paddock on the motorbike, I found that the PPMS was right: the feed was certainly in decline. I was overly optimistic about the paddock's capacity and I was wrong. You can't argue with the liveweight data when it starts declining; it was a fact. Had we acted when the PPMS data was indicating we would have saved ourselves liveweight, pasture and money." Mr Grey stated that preventing an average herd weight loss of 10 kg/animal would save $30/animal; across even a small herd of 400 head, this is an annual saving of $12,000. He indicated that this technology gave him more confidence to enact management decisions relating to looking after the cattle and grazing land. The use of the PPMS technology, as demonstrated at Glenflorrie Station, can offer beef producers financial benefit and can improve grazing land management and animal welfare outcomes.

After twelve months of using the PPMS prototype, all five station managers were able to identify a number of improvements needed for the system, including changes to timeliness of data and presentation of the data. These suggestions have been incorporated into the 2015 version.

Conclusions and Implications

The PPMS is a new software system that can remotely monitor and analyse rangeland pasture and cattle production for beef producers. It enables producers to make better-timed and more profitable decisions on marketing of cattle, stocking rates, supplementation and land management. The PPMS provides beef producers with data that have not required additional rounds of mustering, labour, time or skill.

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Applicability of the Grazing Response Index (GRI) to the Canadian Prairies

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Key words: Grazing Response Index, GRI, rangeland assessment, grazing management

Introduction

The Grazing Response Index (GRI) is a beneficial short term pasture monitoring tool that was developed by the Colorado State University's Range Extension and Integrated Resource Management Program as a simple and effective means of evaluating the current year's grazing impacts on plants. The GRI uses an integrated approach relating to 3 factors that are linked to a plant's response to grazing; the frequency of defoliation, the intensity of defoliation, and the plant's opportunity to grow before or regrow after, grazing. A key outcome of the GRI is that the information is immediately available to producers and land managers as they are the ones who make the observations. This timely assessment information can be used to make management decisions for the following year and can lead to changes in land management that are relatively small, but economically productive and highly beneficial. Due in large part to its simplicity of use and easily understood underlying science-based concepts, GRI has been widely adopted by ranching communities in western USA.

Agriculture and Agri-food Canada (AAFC) along with assistance from partners are exploring the applicability of the GRI in Western Canada through various projects and activities. The poster presentation will provide a summary of information and results from two research studies, a Saskatchewan demonstration project, as well as highlight the development of a GRI information fact sheet and field assessment worksheet.

Materials and Methods

Agriculture and Agri-food Canada along with interested partners have been exploring opportunities to test the applicability of the GRI to the Canadian prairies. AAFC sponsored Dr. Wendy Gardner from the Thompson Rivers University to examine the potential of using the GRI tool in management of pastures across Western Canada and to identify any potential barriers. The project involved two studies: i) The British Columbia (BC) Field Study or "Evaluating the Grazing Response Index against three key forage species in the southern interior of British Columbia", and ii) a GRI Backcasting Study or "Evaluation of Grazing Response Index in three western Canadian provinces" that uses pre-existing and new data to evaluate the GRI against long term trends in range condition across native grassland plant community types found in Saskatchewan, Manitoba and BC.

The BC Field Study involved determining how plant vigour is impacted through treatments of various frequency and intensity clippings and exploring any interactions that may occur with three key forage species. The project tested different frequencies and intensities of defoliation of bluebunch wheatgrass, rough fescue, pinegrass in the Southern Interior of BC. The design involved 75 replicates for each species and plants were clipped at an intensity of 40% and 70% removal and a frequency of a single clipping event or three clipping events conducted at one week intervals. The Backcasting Study compared GRI backcasting scores to range condition data both historical and observed to determine if GRI scoring is reflective of longer term plant community change using sites in BC (7 sites 1990 – 2012), SK (6 sites 1993 – 2012) and MB (5 sites 1983 – 2012). Historical data such as grazing reports, past range condition scores, weather data and site visits in 2010 and 2011 allowed for a building of a model to calculate GRI scores from historical data.

A project is currently underway to demonstrate the GRI on Saskatchewan pastures to facilitate forage management decisions. AAFC is a partner with Ducks Unlimited Canada and the Saskatchewan Forage Council to demonstrate and asses the GRI monitoring approach for tame pastures. The project locations are on the Touchwood Hills Conservation Ranch, 6 miles South of Lestock, Saskatchewan. There are three sites within the ranch with pastures of mixed tame forage blends and a planned grazing intensity. The treatment of this project is to apply the process of GRI evaluation to a rotational grazing system that is already in place.

Conclusion and Implications

The BC Field Study concluded that each species responded slightly differently to various frequency and intensity clipping treatments; however, the broad categories used by the GRI were a good fit. Overall, the study concluded that the GRI can be used to predict plant response in the southern interior of British Columbia.

The results of the Backcasting Study showed that although the GRI scores did not match range condition trends in all cases it did show similar trends for 12 out of 18 transects studies (67%) indicating that there is a fairly strong correlation between GRI index scores and range condition scores over time. The results indicate that the model does a good job at measuring frequency with little variation between the model and the field score. Overall the strong relationship indicates that the short term GRI monitoring tool would be a reasonable fit in western Canada. Site specific differences were noted so it is recommended that when using GRI a longer term plant monitoring data collection process should also be used.

The demonstration project assessing and demonstrating the GRI monitoring approach for tame pastures is still underway although preliminary results show it may have potential for use on tame pastures. It was noted that the GRI frequency score, which is based on native plant regrowth may need to be adjusted to take into consideration tame pastures quicker growth and regrowth. Additional observations and preliminary results will be provided in the poster presentation.
AAFC also collaborated with the creator of the GRI, Dr. Roy Roath from the Colorado State University to lead workshops in the Prairies to introduce rangeland professionals to the concepts and applications of GRI. This will be highlighted in the poster as well as a factsheet and field assessment worksheet that was created by AAFC that targets range management specialists and ranchers.

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Evaluation of Natural Vegetation and Habitat Restoration of Newly Designated Range Land Reserves in the Eastern Desert (Sahara) of Jordan

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Key Words: Jordan Range land, Eastern desert, vegetation cover, habitat restoration

Introduction

About 80% of the total area of Jordan is considered rangeland, where the sporadic vegetation cover in range land provides limited grazing for livestock. Since it represents the future expansion of the country, then it should be seriously studied and invested on a well-planned scale. To evaluate the importance of the vegetation cover to the watershed value of rangelands, the first step is to understand the ecology of plant succession of any particular area. This inventory was undertaken to evaluate botanical composition of designated sites in 3 localities in the eastern desert of Jordan that are designated as rangeland reserves, to improve the conditions of life of the nearby livelihoods and to examine possible approaches of restoration where applicable.

Methodology

The sites of prospective reserves were selected by representatives of the local communities, with accessibility to shepherds and traditional use the main factors that guided the local communities. The areas of the range lands were delineated with help of GIS maps of about 15, 6.5 and 8.5 km^2 areas, respectively, with the size of each reserve was constrained by various factors like topography and management feasibility. Major floral elements and plant communities were registered with photos and herbarium specimens were collected with full passport data as needed for identification. For survey purposes, grids of 250*250 squares were laid out over a google earth image of the area as background. On and off grids were designated for uniform distribution over the study area. In each grid, a line transect (Fig.1) of 100 m length and 4 m width, centered by the coordinated grid center point and oriented by the dominant water runoff direction in the closest wadi. On the ground, each grid center was located using the coordinates delivered from the maps by the GPS, then coordinates of each start and end of each transect were recorded. Data collected included species located within transects and number of individuals for each in addition to general information about the dominant species and status of the sampled grid images where captured. Herbarium specimens of new or unknown species were collected and pressed in herbarium press at the site with all passport data collected on a data collection sheets. As a result the following parameters were calculated:

Species Density: Number of individuals of certain species/Total area of sampling unit, species frequency: Number of sampling units of certain species occurrence/Total number of sampling units
Shannon-Weaver Diversity Index (Shannon and Weaver, 1948): Equation (1) and species richness: Number of species in certain site.

$$H' = - {}_{i}^{s}\Sigma\, pi \ln pi \quad (1)$$

Results and Discussion

As part of the Jordanian Badia, the area represents the Saharan Mediterranean bioclimate, cool variety that is prevailing in most of the eastern area of Jordan (Al Eisawi, 1996). For example, in Wadi Bayer, *Seidlitzia rosmarinus* led the rest of plants in terms of density (%) (Fig. 2) of individuals per unit area followed by *Anabasis setifera*,

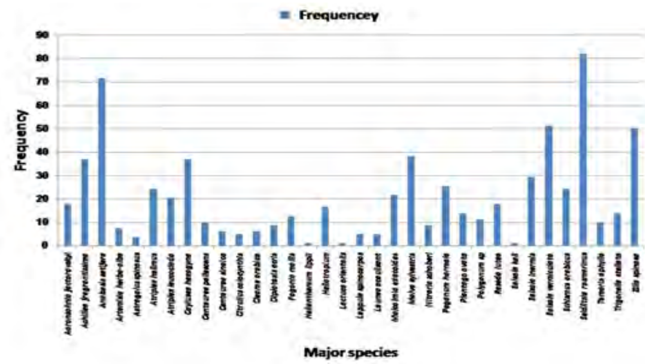
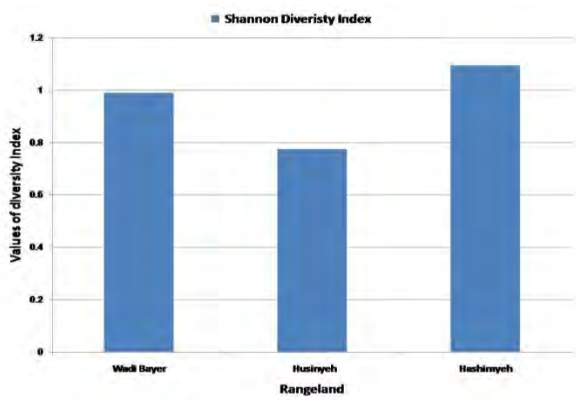


Figure 1. Sampling trasect within each grid. **Figure 2. Density of major species (%) in Wadi Bayer.**

The results of the evaluation of the vegetation cover revealed the leading species in terms of density and frequency of occurrence *Seidlitzia rosmarinus* (Fig. 2 & 3) and the implications of the various values measured along with its importance to human and grazing animals. As biodiversity indicators, Species richness reached 66 in Bayer, 99 in Husinyeh and about 94 plant species in Hashimyeh. On the other hand, Shannon index value ranged from 0.76 to 1.09 from the data collected from the three sites (Fig. 4). Restoration of the habitats using pitting and/or micro-catchment approaches is being applied for the first time in Jordan in 2 of the sites by direct seeding of natural plants, because of objection of the local community; the restoration of the 3rd reserve (Bayer) was postponed.



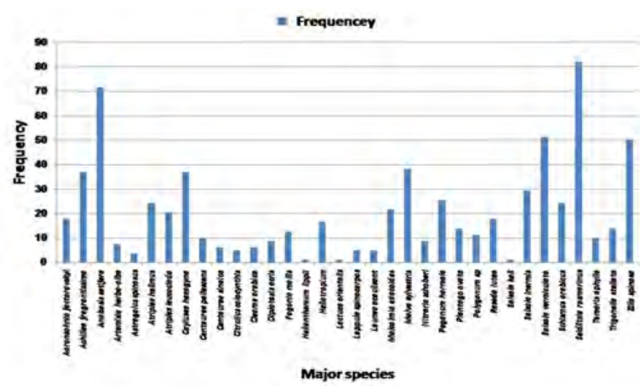


Figure 3. Shannon index of the 3 designated rangeland sites surveyed.

Figure 4. Restoration of habitat by re-planting native species.

Conclusions and Recommendations

Wadi Bayer has such a unique floral composition forming unique plant communities of tall woody shrubs like *Tamarix* and *Lycium sp* that is not represented elsewhere in the Easter Desert of Jordan (Al-Eisawi, 1982). In Al-Husineyeh site *Salsola intermis* leaded the species density and frequency, whilst *Anabasis articulate* was the highest in Al Hashymeh reserve in terms of both parameters measured, however, disturbance was clear in many localities in both of the latter reserves. For all reserves it is recommended to have range land management plan applied rather than strict prohibition, this could be done by regulating grazing activities to be in harmony with floral phenology. Application of micro-water harvesting technique coupled with sound biology and community support can result in re-vegetation of denude land. For the first time in Jordan restoration of the habitats is being applied in the eastern desert and the planted seeds are being monitored for their first growing season, such work could be the start of restoration of desert ecosystem in Jordan.

Acknowledgement

Funding for this research came from the Hashemite Kingdom of Jordan/Badia Ecosystem and Livelihoods Project (BELP)/The World Bank/Global Environmental Facility (GEF).

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Influence of Methodology on the Potential Ranking of Ryegrass Types When Assessing Their Relative Value under Grazing

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Key words: Ryegrass, grazing, measurement, management.

Introduction

Introducing new plant germplasm is one mechanism to improve productivity of rangeland. Part of the decision making process is to understand the relative value of new germplasm when compared to alternatives. For example, many ryegrass cultivars are available, ranging over many morphological types, from leaf width, tiller density, ear emergence date, endophyte type and ploidy. The performance of these types depends on the environment and grazing management imposed. The grazier relies on relative production data measured in various plant screening and agronomic comparisons to make a choice to meet the needs/requirements of their grazing systems.

Agronomic evaluations under grazing, rather than cutting, provide the most meaningful data for the grazier. However, often grazing is applied to experiments en-masse without separation of different types for individual management (Lynch, 1966). Two assumptions were made: i) a similar grazing intensity is applied to all cultivars irrespective of type or characteristic (Burns et al., 1989), and ii) the post grazing response is representative of that cultivar in all situations (*e.g.* when different residuals are left after grazing). This paper describes the first year pasture production of different ryegrass types and examines those assumptions.

Materials and Methods

An experiment comparing the relative production of four ryegrass (*Lolium perenne*) types sown as monocultures under a cafeteria grazing design (where animals have access to all plots at once) was conducted in southern New Zealand (46°23’ S, 168°35’ E, 40 m asl). The climate is described as cool temperate with mean winter and summer temperatures of 9°C and 13°C respectively, with an average annual rainfall of 1135 mm, with a summer maximum. The soils are a Brown silt loam of moderate to high fertility (pH = 5.9, Olsen P = 32 µg/ml, K = 0.42 me/100g). Ryegrass was seeded in early summer (December) 2012 on a plots of 10 x 10 m and managed under rotational grazing by two-year-old steers. Annual yield and post grazing residue were measured. Pastures were grazed when the average pasture cover reached approximately 2500 kg DM/ha with the aim to leave approximately 1400 kg DM/ha as a post grazing residual. Grazing duration was 1-2 days and regrowth interval was 3 to 10 weeks depending on pasture growth, with longest intervals in the winter. Pastures were measured before and after grazing using a calibrated rising plate meter. Analysis of variance and regression analysis that compared the annual pasture production with the post-grazing herbage residuals for individual ryegrass types were provided in Table 1 and Fig. 1, respectively.

Table 1. Ryegrass Types and Average Annual Yield for the First Year after Sowing.

Type	Habit	Ploidy	Ear emergence date (relative to 22 October)	Annual yield (kg DM/ha) LSD=478
A)	Open	Tetraploid	Late (+25 days)	11,620 a
B)	Open	Diploid	Mid (+1 day)	10,260 b
C)	Dense	Diploid	Late (+14 days)	11,340 a
D)	Dense	Diploid	Late (+15 days)	9,810 b

Presented here are two examples of those responses, to illustrate a potential problem when using an open grazing design that allows animals the opportunity for selective grazing. The four ryegrass types chosen here are described in Table 1 and encompass a range of leaf and tiller type, ploidy and ear emergence date. Ryegrass types are paired for comparison. Two cultivars of similar type but different ploidy (A, B) and two cultivars with similar type and ploidy (C, D) provided two distinct examples of responses that varied significantly from the average result.

Results and Discussion

Regression analysis showed two different responses when paired for comparison.

Two examples here demonstrate different responses. The first (Fig 1a) strongly supports the general principle that selectivity is not present and that each cultivar responds similarly across a range of post-grazing residuals. Type A produced significantly more pasture than type B (Table 1) across similar ranges of post-grazing residual. The lines are parallel and clearly different. This anticipated response in a cafeteria grazing design provides the grazier with confidence that type A is superior to type B.

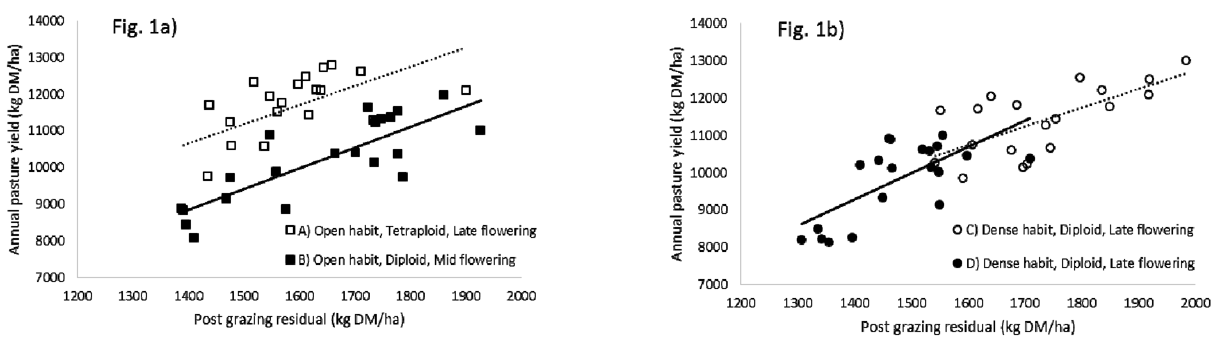

Figure 1. Examples of Two Types of Result from a Cafeteria Grazing Experiment to Test the Relative Responses of Different Ryegrass Types to Cattle Grazing.

The second example (Fig 1b) demonstrates a response that may be related to selective grazing differences between two ryegrasses of similar type. While response also shows that type C produced more than type D (Table 1), the graphical representation (Fig 1b) suggests that the response may be generated by a difference in the post-grazing residual. The fitted lines, while having a similar slope, may be viewed as continuations of one another. This may demonstrate a difference in grazing preference between the two types. Differences such as pseudostem strength, feed quality, endophyte type or status may play a role in these differences. Unfortunately the grazier and the researcher is unable to make a firm decision on the use of either type. Are there other factors playing a role in grazing preference or are the differences in production actually true to type? Would type D, with a lower yield, grow more if the post-grazing residual was higher? These questions remain unanswered by this type of cafeteria style grazing evaluation.

Conclusions and Implications

Cafeteria style grazing evaluations provide a means of evaluating many different grasses in a relatively economical way. Researcher must investigate their data to determine if animal selection is present, to ensure relevance for the grazier.

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New Technologies and Knowledge-Sharing for Improved Pasture Management in Central Asia

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Key words: Knowledge management, information sharing, pasture management, K-Link technology

Introduction

Livestock is the mainstay of agricultural production in Central Asia, providing the income to approximately half of the population. In total, an estimated 72% of the surface area in the region consists of grazing lands. In recent times, overgrazing and breakdown of migratory grazing systems have led to degradation of pasturelands. The increasing impact of human economic activities has caused a massive depletion of grazing lands. Pastures, as specific ecosystems, are not only a place for livestock grazing, but serve also as habitat for a variety of wildlife. Thus pasture condition affects the quality of other benefits provided by these ecosystems. Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), together with governmental partners in all five Central Asian countries, aims to modify laws and regulations, and to reform public agencies working in pasture use and management. The principles of sustainable development, which promote both ecological stability and the generation of long-term socially equitable economic benefit, are guiding our work.

Many of the countries covering Asia's vast temperate and arid rangelands have undergone a revolution in pastoral land tenure over the past twenty years, moving from state-led pasture management to forms of individual or common property systems. Although the political context in each country is very different, the issues which they face are remarkably similar and include the reconciliation of aims such as wealth creation, provision of access to poorer users and environmentally sustainable management. Reform processes are constantly evolving in all Central Asian countries. Twenty years into reform, the potential benefits of experience sharing have never been greater. Globally, our understanding of rangeland systems and their users, and theories of property rights which reflect the needs and practices of those users, have also evolved enormously in recent years. The challenge is to apply these approaches to Central Asia and to disseminate new lessons learned within region.

Photo 1. Practitioners' Conference – Launching of the network in 2014 ©GIZ.

Methods

The GIZ Regional Programme for Sustainable Use of Natural Resources in Central Asia supported the idea of creating a regional pasture network as a platform for exchange of information. The network is comprised of both individual practitioners and representatives of organizations and projects from the five Central Asian republics (Kyrgyzstan, Tajikistan, Uzbekistan, Kazakhstan, and Turkmenistan), China, and Mongolia working in pasture management, but also in forest and wildlife management where these interact with livestock production activities on pastures. Working languages are Russian and English. The network links ongoing initiatives and share information and knowledge about them.

All members of the network can successfully and freely exchange information by using modern online tools such as K-DMS and K-Link: A constantly updated library of key documents is made available through the K-Link Network for sharing and managing knowledge on natural resource management and climate change in Central Asia (https://eba.klink.asia/dms/projects/pasture-network). This tool offers accelerated document search, retrieval and publication on a distributed network of institutions in English, Russian and German languages. Using the K-Link technologies, members of the Regional Pasture Network will manage their documents on both internal and external levels, accessing relevant material in the K-Link Network and directly contributing to it.

The K-Link Network currently orchestrates between knowledge platforms of the University of Central Asia's knowledge hub, the Kyrgyz NGO CAMP Alatoo, Central Asia Regional Ecological Centre (CAREC), the Kazakhstan NGO Karaganda Ecomuseum, and the Kyrgyz State Agency for Environmental Protection (http://klink.asia).

While K-DMS and K-Link help users to find and access documents, a Facebook page is utilized for the discussion of common issues and the exchange of views and news in real time between the members of the regional pasture network. Additionally, regular newsletters and Facebook is used to compile contributions from network members on upcoming events and courses, new publications and reform developments, with links to sites and publications.

Photo 1. K-Link Technology © GIZ

Results

Through the development of capacity, transfer of knowledge, and sharing of reform experiences amongst the individual members and organizations in Central and Inner Asia a sustainable and professional pasture management platform is set up that helps to improve the management. Hereby it plays a catalytic role in scaling up successful models and approaches.

Conclusion

To promote the exchange of experience and expertise in pasture management in Central Asia, China and Mongolia a regional pasture network was created. This enhances national capacities and helps disseminate successful models and approaches across the region. The members of the network can easily access and explore new technologies and techniques, share successful experiences and lessons learnt, accumulate knowledge and use this knowledge in practice, taking into account local environment and climate change. Thus, participants are able to improve the management and use of land resources in Central Asia.

7.5 Technology in fencing, water supply, and livestock health

Holistic Management in a Semiarid Patagonian Sheep Station: Slow Grassland Improvement with Animal Production Complications

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Key words: Grazing systems, short-duration grazing, rangelands, sheep management, semi-arid grasslands.

Introduction

Most of Patagonian stations have been grazed continuously using high, fixed stocking rates for over 100 years, and degradation of rangelands is widespread. Improved continuous grazing systems with lower stocking rates that track forage offer good individual animal production and stop degradation, but recovery of the rangelands is slow and preferred areas are still heavily impacted. Holistic management systems (Savory and Parsons 1980) that generate grazing pulses by concentrating animals in flexible rotational schemes and enable long periods of rest, have been proposed as a way to regenerate rangelands and recover the secondary productivity. We analyzed the experience of a real station that applied holistic management under the hypothesis that it would improve forage production and plant diversity, while maintaining sheep production.

Materials and Methods

Los Pozos sheep station is located in cold semi-arid tussock grasslands of the Magellan Steppe (239 mm mean rainfall), south Patagonia, Argentina. The northern area of the station, comprising 14.387 ha (receptivity 5053 sheep), in comparatively shallower soils and poorer range condition, was converted to holistic management in 2011. A single flock of 3460 sheep grazed a 5-paddock cell. Each paddock was grazed annually in two periods. Duration of grazing was adjusted in relation to forage offer, with a mean of 30 days. The rest of the station, with 12.820 ha of comparatively better soil conditions (receptivity 5958 sheep), remained under continuous grazing with 4872 sheep. Stocking rates in both areas were low, variable and adjusted annually to forage offer. Forage was evaluated annually across all paddocks since 1990 (Oliva et al 2013) by clipping short grasses, graminoids and forbs in twelve 0.2 m^2 samples (n=60 samples per treatment) per paddock at peak herbage mass (data prior to 2005 not shown). Vegetation cover and diversity was estimated using five 100 point-intercept lines in each treatment in 2009 and 2014. Body condition and weight of 100 sheep per treatment (Holistic and continuous grazing) were assessed twice a year.

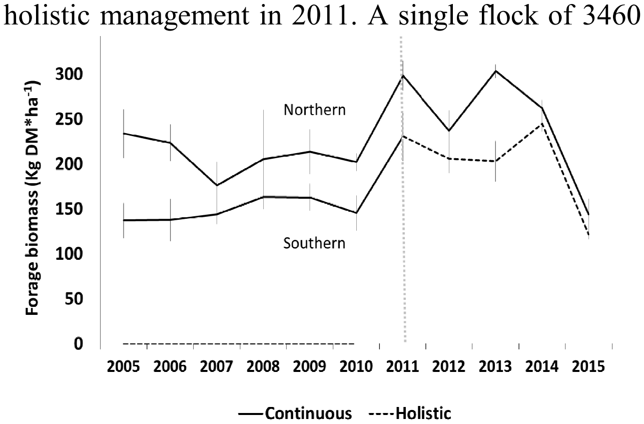

Figure 1. Forage biomass (2005 to 2015) in northern and southern areas of the station. Vertical line marks the beginning of the period with holistic management in the southern area.

Lamb marking rate (%) was estimated from lambs marked (January) vs ewes mated (May of the previous year).

Results and Discussion

The northern area of the station showed lower forage production under continuous grazing in the 2005-2010 period (Fig 1). It did not improve under holistic management. The southern area remained under continuous grazing and showed higher or similar values of forage. Drought in 2015 affected the areas under different management in a similar way. Vegetation cover increased close to 25% (from 56,6 to 71,2%) in the area under holistic management (Fig 2). Main increasers were short grasses *Poa spiciformis* (that gained 50% cover), *Festuca magallanica* (+10%) and *Carex andina* (+33%), and dwarf shrubs, while dominant tussocks of *Festuca gracillima* decreased (-14%). Species richness remained unchanged (31 sp), and the Shannon Weaner index increased from 23,8 to 25,6. Under continuous management cover increased 5% (from 71,6 to 75,6%), mostly by increment in dwarf shrubs, with reduced short grass cover. Tussock cover remained unchanged. Species richness increased 30% under continuous grazing (25 to 31 sp), and the SW index increased 20% from 21,7 to 26,1. Animal production fell under holistic management: Ewes had 18% less liveweight (51,7 continuous vs 43,9 kg holistic) (Fig. 3) and scored 29% less in the condition assessment (2.2 vs 1.6). Lamb marking rates, that were 86±7% during the 2005-2010 period, fell to approximately 60% under holistic management in 2012-2014, while those that remained under continuous grazing reached 70%.

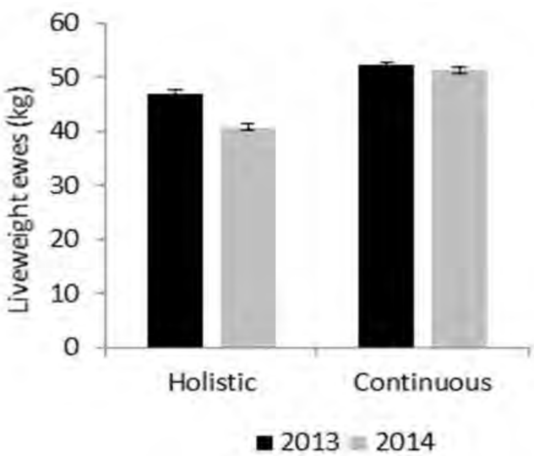

Figure 3. Liveweight of two groups of ewes after shearing in 2013 and 2014.

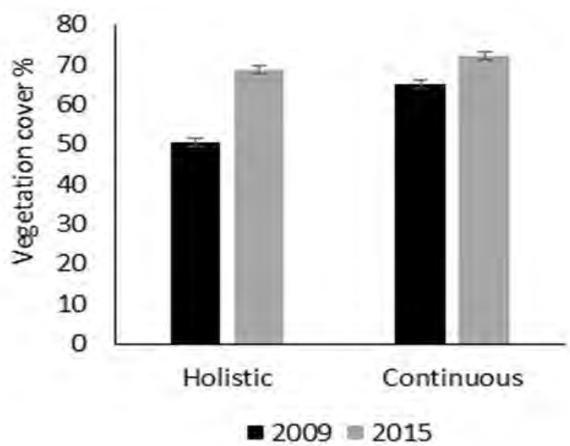

Figure 2. Vegetation cover in 2009 and 2015 estimated by line intercept with MARAS monitors.

Conclusions and Implications

This is one of the few study cases of conversion to holistic management that shows a long historic record of animal performance and range evaluations. Comparisons should take into account that although stocking rates in holistic and continuous areas were regulated in order to assure a similar forage allowance, the northern area has poorer soils and rangeland productivity, and Guanacos, native herbivores, exert in this area a considerable additional grazing pressure. Results indicate nevertheless that long periods of rest induced buildup of short, palatable grasses, an increase that did not reflect in the forage offer at the paddock scale, probably because drought conditions restrained growth. Ewes under holistic management lost bodyweight and corporal condition. Lamb marking rates in 2011-2015 fell at the station scale, probably due to changes in sheep breeds and drought conditions, but the flock under holistic management showed a sharper decline. Holistic management seems to have induced a slow recovery of the rangelands that did not reflect in forage offer, but at the same time, rotation generated loss of animal production. The combination of increased costs and less production indicates that the possible range improvement generated by holistic management comes at a cost and needs determination and a long-term view that is not common.

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Efficacy of Garlic and Neem Seed Extract as Control over Gastrointestinal Parasites in Goats Grazing on Rangeland

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Key words: Parasitism, Caatinga ecosystem, organic meat.

Introduction

One of the most common problems of the small ruminant industry in northeast Brazil is gastrointestinal parasites on rangeland systems. The farmers often use high levels of conventional anthelmintic, increasing the cost of production and resistance of parasites, as well as restricting production of natural products.

Currently, organic producers lack an effective natural product to control gastrointestinal parasites, especially for goat herds. The use of garlic (*Allium sativum*) and neem (*Azadirachta indica*) has been suggested as an herbal product to protect against gastrointestinal parasites (Allen et al., 2007). However, little is known about the efficacy of these products for goats in grazing systems.

By mixing anthelmintic in feed blocks animals will be dewormed continuously; resulting in economic benefits to farmers such as, labor reductions Supplementating feed blocks has been largely utilized for goats in Africa and the Middle East, showing good results when adding anthelmintic agents to control internal parasites. This research evaluated the effectiveness of garlic and neem seed extract, acting as an anthelmintic mix in feed block to the control of intestinal parasites of goats grazing on the rangeland (Caatinga ecosystem – Paraiba state - Brazil).

Material and Methods

The study was carried out using 40, 5 mo old native males goats, non-castrated with an initial body weight between 18 and 20 kg. Before start of the experiment, all animals were diagnosed with moderate nematode faecal egg counts (EPGs> 1000). The treatment consisted of the inclusion of herbal anthelmintic in the feed-blocks. Two plant species with anthelmintic properties were evaluated, the neem (Azadirachta indica) and the Garlic (Allium sativum L.) seed extract were mixed with feed blocks.

The animals were equally divided in four treatments: T1 = Control feed blocks without anthelmintic; T2 = 1.5% Neem seed extract; T3 = 3.0% Neem seed extract; and T4= 2% Garlic seed extract. Feed blocks had the following composition: 20% molasses, 5% urea, 16% corn ground, 26% soybean, 10% salt, 10% hydrated lime, 5% limestone, 3% mineral mix and the percent of each plant seed extract Allen (2007).

The animals grazed/browsed in a rotational grazing system over 60 d during the wet season (January and February 2015) in a scrubland with vegetation similar to Caatinga ecosystem in paraiba state northeast Brazil. Faecal samples were collected from all animals in the morning and animals were weighed to measure weight gain in each 14-day period.

The feed blocks were weighed and offered to animals each week in addition to any block remnants from the previous week. Fecal samples were subjected to the McMaster faecal egg counting technique where 3 grams of faecal sample were prepared for infective larval recovery and differentiation of the nematode species according to procedures described by Coles et al. (1992). The experimental delineation was a complete randomized blocks design, including 10 replicates per treatment. The data were subjected to analysis of variance and the means were compared by Tukey ($P < 0.05$).

Results and Discussion

Herbal extracts did not affect the final body weight, daily weight gain, or feed block intake ($P>0.05$) (Table 1). These results differ from those reported by Nolte and Provenza (1992) who found that the addition of garlic in the Goat performance in a grazing system supplemented with herbal anthelmintic. goat diet decreased the supplement intake.

Table 1. Goat performance in a grazing system supplemented with herbal anthelmintic.

Variables	Control	1.5% Neem seeds extract	3.0% Neem seeds extract	2.0% Garlic extract
Final body weight (kg)	26.60	26.90	26.40	26.35
Daily weight gain (g d^{-1})	90	70	60	80
Feed block intake (kg d^{-1})	0.128	0.135	0.106	0.150

Means without letters are not significantly different ($P\leq0.05$)

The herbal extracts were efficient in controlling parasites *Eimeria* and *Strongyloides* ($P<0.05$). Although the 1.5% Neem seed extract seems to be effective in the control the *Moniezia* species, however, the means were similar among treatments ($P>0.05$).

Table 2. EPGs **of goat in a grazing/browsing system supplemented with feed blocks added herbal anthelmintics*.**

	Control	1.5% Neem seed extract	3.0% Neem seed extract	2.0% Garlic extract
Eimeria *spp.*	62.22 b	30.43 ab	13.95 ab	4.08 a
Moniezia *spp.*	6.67	1.25	12.22	6.73
Trichostrongylus *spp.*	81.93	55.45	78.77	53
Strongyloides *sp*.	208.89 b	95.45 ab	86.05 ab	55.10 a

*Means without letters are not significantly different ($P\leq0.05$) ** EPG = Faecal egg counts

The herbal medicine did maintain low levels of EPGs in the goats. However, they were not successful in eradicating all parasites (Table 2). Burke et al. (2009) affirm that herbal medicine must be a complementary treatment concomitant with conventional drugs and rangeland management practices in the control of parasites. Reducing the use of conventional drugs is a sustainable practice because it may decrease the risk of parasite resistance and assures low drug levels in the products from these systems of production.

Conclusion

The neem and garlic are effective as a complementary treatment to reduce the use of conventional drugs in the control of gastrointestinal parasites such as *Eimeria* and *Strongyloides* in goats grazing in the Caatinga Ecosystem.

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Aboveground Biomass Study Results of Eastern Mongolian *Stipa grandis* Community

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Key words: Dry steppe, precipitation, grazing, fenced area

Introduction

Steppe is the most common vegetation type in Mongolia and covers 1.035 million km which is 66.1% of the total area of the country (Tuvshintogtokh, 2014). A monitoring survey could help find ways to prevent degradation of vegetation, support sustainable use of pastureland, and develop robust methods for restoration of degraded areas. Here we report on a long-term monitoring survey comparing open pastures and fenced areas within the Eastern Mongolian steppe from 2009 onward. *Stipa grandis* is the dominant plant species, with subdominants of the grass-*Leymus chinensis*, the sedge-*Carex korshinkyi*, and several forbs-*Serratula centauroides*, *Polygonum divaricatum*, and *Thalictrum squarrosum* (Mandakh, 1999). Our first objective was to determine the above-ground biomass (AGB) of lifeforms and primary species in the *Stipa grandis*-forb community, and second to reveal the effects of precipitation and grazing on AGB. While 2010 was dry, 2009, 2011, and 2012 had normal rainfall, and 2013-2014 was humid. During this time, livestock numbers increased from 109,006 to 180,238 head (Khongorzul, 2015).

Study method

This study was conducted at the Tumentsoght station of the Sukhbator aimag, within a 100*100 m area fenced to prevent grazing. We measured AGB within 3 randomly placed 1x1m quadrats from 30th June to 20th August each year. Samples were oven-dried at 85°C for 24 h and weighed to assess dry mass. Then we classified the total AGB into shrub, sub-shrub, perennial and annual-biennial forb classes using previous literature (Tuvshintogtokh, 2014).

Results

Seasonal accumulation of AGB differed among years, but reached a peak 20th of July in 2010, and 20th of august in 2012, as well as reached 10th of august at the other years. Also it reached peak between 30th of July and 20th of August in the fenced areas (Fig. 1).

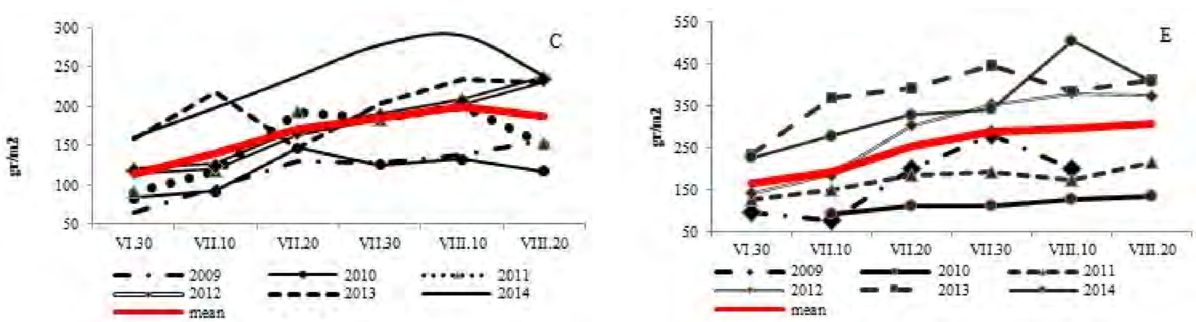

Figure 1. AGB production dynamics of *Stipa grandis*-forb community (2009-2014); C grazed, E fenced.

AGB of sub-shrub, perennial forb and grasses increased significantly, with shrub and *Allium* AGB decreasing from 2009 on within the non-fenced area. Annual-biennial plants decreased after 2009, but again increased in 2013-2014 (Fig. 2). Biomass of sub-shrub, perennial grass and forb AGB increased in fenced areas, while annual-biennial forb biomass decreased, and that of shrubs, perennial sedges and *Allium*s didn't change (Fig. 2). However, biomass of the dominant perennial species significantly decreased, while *Leymus chinensis* and *Cleistogenes squarrosa*'s biomass increased, and *Stipa sibirica* changed little from 2009 onwards. The sub-shrub *Artemisia frigida* and perennial forb-*Serratula centauroides* both increased in AGB, while the perennial forb-*Polygonum divaricatum* was stable after 2009. Notably, the AGB of species within the fenced area changed little from 2009 to 2015, and only *Serratula centauroides*'s AGB increased (Table 1).

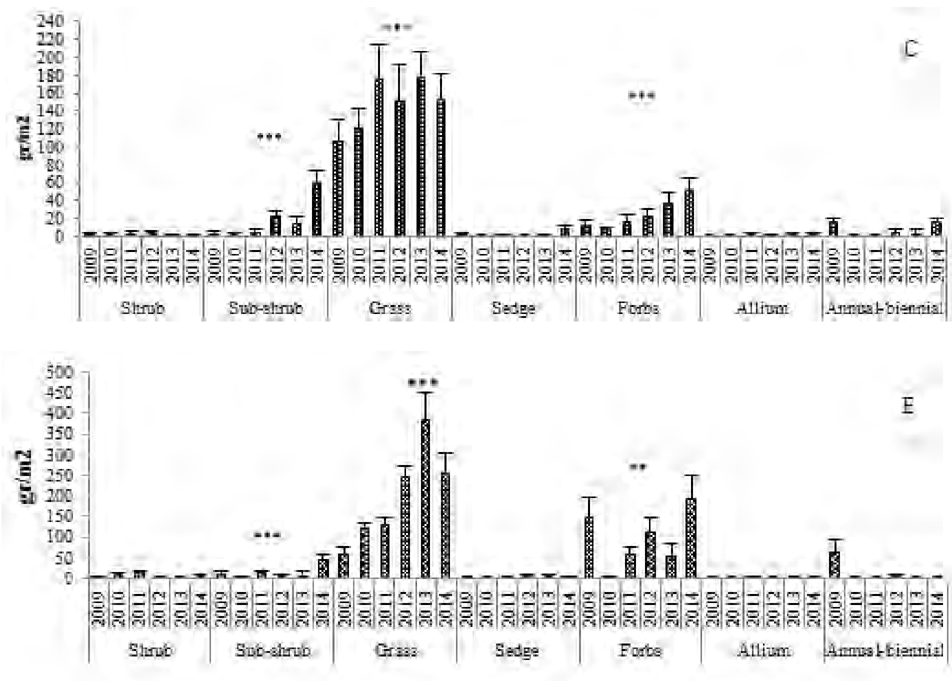

Figure 2. Changes in community AGB by life-form, C grazed, E fenced.
(Significant F-values are labeled:
* denotes P<0.05,
** denotes P<0.01,
*** denotes P<0.001)

Discussion

The effect of increasing livestock numbers and wet years was to decrease *Stipa grandis* AGB, but increase *Leymus chinensis*. *Stipa grandis* is drought tolerant, but grazing intolerant (Chognii, 1981). *Leymus chinensis* is an indicator species of light to moderate grazing (Tuvshintogtokh, 2014), and is a grazing tolerant (Chognii, 1981) rhizomatous grass (Jigjidsuren, 2005). In the absence of grazing, favorable precipitation increased community AGB 1.5 times, and the meso-xerophyte perennial *Serratula centauroides* increased. Grazing also increased *Serratula centauroides* AGB, indicating this species is grazing tolerant (Chognii, 1981). Responses of *Artemisia frigida* suggest vegetative regeneration is high for this species due to many vegetative buds. This species is grazing tolerant and can help maintain range condition (Jigjidsuren, 2005). According to the survey *Artemisia frigida* increased under grazing, results similar to elsewhere (Xie Y, 2007; Tuvshintogtokh, 2013).

Table 1. Aboveground biomass (g/m^2) of selected plant species; C-grazed, E-fenced.
(SG-*Stipa grandis*, SS-*Stipa sibirica*, LC-*Leymus chinensis*, CS-*Cleistogenes squarrosa*, AF-*Artemisia frigida*, PD-*Polygonum divaricatum*, SC-*Serratula centauroides*)

Year	Area	AGB	*SG*	*SS*	*LC*	*CS*	*AF*	*PD*	*SC*
2009	C	**157**	88	8.8	17	4.7	**0.3**	3.5	2.5
	E	**282**	14	11.8	18.5	0.6	7.7	140	1.1
2010	C	**132**	109	1.2	7.7	2.6	1.7	3.5	1
	E	**124**	52.7	11.2	22.1	4	0.6	0	0.01
2011	C	**202**	160	3.9	9.4	2.1	2.3	6.1	2.6
	E	**216**	38.4	33.2	48	2.6	12.2	46.3	1.3
2012	C	**234**	135	20.6	22.2	2.3	9	3	8.2
	E	**381**	64.4	20.9	127	6.7	4.3	73.8	10
2013	C	**235**	92.2	36.6	29	2.9	13.2	0	7.3
	E	**448**	29.5	27.7	299	1.4	0.36	41.4	9.2
2014	C	**290**	57.2	18.7	55.1	5.5	**58**	2.7	26.9
	E	**507**	47.4	60.1	139	3.4	46.6	101	23.7
mean	C	**208**	106.7**	14.9	23.3***	3.3***	14.1**	3.1	8**
	E	**326.2**	41	27.4	108.9	3.1	11.9	67.1	7.5*

Conclusion

The community biomass accumulation reach a peak in early August. Precipitation stimulate the *Stipa grandis* community AGB in dry steppe, also long term grazing modify the palatable species (*Stipa grandis*) to lower quality species. The fenced protection of *Stipa grandis* community in dry steppe leads to increase of rhizome species (*Leymus chinensis, Artemisia frigida*). Finally, *Stipa grandis* community is moving to the *Artemisia frigida* community the effect of long term grazing.

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Driving Miss Daisy: Factors Controlling Sheep Behaviour in Australian Grasslands

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Key words: GPS, data modelling, native grasslands, improved grasslands

Introduction

The use of a range of technologies such as the Global Positioning System (GPS), accelerometers and multispectral spectroradiometers have vastly improved our understanding of spatial distribution, foraging patterns and behaviours of wild and domesticated animals. The aim of this paper was to investigate the grazing behaviour of sheep in native and improved pastures and how they may vary seasonally in response to changes in number of important landscape factors.

Materials and Methods

In this study, Merino sheep were used to ascertain differences in behaviour on Native or Improved grasslands in the Monaro region of southern NSW, Australia. This region is high altitude (~900 m) with native grasslands and improved pastures roughly evenly divided in area. Introduced grasses are commonly sown in this area due to their increased production during the winter months (when low temperature and reduced rainfall greatly reduce forage production) as well as generally higher forage quality. The Native grasslands consist primarily of native *Poa* spp. and *Stipa* spp. along with Barley grass (*Hordeum leporinum*). The Improved grasslands consisted of the introduced grass species, Phalaris (*Phalaris aquatica*), Fescue (*Festuca* spp.) and sub-clover (*Trifolium subterraneum*). Improved grasslands Median rainfall is 520 mm with a mean maximum temperature of 26ºC in January and mean minimum temperature of -2ºC in July.

The study took place during the seasons of Autumn (April), Winter (July), Spring (November) and Summer (February). A mob of 25 wethers, of which between 10-15 wethers (per treatment) were fitted with UNETacker II GPS tracking collars, were placed in each treatment paddock (Native vs Improved) for a seven day period. The GPS collars were programed to 'sleep' for four minutes and wake up to take five positional 'fixes' over a minute. Prior to the initiation of each trial, the Normalized Difference Vegetation Index (NDVI) of both paddocks was determined using a CropCircle ACS-470 (Holland Scientific). The NDVI and elevation data were then krigged using VESPER software (Minasny 2005) to produce a NDVI and Elevation map for each paddock. Paddock boundaries, trees and water trough determined in both pastures prior to sheep grazing them in each season. Data was imported into ArcGIS (Ver. 10.1) in order to determine relationships between GPS fixes and the other variables measured.

Distance travelled was analysed using REML (Genstat). We used Random Forest modelling in the "Rattle" package (Williams 2011) in R (R Core Team 2015) to determine the impact NDVI, elevation, day, hour, speed, distance from trees and distance from watering points had on the spatial distribution of sheep across different grassland types and season.

Results and Discussion

The use of Random Forests produced models in which the predictors explained > 90% of the variation in sheep location. Across all three seasons for the improved grassland, the three most important factors in determining the location of where sheep would graze was generally (in order of importance) the distance from a tree, the distance from water and NDVI. This makes sense in the context of this paddock where tree cover was somewhat sparse and sheep would be seeking shelter either due to cold winds (prevalent during Winter) or shade in the warmer months (Spring, Summer). Likewise the distance to water was also equally important as might be expected. In the Native grasslands, the three most important predictors (in order of importance) were NDVI, distance to water, and distance to trees. In this case the distance to trees is probably of little less value as a predictor of sheep behaviour as the paddock had a much greater density of trees and thus it was almost impossible for sheep to not be around them.

The use of NDVI as estimator of pasture quantity and quality did not provide as good a predictor as might have been expected. This may be explained in a number of ways. In the first instance, that fact that a sheep was recorded as being present in an area of "low" NDVI may be explained in that they were simply walking through this area and weren't necessarily grazing in this 'low' NDVI zone. Moreover in Native grasslands, the NDVI signal is often confounded by large amounts of standing senescent material while there may well be higher quality forage underneath these perennial tussocks. That said, during winter when pasture quality is greatly reduced in both Native and Improved pastures, NDVI was the strongest predictor of location in both grasslands.

While across all Season/Grasslands, sheep in the improved grassland travelled (6,403 m) significantly more than in the Native grassland (5,488 m). The extra distance travelled by sheep in the improved paddock was significantly and consistently greater across all seasons and greatest in Winter (7,278 m, Improved vs 6,055 m, Native) and least in Summer (6,668 m, Improved vs 6,122 m, Native) but were not significantly different between grasslands. We had originally hypothesised that sheep in the native pasture would spend more time (and thus travel greater distances) searching for better quality forage. However our results seem to suggest that sheep in Native grasslands grazing poorer quality native grasses are probably consuming forage until they get "gut-fill" and then are spending more time standing/laying down in order to ruminate, which results in a reduced amount of travel. In contrast, due to higher quality forage available in the improved grasslands, sheep are able to more quickly digest grazed material and thus spend more time grazing (travelling). This is further supported by increased weight gains by sheep grazing in improved grasslands relative to Native grasslands.

Conclusions and Implications

This research indicates that a relatively few number of factors can be used be to explain an animal's location on the landscape. The use of powerful but simple to use and freely available software such as Rattle / R will start to give us better tools to further our understanding of animal behaviour. In spite of these advances, while we are greatly able to understand where animals are in the landscape using GPS collars, we still need better tools that are able to determine more accurately forage quantity and quality.

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Diet Composition and Nutrient Uptake of Cattle in a Pasture-Forest Combining Grazing Area of Northeast Japan

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Key words: Beef cows, nutrient balance, plant species richness, selective grazing, wild plants.

Introduction

Recently, much attention has been paid for conservation of biodiversity in grasslands and rangelands. Grazing animals encounter and consume a wide range of plant species in diverse, species-rich pastures (Ogura 2011). Plant species-richness likely affects the amount and proportion of dietary nutrients for grazing animals, because the nutrient composition of plants varies among species, and access to a wider range of species provides foraging animals a wider range of choices. Ohlson and Staaland (2001) and our previous study (Mizuno *et al.*, 2012) showed that species-rich vegetation improved mineral balance of grazing herbivores. In this study, we investigated diet composition and nutrient uptake of grazing cattle in hilly mountainous pasture-forest combining areas, to evaluate the effects of plant species richness in the grazing area on nutrient status of the animals.

Materials and Methods

Study site and animals

The experiment was conducted on a 20 ha-grazing paddock composed of a temperate pasture (3.1 ha) and a forest (16.9 ha) at the Field Science Center, Graduate School of Agricultural Science, Tohoku University (Osaki, Miyagi, Japan, 38°N, 140°E). Five Japanese Black cows (396±29 kg) grazed from late spring (26 May) to mid-autumn (23 October) in 2014.

Vegetational characteristics

A quadrat (50 cm × 50 cm) was set on 36 positions in the pasture and the forest, respectively (*i.e.*, total 72 positions). The name of plant species emerged and their coverage were recorded on 9–21 June and 21–22 September, 2014.

Foraging behavior of grazing animals

Plant species ingested by the cows were visually identified and recorded by observation 2 hrs for the five cows, at 30-second intervals during foraging bouts in the morning and evening on 19–21 June and 2–5 October, 2014. Vegetation type (*i.e.*, pasture or forest) of the locations where the cows foraged was also recorded. From these data, biting frequency was calculated for each plant species. A GPS device and a motion sensor were fit on all the cows to record their grazing time in pasture and forest.

Chemical composition of diet plants

Based on the data of biting frequency, 10 major species was chosen and hand-clipped by imitating foraging manner of cows. These plant samples were used for chemical analysis to determine concentration of TDN, CP, NDF, ADF, macrominerals (Ca, P, Mg, K, Na, S, Cl), trace elements (Se, Co, Fe, Mn, Cu, Zn) and amino acids (Gly, Ala, Val, Leu, Ile, Ser, Thr, Met, Phe, Tyr, Asp, Glu, Arg, Lys, His and Pro). Bite size of each plant species was also measured by hand-clipping of the plant samplings.

Estimation of nutrient uptake by the animals

Nutrient content of the diet for the cows was estimated by using the data of biting frequency and chemical composition of the plant samples. The data of nutrient content, grazing time and bite size of the cows were used to estimate nutrient uptake of each cow. In this study, in order to evaluate the contribution of forbs and woody plants on nutrient uptake of animals, nutrient content of diet and the amount of nutrient uptake were also estimated assuming that the cows grazed only the two major monocots; *Anthoxanthum odoratum* and *Carex albata*, which were representative plant species in the pasture.

Results and Discussion

Vegetative characteristics
A total of 80–85 species were identified in the grazing paddock. In the pasture area, *A. odoratum*, *Rumex acetosella* and *C. albata* were dominant throughout the seasons. In the forest area, the coverage of forbs was high (16.5%) in early summer, and the coverage of tree leaves was high (21.3%) in autumn.

Foraging behavior
The cows foraged 25.0 and 33.0 plant species and 7.7 h/day and 6.5 h/day in early summer and autumn, respectively. They foraged in forest areas longer in early summer (2.8 h/day) than in autumn (1.4 h/day) ($P<0.05$). According to this, biting frequency of tree leaves was higher in early summer (22.5%) than in autumn (6.6%). Among the ten major species ingested by the cows, seven species (*Acer rufinerve*, *A. odoratum*, *C. albata*, *Carpinus laxiflora* Blume, *Disporum smilacinum* A. Gray, *R. acetosella*, *Viburnum dilatatum* Thunb.) were common for both seasons.

Chemical composition of diet plants
Chemical composition varied among the plant species. Particularly, the variation was greater in mineral content than TDN, CP and amino acids. Tree leaves showed higher Ca content (6.7–16.3 g/kg DM) than that of monocots (1.7–9.8 g/kg DM) and forbs (3.9–6.9 g/kg DM), throughout the seasons. The content of amino acids was high in *R. acetosella* throughout the seasons. High amino acid content was shown in *A. odoratum* and *Viola grypoceras* in autumn.

Estimation of nutrition uptake by cows
The concentration of nutrients in the diet of grazing cows were different in summer than autumn ($P<0.01$) (Table 1), due to the difference of plant species and its proportion foraged by cattle. Ca, Mg and Co concentration were 17–49% higher and S, Cl and Leu concentration was 6–34% lower in the actual diet than those values estimated by assuming that the cows grazed only the two major monocots ($P<0.05$).

Table 1. Estimation of nutrient content of diet of cows.

Season	Diet	CP	TDN	Ca	P	Mg	K	S	Se	Co	Fe	Mn	Cu	Zn
		g/kg DM							ppm					
Early summer	Monocots	136.6	644.4	2.79	2.83	1.74	18.14	1.81	0.042	0.125	79.20	481.3	6.03	38.26
		(19.95)[a]	(94.01)	(0.40)	(0.36)	(0.27)	(2.30)	(0.33)	(0.01)	(0.02)	(14.60)	(59.91)	(0.72)	(5.45)
	All	116.9	550.3	4.15	2.06	2.04	14.81	1.35	0.035	0.166	69.12	499.8	5.63	36.82
		(33.97)	(103.35)	(0.29)	(0.95)	(0.33)	(4.95)	(0.37)	(0.02)	(0.02)	(15.27)	(89.14)	(1.32)	(12.08)
Autumn	Monocots	200.5	712.5	3.89	3.21	2.05	17.37	2.40	0.032	0.123	77.84	599.9	7.26	36.99
		(5.35)	(6.75)	(0.05)	(0.09)	(0.02)	(0.43)	(0.05)	(0.00)	(0.01)	(0.54)	(15.03)	(0.23)	(0.45)
	All	197.9	678.5	4.88	3.21	2.47	16.87	2.20	0.055	0.172	81.09	615.5	7.29	53.72
		(13.02)	(10.00)	(0.88)	(0.31)	(0.08)	(0.95)	(0.09)	(0.01)	(0.02)	(1.90)	(14.73)	(0.13)	(10.70)
Statistics[b]	Diet			**		**		**		**				
	Season	**	**	**	**	**		**				**	**	
	Interaction								**					*

Season	Diet	Gly	Ala	Val	Leu	Ile	Thr	Met	Phe	Tyr	Glu	Arg	Lys	His
		g/kg DM												
Early summer	Monocots	8.52	11.50	9.03	13.21	6.64	7.85	2.59	8.88	2.49	16.96	8.09	8.98	3.24
		(1.26)	(1.59)	(1.31)	(1.99)	(1.03)	(1.15)	(0.38)	(1.35)	(0.30)	(2.61)	(1.19)	(1.35)	(0.48)
	All	7.75	9.34	7.91	11.90	5.91	6.85	2.15	7.76	2.24	14.17	6.96	8.02	2.85
		(2.09)	(2.86)	(2.26)	(3.10)	(1.61)	(1.97)	(0.74)	(2.11)	(0.82)	(4.13)	(2.26)	(2.12)	(0.80)
Autumn	Monocots	12.03	15.55	13.08	19.33	9.77	12.23	3.89	13.42	3.11	19.59	10.63	13.24	53.34
		(0.73)	(0.49)	(0.43)	(0.59)	(0.29)	(0.41)	(0.15)	(0.46)	(0.14)	(0.52)	(0.41)	(0.35)	(1.85)
	All	11.89	14.55	12.62	16.03	9.48	11.65	3.61	12.80	3.15	18.98	10.16	12.64	49.30
		(0.79)	(0.83)	(0.80)	(1.00)	(0.58)	(0.72)	(0.22)	(0.83)	(0.13)	(1.00)	(0.62)	(0.65)	(4.82)
Statistics[b]	Diet				*									
	Season	**	**	**	**	**	**	**	**	**	**	**	**	**
	Interaction													

Nutrient content of diet of grazing cows which ingested only "monocots" (*Anthoxanthum odoratum* L and *Carex albata* Boott) or ingested "all" (monocots, forbs and tree leaves) in early summer and autumn were estimated.
a: Number means Standard deviation, b: Two way ANOVA. * Differ significantly P < 0.05, ** differ significantly P < 0.01.

Conclusions and Implications

This study suggests that species rich vegetation including monocots, forbs and trees improve nutrient balance of grazing animals, due to the contribution of forbs and tree leaves which have high concentration of minerals and amino acids.

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Effect of Native Grasses, Forbs and Trees on Nutrient Uptake of Grazing Cattle in a Temperate Region of Japan

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Key words: Amino acid, diet composition, forest, sown grass pasture, mineral.

Introduction

Plant species-richness affects the amount and proportion of dietary nutrients available tor grazing animals, because the nutrient composition of plants varies among species, (Ohlson and Staaland, 2001; Mizuno et al., 2012). Our previous study suggested that species-rich vegetation improved nutrient balance of minerals and amino acids for grazing herbivores, because some forbs and tree species contained more minerals and amino acids than monocots (Mizuno et al., 2012; Takamizawa et al., 2016). Therefore, we examined the contribution of native grasses, forbs and tree plants to meet the nutrient requirements of the animals, by comparing diet composition and nutrient uptake by cattle grazed in a sown grass pasture and a combined sown pasture-forest area.

Materials and Methods

Study site and animals

The experiment was conducted in the Field Science Center, Graduate School of Agricultural Science, Tohoku University, Japan (Osaki, Miyagi, Japan, 38°N, 140°E) in mid-summer 2014. Two experimental plots were seeded in 2013; *i.e.*, an orchard grass (*Dactylis glomerata*) and reed canary grass (*Phalaris arundinacea*) pasture (SP, 1.0 ha) and a combined paddock (PF) of an orchard grass pasture (0.8 ha) and a cedar forest (0.9 ha). The cedar forest was not used as a grazing paddock before this experiment, and any sown pasture plants were not introduced into it. Five Japanese Black cows (weight?) were allocated to each plot and grazed on 4–8 August, 2014. In PF paddock, the pasture and the forest neighboring were adjacent to each other, and the animals in this paddock had access to both areas during the grazing period.

Vegetational characteristics

A quadrat (50 cm × 50 cm) was set on 10 positions in each pasture and 20 positions in a in a forest (i.e. total 40 positions). Plant species and their coverage were recorded on 9–21 June and 10–15 July, 2014.

Foraging behavior of grazing animals

The number of bites of individual plant species foraged by the animals was recorded by visual observation. In each plot, two observers followed two different animals each day, and recorded foraged plant species at 30-second intervals during 5:00–17:00 on 5–6 August 2014. Foraging behavior was not disturbed by this observation because all the animals were accustomed to existence of the observers. From these data, biting frequency was calculated for each plant species. On PF paddock, vegetation type (*i.e.*, pasture or forest) of the locations where the cows foraged was also recorded. A GPS device and a motion sensor were set to all the cows to record their grazing time in pasture and forest, respectively.

Chemical composition of plant material

Based on the data of biting frequency, major 11 species was chosen and hand-clipped by imitating foraging manner of cows. The major 11 plant species were *Artemisia princeps* (mugwort), *D. glomerata*, *Miscanthus sinensis* (silver grass), *Morus bombycis*, *P. arundinacea*, *Plantago asiatica*, *Polygonum cuspidatum*, *Pueraria lobate* (kudzu vine), *Robdosia inflexa*, *Rumex obtusifolius* (broad-leaved dock), and *Sasa palmate* (dwarf bamboo). These plant samples were used for chemical analysis to determine concentration of TDN, CP, NDF, ADF, macrominerals (Ca, P, Mg, K, Na, S, Cl), trace elements (Se, Co, Fe, Mn, Cu, Zn) and amino acids (Gly, Ala, Val, Leu, Ile, Ser, Thr, Met, Phe, Tyr, Asp, Glu, Arg, Lys, His and Pro). Bite size of each plant species was also estimated by hand-clipping method imitating foraging manner of cattle.

Estimation of nutrient uptake by the animals

Nutrient content of diet of each cow was estimated by using the data of biting frequency and chemical composition of the plant samples. The data of nutrient content, grazing time and bite size of each the cows were used to estimate the amount of nutrient uptake of each cow. These data were compared between SP and PF.

Results and Discussion

Vegetative characteristics

The most dominant plant species was orchard grass both in SP (51.8% in coverage) and PF (48.2%) in the pasture area. In the forest area of PF paddock, the coverage of monocots, forbs, trees and ferns were 17.9%, 22.2%, 24.3% and 13.1%, respectively.

Foraging behavior

The cows foraged 5.5 h/day (SP) and 6.1 h/day (PF; 5.3 h in pasture and 0.8 h in forest). In SP plot, 4.5 plant species were grazed by the cows, and biting frequency was high in orchard grass (89.2%) and reed canary grass (8.4%). In PF pasture, 10.0 plant species were grazed by cattle, and biting frequency was high in orchard grass (75.0%) and reed canary grass (15.0%). In PF forest, 21.0 plant species were grazed (monocots 48.6%, forbs 29.1%, trees 20.9% and ferns 1.4%). In the whole PF paddock, cattle foraged 28.5 plant species in average.

Chemical composition of diet plants

Chemical composition varied among the plant species as shown in our previous study (Takamizawa et al., 2016). CP content of broad-leaved dock (283 g/kg DM) and kudzu vine (270 g/kg DM) were especially higher than orchard grass (91 g/kg DM) and average value of whole plant species (172 g/kg DM). Trace element, particularly Se content was high in dwarf bamboo (0.10 ppm) compared to that in average value of whole plant species (0.03 ppm). Tyrosine content of broad-leaved dock (14.0 g/kg DM) was higher than that of monocots (1.0–3.0 g/kg DM).

Estimation of nutrition uptake by cows

The concentration of nutrients in the diet of grazing cows was different between SP and PF. The content of CP, Ca, Na, Se, Fe and amino acids in PF cows was 11–78% higher than those in SP cows. The amount of nutrient uptake also differed between the plots; the intake of Se was high in PF cows (1.6 mg/kg BW/day) compared to SP cows (1.0 mg/kg BW/day), and the intake of Tyr also higher in PF cows (19.2 mg/kg BW/day) than in SP cows (15.2 mg/kg BW/day).

Conclusions and Implications

This study showed that cattle foraged forbs and tree leaves by combining a forest with a sown grass pasture, and increased the uptake of some trace elements and amino acids. The results indicate that combination of a forest area with a sown grass pasture increase the intake of minerals and amino acids by the animals due to the contribution of native grasses, forbs and tree leaves which have high concentration of minerals and amino acids.

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Livestock Health Management through Traditional Siddha (Indian Medicine) Practices in India

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Key words: livestock health, lactation, medicinal plants, ethno-botany

Introduction

India is a land of villages. About 70% of population lives in rural areas. But a good number of the population is dependent on agriculture, especially livestock production. There is no gainful employment in agriculture. Under these circumstances, small and marginal livestock producers are unable to afford the health management using recent technologies. So they depend on the traditional Siddha medical practices (Indian medicine) for livestock health management. In India, traditional Siddha has been practiced for the past 5000 years for the maintenance of cattle health. Cattle breeders are poor and illiterate but they are competent in using traditional knowledge for treating and preventing livestock diseases and disorders. The present objective of this study is to provide information related to traditional Siddha knowledge of health management of cattle. This paper deals with traditional Siddha and ethno-botanical practices in maintenance of cattle health.

Materials and Methods

The health management information is collected from marginal and small cattle rearers through various questionnaires and ancient palm scripts and it is summarized for effective health management of farm animals through traditional Siddha practices. *Curcuma aromatica* 9g, *Piper nigrum* 9g, *Allium sativum* 9g, *Ferula foetida* 9g, *Piper longum* 9g, *Nigella sativa* 9g, *Curcuma longa* 9g, *Acorus calamus* 9g, *Areca catechu* 18g, *Piper betle* 18g, *Boerhavia diffusa* 18g, *Acalypha indica* 18g are powdered and given orally for 48 days to improve the general health of cattle. Udder infection and poor lactation of cows is treated by internal administration of *Asparagus racemosus* root tubers for 7 days. Powders of *Aristolochia bracteata* root 20g and *Cyperus rotundus* tuber 20g are orally administered to cows for 21 days to treat infertility. *Capsicum annum* 175g, *Santalum album* 175g and *Allium cepa* 350g is completely mixed in 500 ml of cow milk and administered orally for 3 days for expulsion of placenta after parturition. *Cardiospermum halicacabum* 525g in one litre of fermented porridge is administered orally for 3 days as a single medicine for the expulsion of placenta after parturition. For enhanced production of milk, *Viscum album* 175g in fermented porridge is orally administered for 3 days in early morning. For enhancement of weight leaves of *Aristolochia indica* and *Acacia suma* are given along with the fodder for 7 days. Diarrhea and dysentery symptoms are treated with *Ficus glomerata* fruits 100g, *Cassia auriculata* bark 50g, *Phyllanthus reticulatus* bark 50g mixed with rice flour 300g through oral route until the symptoms recede. Bovine tuberculosis infection in cattle is orally treated with *Leucas aspera* leaves 250g mixed with fermented porridge for 48 days. For eye infection *Madhuca indica* leaf juice 10ml is instilled in eyes for consecutive 3 days. Cattle ascites is treated by *Lagenaria ciceraria* matured leaf juice 500ml and *Allium cepa* juice 500 ml internally for 7 days. For epistaxis *Catunaregam spinosa* root bark 100g, *Allium sativum* 100g, *Acorus calamus* 35g is sprayed in nostrils for 3 days. Jaundice is treated orally with *Corollacarpus epigaeus* tuber 70g and *Tinospora cordifolia* stem 70g along with cattle feed for 7 days. For urinary tract infection *Trichodesma indica* juice 1liter, *Cuminum cyminum* 35g mixed with butter 100g is given internally for 3 days. For constipation *Carum copticum* 500g, *Ferula foetida* 70g, *Phyllanthus emblica* 100g are thoroughly mixed and orally administered for 7 days. Cataract in cattle is generally treated with *Ricinus communis* leaf juice 10ml mixed with salt 1g and instilled in eyes for 15 days. For mouth ulcer *Allium sativum* 35g, *Ferula foetida* 35g, Asphaltum 35g, *Allium cepa* 35g are given along with feed for 10 days. Sorghum toxicity is treated by the powders of *Crateva religiosa* bark 35g, *Gymnema sylvestre* leaf 35g, *Nicotiana tabacum* leaf 35g, *Acorus calamus* rhizome 35g orally for 7 days. For poisonous insect bites *Nymphaea stellata* flower 50g and *Glycyrrhiza glabra* root 50g mixed with *Citrus limon* juice 200ml is given orally as a single dose. Foot and mouth disease is managed by oral administration of *Musa sapientum* fruit 500g, Cane sugar 200g, Ghee 200g mixed with rice flour for 48 days. General skin diseases are treated by topical application of *Strychnos nux-vomica* seeds and *Acorus calamus* rhizome mixed with castor oil. The traditional medical information was obtained from twenty-five Indian cattle farmers with relevance to Siddha Ethno-veterinary literature available in National Institute of Siddha. The formulation dosage and duration depend upon the stages of the disease and the experience of the farmers.

Conclusion

Cattle health management sector has high potential for socio-economic transformation in rural India. The small and marginal farmers with their strong knowledge in traditional health management are maintaining the original gene pool of the native livestock. The exotic breeds find it difficult to acclimatize in India. Their health management is fully dependent on the modern veterinary medicines and chemical supplements in their feed. Nowadays modern dairy industries use antibiotics and other chemical materials for livestock health management. But these traditionally treated cattle with medicinal plant supplements provide eco friendly milk, milk products, dung manure, etc.

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PAPER SUBMISSIONS BY THEME AND SUB-THEME

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Afghanistan	1
Algeria	3
Argentina	13
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Bangladesh	2
Belgium	1
Brazil	10
Burkina Faso	2
Cameroon	9
Canada	147
China	49
Cote d'Ivoire	2
Egypt	1
Ethiopia	12
France	6
Georgia	1
Germany	7
Ghana	10
India	14
Iran	4
Italy	3
Japan	7
Jordan	3
Kenya	11
Kyrgyzstan	1
Lebanon	1
Libya	1
Mexico	8
Mongolia	29
Morocco	3
Nepal	4
New Zealand	4
Nigeria	3
Other	9
Pakistan	3
Peru	4
Philippines	2
Poland	1
Portugal	2
Saudi Arabia	2
Senegal	1
South Africa	24
Sri Lanka	1
Sudan	6
Switzerland	1
Syria	1
Tajikistan	1
Togo	1
Tunisia	2
Turkey	2
Uganda	6
United Arab Emirates	1
United Kingdom	3
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