Landscape changes in Mediterranean extensive land use systems.

Understanding non-uniformity in concepts, methods and trends through case study analysis in South Portugal

PhD thesis by Anne M. van Doorn

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Évora, Portugal. June 2007

This thesis does not include the comments of the jury

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O que mais há na terra, é paisagem.
José Saramago, Levantado do Chão

(What there is most on earth, is landscape)

Abstract

Land cover, land use and landscape changes in the Mértola municipality in South Portugal of the period 1958 - 1985 are explored by means of aerial photo interpretation, interviews with land owners and a range of mathematical and statistical techniques. Conceptualisation of frequently used terminology as land abandonment and the application of commonly applied techniques as mapping land cover deserve extra attention in projects carried out in Mediterranean agro-silvo-pastoral systems. Extensification trends, meaning a shift from arable land to forest plantation and scrub, mark the major trends in the area. Within the study period this process has caused a more heterogenous landscape pattern. Analysis of the determinant factors of the location of land use change, reveals that the type of land owner is an important predictive variable when arable land changes to forest plantation or to agro-silvo-pastoral systems. In the case of land abandonment, biophysical conditions are more decisive.

Resumo

Em duas áreas pertencentes ao concelho de Mértola, localizado na região do Baixo-Alentejo no Sul de Portugal, as mudanças de ocupação do solo, de uso do solo e da paisagem são exploradas no periodo 1958-2000, recorrendo à foto-interpretação, a entrevistas com agricultores e uma rama de diferentes técnicas de matemática e estatística. O uso unívoco de conceitos, como abandono da terra, metodologias e ferramentas, como a cartografia de ocupação do solo, merece atenção especial na investigação de paisagens agro-silvo-pastorís no Mediterrâneo. A mudança mais comum é a transição da terra arável para montado, novas florestações e mato. Durante o periodo de estudo este procceso resultou numa paisagem mais heterogeneia. A análise das forças motrizes de 3 transições de terra arável, revela que as variáveis sócio-económicas locais estão fortemente relacionados com a ocorrência de transição de terra arável para novas florestações e para montado, enquanto as variáveis biofísicas são mais relacionadas com o abandono de terra arável.

Preface

The first time I arrived in the Alentejo in the autumn of 2001, I was astonished by the outstanding beauty of the montados in South Portugal. As a Dutch student I was not at all familiar with this kind of landscape, but soon I became so while writing my master thesis on the application of the agro-environmental measures.

When the opportunity came across to spend some years in this region of Portugal to do a PhD, the decision was quickly taken. As easy it was to become familiar with the landscape, the difficult it was to become familiar with the Portuguese language. But what seemed impossible in the beginning, having a small talk in Portuguese, was just normal in the end. I have experienced living and working in another country as very enriching.

While it seems to be common to spend part of the preface of a Phd thesis referring to the hard time working and the offers that were made, I would like to stress that I experienced my PhD as a luxury: spending years in a beautiful country, thinking about an interesting subject, spending time with inspiring people and trying to improve your writing skills; there are much worse jobs one can think about.

During the last 3,5 years I received a lot of support from different people, as it was a multi-lingual experience I would like to express my appreciation also multilingual.

Gostava de agradecer todos os agricultores que tenho entrevistado, para a paciência ao escutar, ao tentar perceber o meu português esquisito, ao responder às minhas perguntas e ao explicar-me as prácticas da agricultura portuguesa.

A minha orientadora Teresa, muito obrigada por ter-me dado a oportunidade de fazer este doutoramento, pelo apoio inspirador e pela introdução na communidade Europeia da Ecologia da Paisagem.

Devo muito agredecimentos às minhas colegas da universidade de Évora: Ana Paixão Ferreira (para o optimismo infinito, e o apoio durante as entrevistas), Milena Dneboska (para a introdução na modalidade de orientação) Diana Jézova (para o troco das dúvidas e desafios de fazer um doutoramento), Rosário Oliveira (para a introdução na communidade de Amendoeira da Serra e as conversas sobre a relatividade da ciência) e todos os outros 'Dynamos' (para as reuniões inspiradores)! Não esqueço o pessoal do secretariado do Departamento Planeamento Biofísico e Paisagístico, Dª Arlete, Vanda, Sr. Galvoeira e Dª Mariana, sempre apoiante, obrigada! Ao outro lado do país: o pessoal da Universidade de Coimbra, Helena Freitas e Helena Castro, obrigada pela boa cooperação durante o projecto VISTA. Rita Alcazar da Liga Portuguesa para a Natureza, Carlos Gonçalves da zona Agraria de Beja, obrigada pela ajuda. Queria agradeçer as pessoas de Associação para o Desenvolvimento do Património de Mértola (ADPM), o Monte de Vento e a Associação dos agricultores de Campo Branco em Castro Verde.

Fernando Moital amareçe atenção especial, graças á ele fiquei a conhecer um outro lado da vida rural no Alentejo: os ciganos, os passeios de canoa e o descortiçamento. Luís Quinta Nova, obrigadíssima para corrigir o resumo extenso em Português !

The people of the VISTA-project I want to thank for the collaborative project years we had. Especially Martha, thank you for supporting with the statistics and helping me to improve my scientific writing skills.

Tenslotte, ben ik familie en vrienden in Nederland dankbaar voor de steun en interesse die ik gedurende de afgelopen periode heb ontvangen, ondanks dat het over zo'n afstand was en het niet altijd makkelijke tijden waren.

Het meest dankbaar ben ik Bas, voor het samen zijn.

Anne van Doorn
Wageningen, juni 2007

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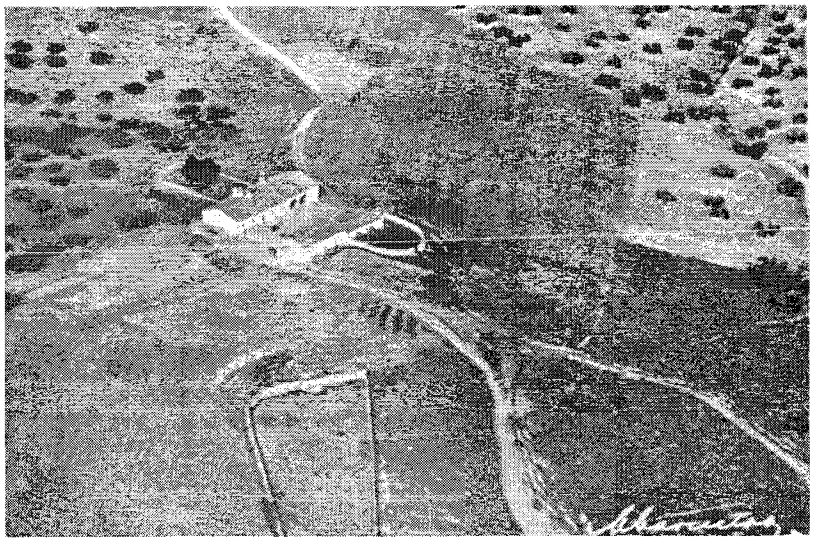


Chapter 1 General Introduction

1 Back ground & research topics

1.1 Changing landscapes in Europe and the Mediterranean region.

European landscapes evolve through time by natural and cultural factors, with changing directions and rates. Today's most valued rural landscapes are often the result of traditional agricultural practices, which have been developed within the limits of the carrying capacity of the ecosystem, providing food and raw material for the local population. As unplanned by-products valuable habitats for flora and fauna and high levels of biodiversity have emerged, as well as landscapes that support multiple functions as habitation, recreation, identity, etc. (Meeus 1995; Pinto-Correia et al. 2004). At present it seems as if these 'post-industrial' landscapes in the past were stable, while in fact they changed constantly, but maintained their identity and created a European natural and cultural heritage.

The importance of the European landscape as a fundamental part of our natural, historical, cultural and scientific heritage is also recognized by most member countries of the Council of Europe. The European Landscape Convention, that has been ratified until now by 26 European countries, states that:

- the landscape has an important public interest role in the cultural, ecological, environmental and social fields, and constitutes a resource favourable to economic activity and whose protection, management and planning can contribute to job creation;
- the landscape is an important part of the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as in areas of high quality, in areas recognized as being of outstanding beauty as well as everyday areas;
- developments in agriculture, forestry, industrial and mineral production techniques and in regional planning, town planning, transport, infrastructure, tourism and recreation and, at a more general level, changes in the world economy are in many cases accelerating the transformation of landscapes;

(source: www.coe.int)

Rapid and major land use changes, occurring under influence of demographic developments, market regulation, public policies and technological innovations have been changing the rural landscape, mainly in the 2nd half of the 20th century, to such extent that these changes are seen as a threat to the values related with this landscapes (Meeus et al. 1990; Vos et al. 1999). The nature and speed of modern land use changes differ greatly among European regions, but in general three basic processes can be distinguished: intensification, extensification and urbanization. Extensification can be defined as the reduction of external inputs, like fertilizers and labour per unit of land, while intensification is the opposite. Urbanization is the sprawl of houses and industries that occurs mainly in the vicinity of urban centres of central and western Europe. The location of processes of intensification and extensification are less clear to be defined, however, in general it can be said that intensification is more likely to occur in North-west Europe and extensification in the regions with strong biophysical limitations and in the periphery of Europe, such as parts of the Mediterranean region.

In the latter region, landscapes have strongly been shaped by agro-pastoral systems that date back to Neolithic times. The dynamic equilibrium of grazing, cultivation and other agricultural practices contributed much to the striking biodiversity and attractiveness of the Mediterranean landscapes (Naveh 1982; Grove et al. 2001; Pinto-Correia et al. 2004). Here, both extensification and intensification processes have changed the rural landscapes dramatically. Especially extensification and ultimately the abandonment of agricultural land are processes that are closely related to the areas that have marginal conditions for agriculture. These conditions are the result of both hard biophysical conditions as shallow soils, extreme climatic conditions and a peripheral location as socio-economic factors as land tenure, land use history and demographic trends. In literature several effects on the rural landscape of extensification and land abandonment have been identified: a simplification of the diverse traditional land use mosaic (Pinto-Correia 1993a), the loss of small scale heterogeneity (Fernandez Ales et al. 1992), landscape fragmentation (Regato Pajares et al. 1995) and an increase of scrubland and woodland (Romero-Calcerrada et al. 2004).

1.2 The Portuguese landscape and its changes

In Portugal, the diversity of landscapes in relation to the country surface is high, in relation to other European regions. This diversity is the result of 1) the presence of three climatic influences (Atlantic, Mediterranean and Continental); 2) a strong and diverse relief; 3) a diversified lithologic constitution; 4) an extensive coast and 5) a long history of human occupation (Ribeiro 1991; Cancela d'Abreu et al. 2004). From 154 BC the Romans had a remarkable influence on the Portuguese landscape by introducing orchards, vineyards and olive grooves. Subsequently, from the first century the Moors introduced irrigation systems and in the 15th and 16th century the great discoveries influenced the agricultural landscape by the cutting of wood for ships and the introduction of corn as a new crop (Caldas 1991; Castro Caldas 1994; Firmino 1999). This introduction contributed to an intensive transformation of the landscape, and is not the only example in Portuguese history. Crop deceases and national policies left their marks on the rural areas. A decisive national policy for the Portuguese countryside was the cereal campaign in the first half of the 20th century, which aimed at self sufficiency in cereal production, at national level. In that period, large areas, even those without potential for crop cultivation, were cultivated, resulting often in high erosion levels and soil degradation (Roxo et al. 1998). Later on, many of the highly degraded areas were planted, in the first period with Pine, than with Eucalyptus , being the forest plantations seen as a solution to use the unproductive areas, and contributing at present to an excessive occurrence of devastating wild fires. New plantations of pines, but also of other, autochthonous species, have also since the beginning of the 1990s been undertaken with the support of the CAP afforestation measures (Oliveira 1998)

At present the rural landscapes of Portugal are characterized by clearly contrasting regions. In the North, the green Minho region, with an abundant rainfall (1600 mm) all year round, there are the so-called small scaled hamlet landscapes (Grove et al. 2001). The small scale mosaic of these landscapes has been constituted by traditional mixed land use systems, with typical features as crop cultivation on small terraces with dry stone walls and complex irrigation systems (*lameiros*) . The region is known for the valuable agricultural traditions, the preservation of autochthonous cattle species and the attractive scenery, constituted by traditional landscape patterns, which is valued for its touristic potential (Pinto-Correia et al. 2004).

The small scale green Minho region is in contrast with the Alentejo region in the south of Portugal (only 500 mm of rainfall), where the extensive savannah like land use systems are managed by very large farm units. An agro-silvo pastoral system dominates the plains, optimising the strong annual fluctuations of temperature and precipitation by a combination of cultivation of cereals, extensive livestock breeding and fallow (Pinto-Correia 1993b). The open woodlands of oak trees accommodate high levels of biodiversity and is the habitat of some endangered mammals as the Iberian lynx (Blondel et al. 1999) . The unique scenery of the region is closely related to the strong regional identity.

In the central part of Portugal forests are dominating the country side. Besides this strong north-south contrast, the costal areas differ strongly from the interior parts of the country. While close to the sea the urban dynamics have their impact on the rural areas, the interior, the deep country side closer to the border with Spain, preserves still many of the agricultural traditions

Although along the whole history of the Portuguese landscape various intensive transformations can be observed, recently the changes have become more frequent and intense and seem to occupy larger areas. In the last decades of the 20th century the main trends in the rural landscapes, which are mainly driven by (inter) national agricultural policies, are (Cancela d'Abreu et al. 2004):

- the abandonment of agricultural activities in marginal areas.
- intensification of agriculture, especially the introduction of irrigation.
- the expansion of permanent culture like wine and olives
- the afforestation of agricultural areas

1.3 Impact and actual problems

In spite of the impact of the intensive landscape transformations, many of the traditional land use patterns and agricultural practices are up to now still preserved. The rural landscapes are valued for the cultural heritage, the scenery, their multi-functionality and high levels of biodiversity. Though a couple of principle problems and threats for the rural landscapes of South Portugal can be distinguished (Cancela d'Abreu et al. 2004):

- The lack of community dynamism in the peripheral areas contribute, together with changes in land use systems, to a simplification of the traditional land use mosaic in some areas, an extensification of uses and increase of forested areas, and thus a reduction of touristic potential, through the lack of character, and elevated risks of wild fires.
- A severe degradation of natural resources, especially of soil and water.
- The lack of spatial planning connected with agriculture and forestry, indirectly leading non-coherent decisions and thus to erosion, increased risk of wild fires, reduction of biodiversity etc.

So, the Portuguese rural landscapes are threatened by several factors, resulting in a loss of scenery, biodiversity, traditional structures, landscape history and the specific character of different landscapes. Landscapes loose their attractiveness and with it, quality of life and socio-economical value. In spite of the elevated rate of landscape change and the associated problems, in South Portugal the processes, causes and effects have been little studied (Lourenço et al 1998; Casimiro 2002). This counts especially for the Alentejo and the Algarve landscapes where dramatic changes take place (Pinto-Correia 1995). An assessment of the qualities, the trends and threats of these landscapes is urgently needed.

The present study has been carried out in two case study areas, Amendoeira da Serra in the north and João Serra in the west, both located in the municipality of Mértola that is part of the southern part of the Alentejo region. The areas can be characterised by a peripheral location, marginal conditions for agriculture due to poor soils and a long summer drought, and a sparsely distributed population. More information about the case study areas can be found in each of the following chapters.

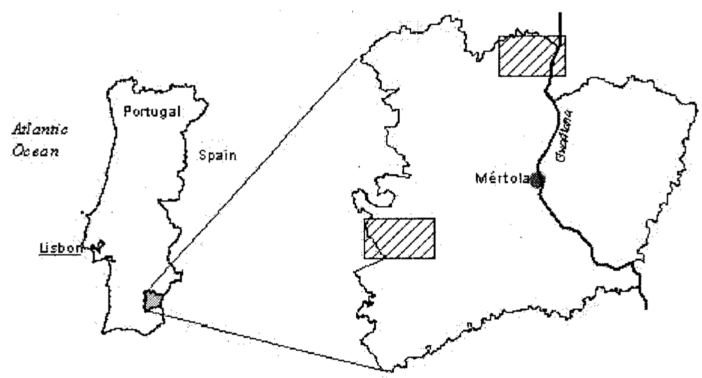


figure 1: Location of the study areas

2 Scientific contributions: approaches in landscape research

To reduce the negative impacts of land use and landscape changes or even to alter the direction of change, the development of new management strategies and policies is of great importance. Such new strategies and policies should respect local specificity and maintain the identity of local landscapes; and should be underpinned by conclusive knowledge on the identity and character of landscapes, their trends and threats, and the landscape qualities and functions, and the factors as well as the impacts of landscape change. The landscape as a research topic is discussed widely and is being studied by many disciplines.

Landscape ecology, as a sub-discipline of ecology, addresses the causes and consequences of the spatial heterogeneity of landscapes (Forman 1995). It is a young discipline, used for the first time by Carl Troll in the early 20th century, who combined methods of geography and ecology for his study (Turner 1989). The emergence of the use of aerial photographs between the two world wars opened many new perspectives for looking at our environment and the landscape. The landscape was not anymore seen as just an aesthetic asset or part of the physical environment, but as the 'total spatial and visual entity of the human living space (Naveh 2000). Corresponding to the 'mother' sciences two fundamental different fields: the more biological one (mainly located in North America) and the geographical one (mainly located in Europe). While in Europe in the 1960's and 70's the focus of landscape ecology was on the structural dynamics of landscapes on different dimensions; nature conservations aspects brought up by zoologists, later on resulting in the meta-population theory, were the main aim of research in North America. In the 1980's the discipline has been institutionalised by the foundation of the International Association for Landscape Ecology (IALE) and interest has been increasing significantly since the 1990's. According to the association, core themes of landscape ecology are :

- the spatial pattern or structure of landscapes, ranging from wilderness to cities,
- the relationship between pattern and process in landscapes,
- the relationship of human activity to landscape pattern, process and change,
- the effect of scale and disturbance on the landscape

(source: www.landscape-ecology.com)

As we can see landscape ecologists are concerned with broad-scale issues of land use and human landscape structure (Wiens 1992), this is also reflected in the top ten of research topics, which was compiled during a special session of the IALE meeting in 2001 in the USA in order to structure and focus the rapidly evolving discipline, to face new problems and challenges. This priority list includes: (1) ecological flows in landscape mosaics, (2) causes, processes, and consequences of land use and land cover change, (3) nonlinear dynamics and landscape complexity, (4) scaling, (5) methodological development, (6) relating landscape metrics to ecological processes, (7) integrating humans and their activities into landscape ecology, (8) optimization of landscape pattern, (9) landscape sustainability, and (10) data acquisition and accuracy assessment (Wu et al 2002).

Together with the increasing interest in Landscape Ecology in the 1990's, also the demands changed. Research projects, and not only the ones regarding landscape research, are increasingly required to be more applied and relevant to society, especially in relation to landscape policy and planning. In this way they are expected to contribute to solve environmental problems and land use conflicts on local, regional, national and international level (Tress et al 2006).

Problem focused landscape research means that the research becomes strongly contextualised. Situating the research in a determined area, means coping with real world problems and taking into account a range of specific, external factors. In this way the obtained results presumably might not be so directly applicable in general. Although a certain degree of generalization makes scientific knowledge valuable, strong contextualised knowledge is more socially robust (Nowotny et al 2001).

Recent publications stress the importance of interdisciplinary approaches in landscape research, because 'the complexity of the real world and its problems are in contrast to the disciplinary organization of science' (Tress et al. 2001). Interdisciplinarity can be understood as approaches that involve several unrelated academic disciplines in a way that forces them to cross subject boundaries to solve a common research goal. Because landscapes are the result of natural and human factors, they demand to be studied in an interdisciplinary way. In spite of the common acknowledgement of the importance of interdisciplinary research, there still exist many conceptual and methodological barriers to be solved (Fry 2004). Nevertheless, Wu et al. (2002) called it one of the key issues in landscape ecology.

Within this respect landscape ecology, being a young rapidly evolving discipline gains importance in policy making. With regard to the rapid and dramatic changes in European rural landscapes, landscape ecology can offer the interdisciplinary problem oriented approach that focuses on applied landscape studies.

3 Aims, Scope and scale of the present research

Given the fact that important land cover changes are taking place in South Portugal which have little been studied, in combination with the research priority, within landscape ecology, of understanding the processes behind landscape change, a challenging subject of research emerges that has been used in the research work here presented.

The areas selected as case study are located in the municipality of Mértola. The area has a Mediterranean climate, an undulating relief with poor and shallow soils and is located in a peripheral part of the country. Due to these conditions the area can be considered marginal in terms of agricultural production, although for some landowners agriculture continues to be a relatively important source of income. The rest of the sparsely distributed population has other jobs, is unemployed or retired (Pinto-Correia et al. 2006). Extensive livestock breeding, mainly sheep, and cereal growing are the main agricultural activities, although they suffer from not being competitive in an increasingly globalised market. Since the Portuguese entrance into the European Union, subsidies and regulations of the Common Agricultural Policy are increasingly determining land use practices in the area, one of the most visible articulations being the introduction of forest plantations, subsidized by successive instruments but mainly in the 1990s through the EU Reg.2080/92 (Oliveira 1998).

The key theme of the thesis is to monitor structural and compositional landscape changes and to identify the associated driving factors in case study areas in Southeast Portugal. A secondary objective is to emphasize the importance of a clear use of concepts, methods and tools when doing landscape research in agro-silvo pastoral landscapes in the Mediterranean.
The thesis addresses the following key questions:

1. How can the frequently used concept of land abandonment be defined in relation to land cover and land use? What type of land cover and land use can be found when an area is considered as abandoned?
2. How does the matrix-patch-corridor paradigm and the classification and mapping of land cover apply to agro-silvo-pastoral systems? Which classification makes sense in these systems ?

3. Which structural and compositional landscape changes in the sample areas have taken place during the last 50 years?
4. What are the most explanatory factors for the location of changes in arable land?

In landscape ecology the scale issue is one of the most important parameters to establish. Defining the scale of a study should be done in relation to the objective (Forman et al. 1986). Because many changes in the rural landscape structure originate from the local level, understanding the processes of change starts with studying what is going on that level. One of the main goals of the study is to investigate the explanatory variables of landscape change, and one of the hypotheses is that the type of landowners is a determinant factor. In consequence the scale of study should be large enough to cover sufficient number of different types of properties, but small enough to allow for interviewing a representative sampling of

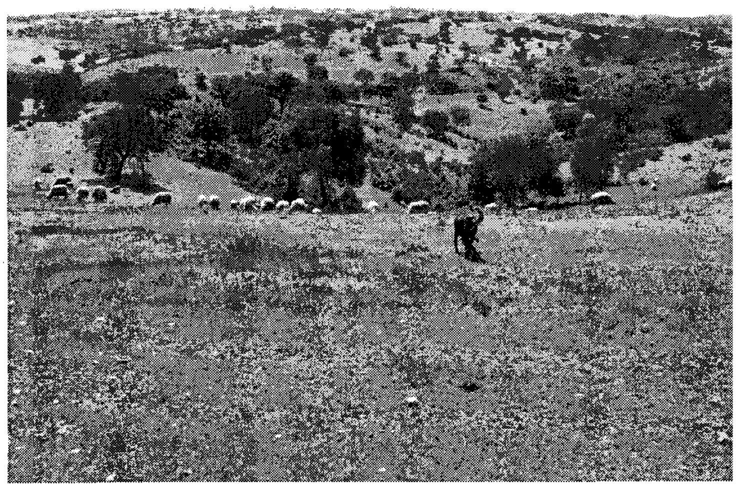


figure 2: The landscape of the study area of Amendoeira da Serra

land owners. On the other hand a sample area of a limited number of square km allows comprehending the different aspects of a landscape change study, while the amount of work remains manageable.

4 Framework for the PhD: the VISTA project

The present PhD has been carried out as part of the EU funded Fifth Framework project VISTA (EVK2-2001-00356 - Vulnerability of Ecosystem Services to land use change in traditional agricultural landscapes, 2003 - 2005). This project aimed to compile an integrated assessment of the vulnerability of European traditional agro-pastoral landscapes to land use change. More specifically, the present work was elaborated within the framework of the work package entitled: 'Historical Land use change and future projections. This work package aimed to:

1. analyse patterns in past land use change, and relate these to landscape attributes;
2. generate future projections of land use change based on scenarios of socio-economic, policy and climate change that include plausible global trends and specific local policy and management options based on the ATEAM scenarios (Rounsevell et al. 2003).

The presented analysis will just touch briefly on some of the results of the VISTA project. In chapter six some general results of the project are described. In spite of the divergence of the work developed under the VISTA project and the PhD-project, the VISTA project has framed the present work for a great part.

A personal growing concern became the risk of oversimplification of landscape trends in peripheral Mediterranean landscapes, for the purposes of more elaborated analysis. During the VISTA-project, several times I came across the assumption of a needed simplification of the real world in order to get models function. Often this resulted in an oversimplification, that resulted in data that had very less to do with the landscape that was dealt with. This concern has also been put forward by other authors as Lambin et al. (2001) who state that 'common understanding of land cover change is dominated by simplifications which, in turn, underlie many environment-development policies'. This is especially true in Mediterranean areas, where land use is often mixed, land cover borders are fuzzy and the relation between land cover and land use is rarely straightforward. Here, an extreme simplification of processes of landscape change often leads to misassumptions. As a consequence, I felt the need to emphasize and understand in detail, the more complex reality of Mediterranean landscapes.

5 Used concepts

A clear definition of the used concepts, also the more commonly known ones, contributes to establish the theoretical framework of the study. In the following section the most frequent concepts in this thesis are mentioned and a description is given.

The central topic of the thesis is 'the landscape'. Of the wealth of existing definitions the one given in the European Landscape Convention has been chosen to adopt because of the general acceptation, its simplicity and applicability to the subject of the thesis and is as follows:

> 'Landscape ' means an area, as perceived by people, whose character is the result of the action and interaction of natural and / or human factors.
>
> (source: www.coe.int)

The thesis focuses on *rural* landscapes. According to the definition by OECD (the international Organisation of Economic Co-operation and Development) rural regions have less than 150 inh / km2. Rural landscapes used to be understood as areas dominated by agriculture that are sparsely populated and far away from the influence of large towns. However, due to changes in society, policies and (world) agriculture is not dominating anymore in many rural areas in Europe. Maybe in a spatial sense yes, but not economically or socially. From essentially a production and living space some decades ago, the rural landscapes have become progressively in Europe a space of consumption, where land use patterns nevertheless are still dominated by production systems" (Pinto-Correia and Kristensen 2006, to be submitted) So a more contemporary definition of rural areas could be: areas that are sparsely populated and dominated by non-built land cover, where the land use is pre-dominantly agricultural or formerly used for agriculture but today also with other functions.

Spatial heterogeneity refers to the spatially structured variability of a property or interest (Wagner et al. 2005). Specifically, spatial heterogeneity of the landscape means the non-random distribution of objects (e.g. patches, elements, corridors) across the landscape (Forman et al. 1986) This means that the landscape always has a structure, a pattern. *Driving factors* are the influential processes in the evolutionary trajectory of the landscape (Burgi et al. 2004). *Land cover* is the observed (bio) physical cover on the earth's surface' (Di Gregorio et al. 2000). Examples of land cover categories are: forest, grassland, bare rock etc. *Land use* is dealing with the human activities on a particular piece of land (Lillesand et al. 1994). Examples of land use categories are: agricultural land, forestry, transport. *Montado* is the agro-silvo-pastoral system of southern Portugal characterised by a open oak forest in association with animal grazing and cultivation (Pinto-Correia 1993b). *Extensification* of land use means: 'using less intensive ways of farming'. This involves using fewer chemical fertilizers, leaving uncultivated areas at the edges of fields, reducing herds of cattle etc. This allows lower yields from the same area of farmland, which is necessary if the production levels are too high (Collin 1988).

6 Structure of the thesis

The next chapters are made up of four separate research papers, each one dealing with an aspect of the work carried out during the PhD. Since the papers are separate research articles, some sections, for example the methods section describing the study area, might be repetitive. I tried to overcome this by highlighting in every article another aspect or process of the study area(s) that is relevant for the specific paper. Figure 2 shows a schematic representation of the research, data flow and where the four papers are positioned. Figure 3 depicts a schematic overview of the structure of the study and the papers presented.

Paper A is a conceptual discussion about a frequently used concept in landscape studies in the Mediterranean: land abandonment. The paper discusses the notions of land abandonment, agricultural abandonment and secondary succession (shrub encroachment) and their interrelation.

Paper B deals with the concerns of land cover mapping in continuous landscapes. By comparing two mapping approaches in a case study area, issues as classification and delineation of patches in agro-silvo pastoral landscapes are discussed.

Paper C compares structural and compositional landscape changes in two case study areas by applying transition matrices and landscape metrics. Contrarily to what is often observed in Mediterranean landscapes undergoing extensification processes, an increase of landscape heterogeneity has been found

Paper D investigates the explanatory factors for change of arable land in the study area of Amendoeira da Serra. By adopting logistic regression and comparing the goodness of fit of different models, most important factors for explaining the changes are identified.

The final chapter presents the main conclusions, a review of the used approaches and methods, and ends with some recommendation for further research. The appendices include the interview guide in English that was used to interview the landowners in the study area, and a list of publications and presentations.

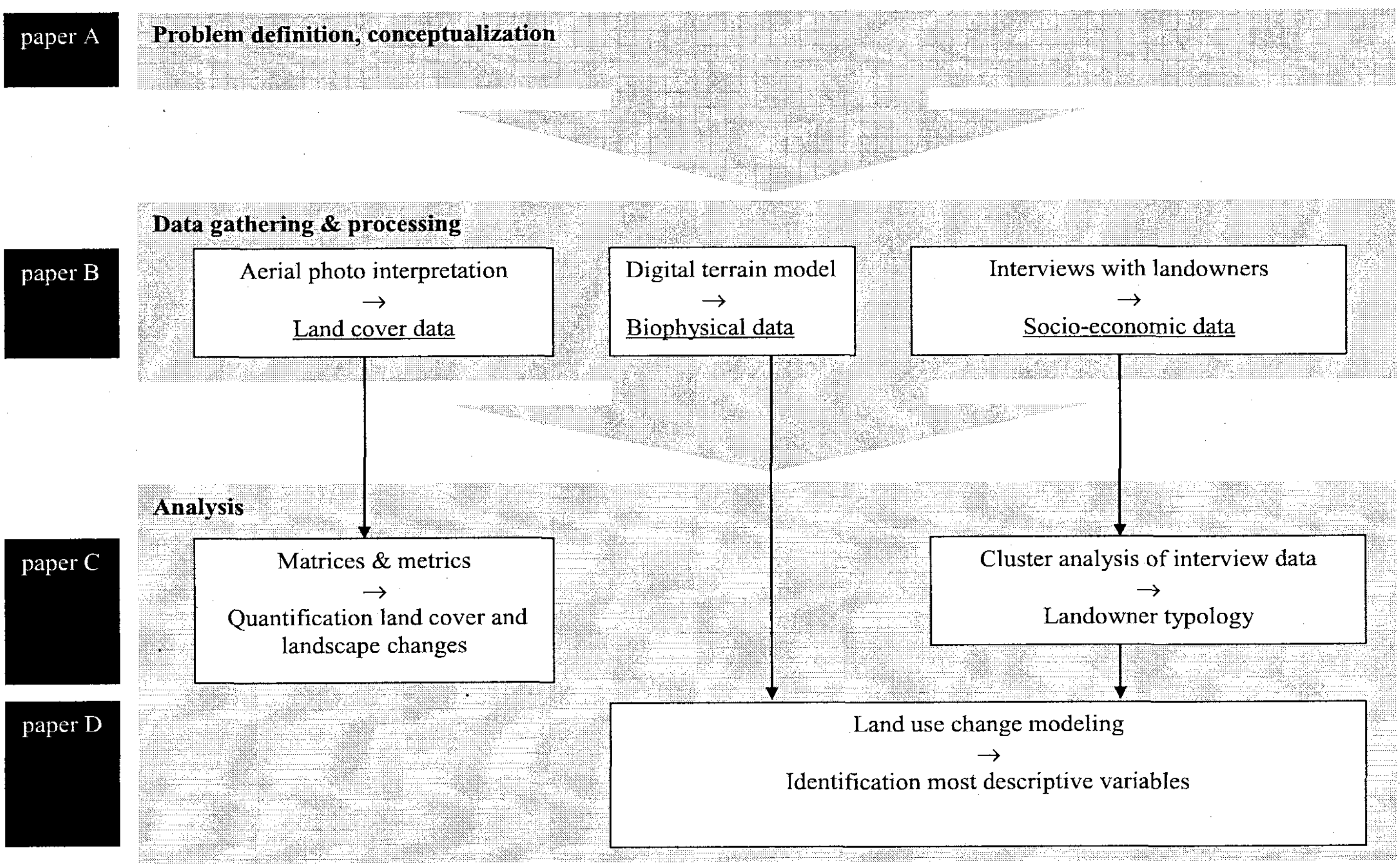


figure 3: Schematic representation of the present project and the positioning of the research papers compiling the thesis.

References

Blondel, J., Aronson, J., 1999. Biology and Wildlife of the Mediterranean Region. Oxford University Press, Oxford / New York.

Burgi, M., Hersperger, A.M., Schneeberger, N., 2004. Driving forces of landscape change - current and new directions. Landscape Ecology, 1-12.

Caldas, E., 1991. Paisagem Agrária. In: Portugal Moderno. Agricultura e Pescas. POMO, Lisbon.

Cancela d'Abreu, A., Pinto-Correia, T., Oliveira, R., 2004. Contributos para a identifica‡ao e caracteriza‡ao da Paisagem em portugal Continental. Direc‡ao -Geral do Ordenamento do territ¢rio e Desenvolvimento Urbano, Lisbon.

Casimiro, P.C., 2002. Uso do solo, Teledetec‡ao e Estrutura da Paisagem. In: Universidade Nova de Lisboa, Faculdade de Ciˆncias Sociais e Humanas., pp. 1-572.

Castro Caldas, E., 1994. Evolução da paisagem agrária. In: Cancela d'Abreu, M. (Ed.), Paisagem. Direcção Geral do Ordenamento do Território e Desenvolvimento Urbano, Lisbon.

Collin, P., 1988. Dictionary of Ecology and the Environment. Peter Collin Publishing, Teddington.

Di Gregorio, A., Jansen, L.J.M., 2000. LCCS: Land cover classification system. In: FAO, Rome, Italy.

Fernandez Ales, R., Martin, A., Ortega, F., Enrique, E.A., 1992. Recent changes in landscape structure and function in a Mediterranean region of South West Spain. Landscape Ecology 7, 3-18.

Firmino, A., 1999. Agriculture and landscape in Portugal. Landscape and Urban Planning 46, 83-91.

Forman, R.T.T., 1995. Land mosaics, the ecology of landscapes and regions. In: Cambridge university.

Forman, R.T.T., Godron, M., 1986. Landscape Ecology. Willey, New York/ Chichester/ Brisbane/ Toronto/ Singapore.

Fry, G.L.A., 2004. Interdisciplinarity and transdisciplinary approaches. In.

Grove, A., Rackham, O., 2001. The Nature of Mediterranean Europe. An Ecological History. Yale University Press, London.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11, 261-269.

Lillesand, T.M., Kiefer, R.W., 1994. Remote sensing and image interpretation. John Wiley & sons, USA.

Lourenço, N., Pinto-Correia, T., Jorge, M.R., Machado, C.R., 1998. Farming strategies and land use changes in southern Portugal: land abandonment or extensification of the traditional systems? Mediterrâneo 12/13, 191-208.

Meeus, J.H.A., 1995. Pan-European landscapes. Landscape and Urban Planning 31, 57-79.

Meeus, J.H.A., Wijermans, M.P., Vroom, M.J., 1990. Agricultural landscapes in europe and their transformation. Landscape and Urban Planning 18, 289-352.

Naveh, Z., 1982. Mediterranean landscape evolution and degradation as multivariate biofunctions: Theoretical and practical implications. Landscape and Planning 9, 125-146.

Naveh, Z., 2000. What is holistic landscape ecology? A conceptual introduction. Landscape and Urban Planning 50, 7-26.

Nowotny, H., Scott, P., Gibbons, M., 2001. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge.

Oliveira, R., 1998. Causas para a desfloresta‡ao e degrada‡ao da floresta - estudo-caso para o concelho de M,rtola- Portugal. Catena 12-13, 75-93.

Pinto-Correia, T., 1993a. Land abandonment: Changes in the land use patterns around the Mediterranean basin. Options Méditerranéennes, The situation of agriculture in Mediterranean countries 1 (2), 97-112.

Pinto-Correia, T., 1993b. Threatened landscape in Alentejo, Portugal: the 'Montado' and other 'agro-silvo-pastoral' systems. Landscape and Urban Planning 24, 43-48.

Pinto-Correia, T., 1995. Land marginalisation in Portuguese rural areas: a general view over the actual process and the foreseeable trends for the near future. In: The Spatial Planning Agency, The Hague, the Netherlands, pp. 103-118.

Pinto-Correia, T., Vos, W., 2004. Multifunctionality in Mediterranean Landscapes - past and future. In.

Pinto-Correia, T., Breman, B., Jorge, V., Dneboska, M., 2006. Estudo sobre o Abandono em Portugal Continental. Análise das dinámicas da Ocupação do Solo, do Sector Agrícola e da Comunidade Rural. Tipologia de Areas Rurais. In: Universidade de Évora, Évora, pp. 1-211.

Regato Pajares, P., Castej¢n, M., Tella, G., Gim,nez-Caballero, S., Barera, I., Elena-Rosello, R., Jongman, R., 1995. Analysis of changes in Mediterranean mountain regions of Spain: seven study cases. In: Landscape changes in Europe. ECNC, Netherlands.

Ribeiro, O., 1991. Portugal, o Mediterrâneo e o Atlântico. Sá da Costa, Lisbon.

Romero-Calcerrada, R., Perry, G.L.W., 2004. The role of land abandonment in landscape dynamics in the SPA 'Encinares del r¡o Alberche y Cofio', Central Spain, 1984-1999. Landscape and Urban Planning 66, 217-232.

Rounsevell, M.D.A., Annetts, J.E., Audsley, E., Mayr, T., Reginster, I., 2003. Modelling the spatial distribution of agricultural land use at the regional scale. Agriculture, Ecosystems & Environment 95, 465-479.

Roxo, M.J., Mourao, J.M., Casimiro, P.C., 1998. Políticas agrícolas, mudanças de uso do solo e degradação dos recursos naturais - Baixo Alentejo Interior. Mediterraneo 12/13, 167-189.

Tress, B., Tress, G., 2001. Captitalizing on multiplicity: a transdisciplinary systems approach to landscape research. Landscape and Urban Planning 57, 143-157.

Tress, B., Tress, G., Fry, G., Opdam, P., 2006. From Landscape Research to Landscape Planning. Springer, Dordrecht.

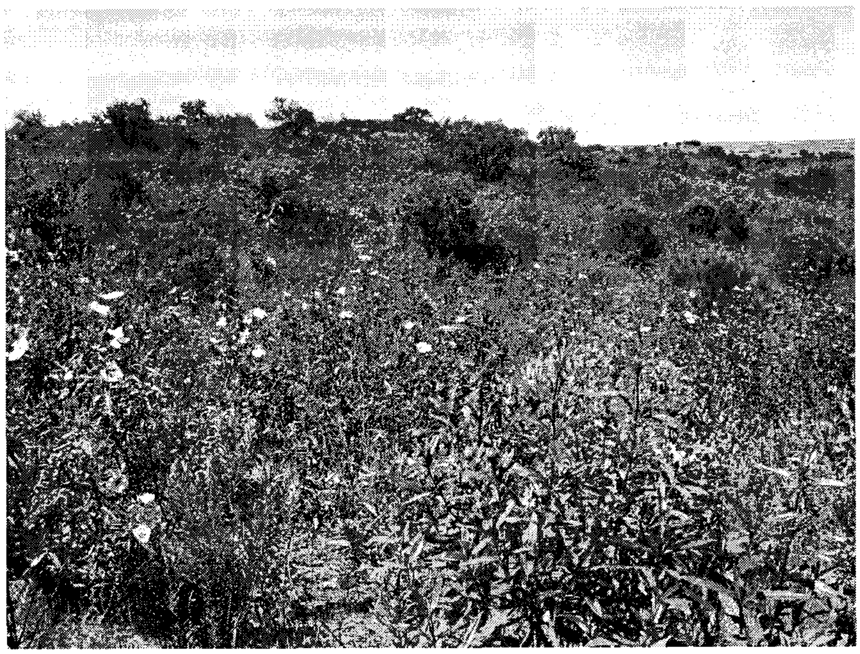
Turner, M.G., 1989. Landscape Ecology: the effect of pattern on process. Annual reviews of Ecological Systems 20, 171 - 197.

Vos, W., Meekes, H., 1999. Trends in European cultural landscape development: Perspectives for a sustainable future. Landscape and Urban Planning 46, 3-14.

Wagner, H.H., Fortin, M.J., 2005. Spatial analysis of landscapes: concepts and statistics. Ecology 86, 1975-1987.

Wiens, J., 1992. What is landscape ecology, really? Landscape Ecology 7, 149-150.

Wu, J., Hobbs, R., 2002. Key issues and research priorities in landscape ecology: An idiosyncratic synthesis. Landscape Ecology 17, 355-365.



Chapter 2 Paper A

Refining the concept of land abandonment: Experiences from southern Portugal.

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Abstract

To develop integrated management policies that can deal with the issues concerning land abandonment in the Mediterranean, there is a need to evaluate the process of change taking place. Therefore, land cover as well as land use has to be monitored in a detailed way. This is because the relationship between cover and land use is not as direct as has often been assumed, especially in relation to the processes of land abandonment. Encroachment of scrub formations is generally used as a proxy to monitor these processes. The question is what this indicator really means in terms of land use. In this paper the necessity of a careful assessment of land use practices is discussed. Detailed research based on evaluation of land cover changes through aerial photo interpretation and interviews with farmers to understand the land uses in a case study area in southern Portugal has been carried out. The study shows that areas dominated by scrub encroachment do indeed indicate areas where agricultural practices e.g. ploughing and grazing, have been declining. However, an understanding of the land use systems in place, through interviews with farmers, shows that these areas did not represent a lack of use, but rather they can be considered as areas with multiple and mixed land uses. These findings have implications for the conceptualization of abandonment.

Keywords

Land abandonment, land cover, land use, scrub lands, multiple use

Introduction

In this paper the concept of land abandonment is discussed and illustrated by a case study in south Portugal, a region where it is a relatively recent process (Alves *et al.* 2003). Concepts such as land abandonment, agricultural abandonment, scrub encroachment and their interrelations are rarely discussed in literature but often confused in studies of land abandonment.

It is therefore necessary to focus on these issues, hence the present paper. First, these three concepts are presented and the confusion associated with their use. The paper will then focus on the study area, and present the results of aerial photo interpretation and interviews with landowners. The conclusions present the implications of the findings for conceptualization of abandonment in landscape research that aims at improving landscape management and policies.

Abandonment and scrub encroachment

The rural landscapes of the Mediterranean, e.g. those resulting from the agro-silvo-pastoral systems of Portugal, have been characterized over centuries by multifunctional land use. In this kind of land use system, scrub formations constitute an integral part of agricultural practice (Brum Ferreira 1995; Bandarra 1993). Long fallow periods in combination with extensive livestock grazing result in a heterogeneous landscape pattern with alternating scrub densities.

However, when agricultural practices e.g. grazing and cultivation, decrease, secondary succession of former cultivated fields and pastures in many cases leads to an increase of scrub area. Scrub encroachment is often considered to be an undesirable process since it increases the risk of wild fires (Moreira *et al.* 2001; Fernandez Ales & Matin 1992). It also causes a decline in biological diversity (Gonzalez Bernaldez 1989) and might be a threat to the multifunctionality of traditional cultural landscapes (Pinto Correia 1993b). In socio-economic terms areas of scrub are often considered to be symbols of social structure and population decline (Brum Ferreia 1995).

A decline of agricultural practices can lead to agricultural abandonment. This concept is often mixed with the concept of land abandonment, though a distinction between both terms is desirable. While agricultural abandonment indicates the withdrawal of agricultural activities at a particular area, land abandonment involves a decline of *all* human activities or use of the land. Although there is confusion over the concept 'land abandonment' it is a common theme in research on rural landscapes and agricultural marginalization. However, before applying the concept, some aspects have to be clarified.

Land abandonment can be seen as a process or as a state. For example, Burel & Baudry (1995) consider it as a process and define it as any apparent reduction in farmers' stewardship over a large range of spatial and temporal scales. Abandonment may also be seen as a state which is a result of a process, and is defined by Pinto Correia (1993b): 'the soil stops being managed and used'; or, in economical terms, abandonment occurs when land is not used for any economic activity (Coppola 2004). Defined as such but not taking into consideration the dynamics preceding the final state, the concept becomes more practical to apply and will be used in this way in the paper.

Often the assumption is made that land abandonment is a one-way gradual process, which is dealing with agricultural practices, without taking into account the type of agriculture. Bandarra (1993) stressed the difference between northern and southern European countries when dealing with land abandonment. In northern countries, where land use is strictly planned and where the distinction between arable land, pastures and forest is clear, the notion of abandoned land is relatively easy to monitor. In the Mediterranean countries, with intermixed land uses and less visible contrasts between units, the processes of land abandonment are more difficult to identify. This is especially true for land use systems with long periods of fallow where it is difficult to define the boundary between fallow and scrub. In consequence, the concept of land abandonment should be defined according to the agricultural system itself and its development in the region.

These considerations also cause problems in land cover mapping, because of difficulties in definition and delimitation of land cover class e.g. Feio (1998). In many landscape studies dealing with processes of land abandonment the land cover class 'shrub land' is used as a proxy for land abandonment although in English useage shrubland is actually scrub, with shrubs being only individual (Fernandez Ales & Matin 1992; Dunjo *et al.* 2003; Romero-Calcerrada & Perry 2004). This indicator is relatively easy to monitor on aerial photographs, although what it really indicates in terms of land use is doubtful. Relying on this indicator, conclusions could be drawn about agricultural activities. When shrubs are invading, leading to scrub formation, one can conclude that disturbances such as grazing and ploughing are less frequent or intensive. But what does it really say about the farmers' stewardship over an area? When agricultural abandonment takes place, does it automatically involve land abandonment? Does it mean that the area is not used for anything or have only the agricultural activities been stopped? What kind of land use activities are still practiced?

When monitoring is carried out on the basis of changes in land cover only, the implicit assumption is made that agricultural practices e.g. livestock rearing and cultivation are the only economic activities carried out in the area. But in many cases of the Mediterranean, practices such as extensive livestock breeding, hunting and beekeeping are economic activities that can be carried out in areas dominated by scrub. Consequently, using scrub cover as the only indicator may not be sufficient when dealing with issues concerning land abandonment in an integrative way, involving ecology, economy and other aspects.

Methodology

Study Area

One of the Less Favoured Areas (LFAs) in Portugal where population density is low and continues to decrease (Instituto Nacional de Estatistica, 2001), is the municipality of Mértola in the province of Alentejo as shown in figure 1. The region has a hill relief with poor and shallow soils, and a typical Mediterranean climate, with long dry summers and moist winters.

Due to these natural conditions in combination with its peripheral location and historical factors, the whole region of Mértola is currently one of the most marginal areas in Portugal for agriculture. Recent studies dealing with marginalization and rural dynamics in Portugal consider the region fragile in terms of rural economic development (GPPAA 2004; Breman & Pinto Correia 2003).

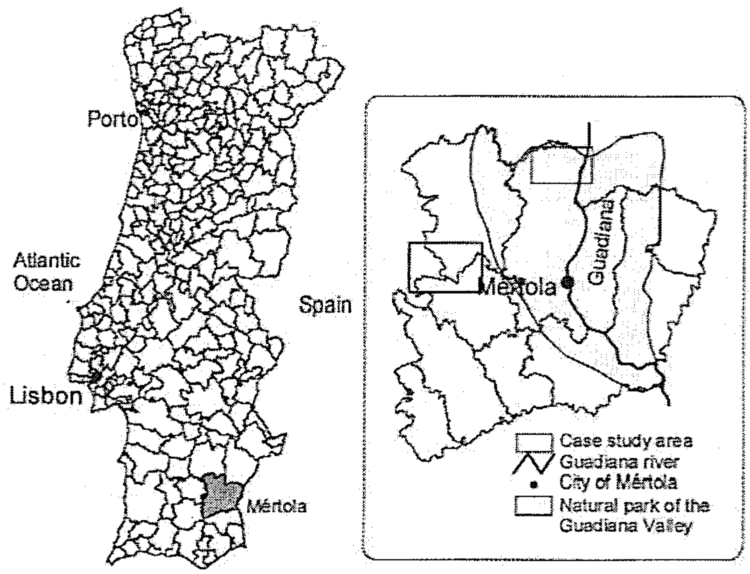

figure 1. Location of case study areas, north: Amendoeira da Serra, west: João Serra.

In terms of landscape history, large parts of the region were covered with scrub in the 19th century. These areas were commonly used for activities such as hunting, livestock breeding and collection of wild fruit. Under the influence of policy incentives, improved market structures and increasing population these semi-natural areas have been gradually converted into arable land aimed at maximizing cereal production. Even areas with unfavourable conditions for agriculture were cultivated (Roxo *et al.* 1998). Also the *Montado* open oak forest combined with cultivation and extensive livestock breeding (Pinto Correia 1993a), which is also widespread in the region, was subject to such intensification.

The traditional land use practices e.g. cereal growing and the *Montado* have gradually declined in economical importance during the second half of the 20th century. However, since Portugal entered the EU the influence of the Common Agricultural Policy (CAP) and its associated subsidies, can be clearly observed in the region. Cultivation of cereals has increased and there is a significant increase of forest plantations. The most recent ones are planted with oak and pine as the preferred species, within the framework of one of the second-pillar measures of the CAP in Portugal i.e. afforestation of agricultural areas.

In spite of the recent increase of cultivation and forestry, more than 20% of the municipality is still covered with scrub today, according to CORINE 2000 (Instituto do Ambiente and IGEOE 2005).

Within the municipality two areas of 44 km^2 each, Amendoeira da Serra and João Serra are chosen as case study areas.

Aerial photographs and cartography

To detect changes in land cover, aerial photographs of three years were used: 1958, 1969 and 1985. For 1990 and 2000 digital orthophotomaps were used. The scale of the aerial photographs varied between 1:26,000 and 1:15,000. The orthophotomaps had a resolution of 1 m. The photographs were scanned with a resolution of 600 dpi and ortho-rectified, using the orthophotomaps of 2000 as georeference. Identification of the land cover classes was done on screen and with elaborate fieldwork for the present situation. Digitising was done in ArcView 3.2, using a minimal mapping unit of $500m^2$.

	Land cover classification
1	Hamlets/farm buildings
2	Water lines/reservoirs
3	Agricultural area/pasture, < 20% scrub cover, with/without tree cover
4	Low, scattered scrub (*matorral*), 20-50% scrub cover, with/without tree cover
5	Middle, discontinuous scrub (*matorral*), 50-75% scrub cover, with/without tree cover
6	High dense scrub (*matorral*), > 75% scrub cover
7	Forest plantation
8	Other

Table 1. Land cover classification.

For the interpretation a land cover classification of nine classes was used, which is an aggregation of the original land cover classification and is shown in Table 1. To understand this classification, a closer look at the landscape and its associated management is required. The landscape in the study area is characterized by a gently rolling relief and a mosaic of alternating land uses varying from pastures to scrub and trees. The tree cover is mainly formed by differing densities of holm oak. The ground vegetation is extensively used, resulting in a varied pattern of pasture alternated with various densities of scrub cover. The specific combinations of different tree densities and varieties in the ground vegetation represent different management regimes. For the purpose of this paper we will make a distinction only between the different scrub covers.

Land cover class 3 is arable land or pasture with less than 20% scrub cover. The vegetation is dominated by species such as *Chamaemelum mixtum, Tolpis barbata* and *Agrostis pourretii.*

Classes 4, 5 and 6 are scrub land classes, varying in height and density, which are in an ecological as well as a landscape point of view, clearly distinct. The classes are distinguished according to the nomenclature of Tomaselli (1981) for *matorral. Matorral* is defined as a shrubby formation of woody plants found in Mediterranean climates.

Class 4 is low, scattered *matorral* and corresponds to natural pasture where sparse scrub covers 20-50% of the surface. The scrubs have a maximum height of 0.6 m and common species are *Lavendula stoechas, Genista hirsute, Carlina corymbosa* and *Helichrysum stoechas.*

Middle discontinuous scrub (*matorral*) is between 0.6 and 2.0 m high and has a cover between 50-70%. It is a relatively homogeneous formation of *Cistus ladaniferus*, but also *Quercus ilex, Lavandula stoechas, Genista hirsute* can be found. It grows mainly on former cultivated land or recently burned areas, since *Cistus ladaniferus* is an active pyrophyte. This type of *matorral* probably represents an alternative stable state, which is highly persistent in the absence of human intervention, because seed establishment of *Quercus* species is difficult in this kind of scrub (Acacio 2005).

The third scrub class is high, dense *matorral*, which can reach a height of more than 2.0 m, and can especially be found along the water courses. It is a species rich, heterogeneous formation with species such as *Arbutus unedo Olea oleaster, Pistacia lentiscus* and *Quercus rotundifolia.*

Interviews

In addition to the observations from aerial photographs, which give information on land cover and associated changes, interviews with landowners and farmers were carried out. In a structured interview, farmers were asked about their past and present land management, and about their attitudes and opinions towards the concepts of land abandonment. The goal of the interviews was multiple, aiming at facilitating the interpretation of the aerial photographs and to relate observed land cover to land use and agricultural management: (1) to obtain some census data of the land owners; (2) to understand the farming system; (3) to understand the relation between land cover and land use; (4) to obtain data on past farm management and (5) to examine the opinions and attitudes towards land abandonment. Especially this final goal aimed at understanding when areas are really considered as abandoned by local people and how these areas can be identified. It was subdivided into three parts: (1) questions about the regime of fallow land; (2) questions about the part of the property which is outside agricultural production and (3) the concept of land abandonment.

In both case study areas there are approximately 79 landowners. However, due to a lack of updated data on land ownership and because of complex inheritance processes, property structure and ownership are often unclear.

The sample of the landowners to be interviewed had to correspond to the wide variety of different types of landowners present in the area, from small peasant farmers to large, urban landowners. Selection of interviews took place on basis of type of landowner and accessibility. The interviews were carried out in spring/summer 2004 and adopting a structured question list consisting of 28 questions.

Results

Aerial photographs

The change in scrub cover of the study area with most dramatic changes, the area of Amendoeira da Serra can be seen in the maps of Figure 2 and the graph of Figure 3.

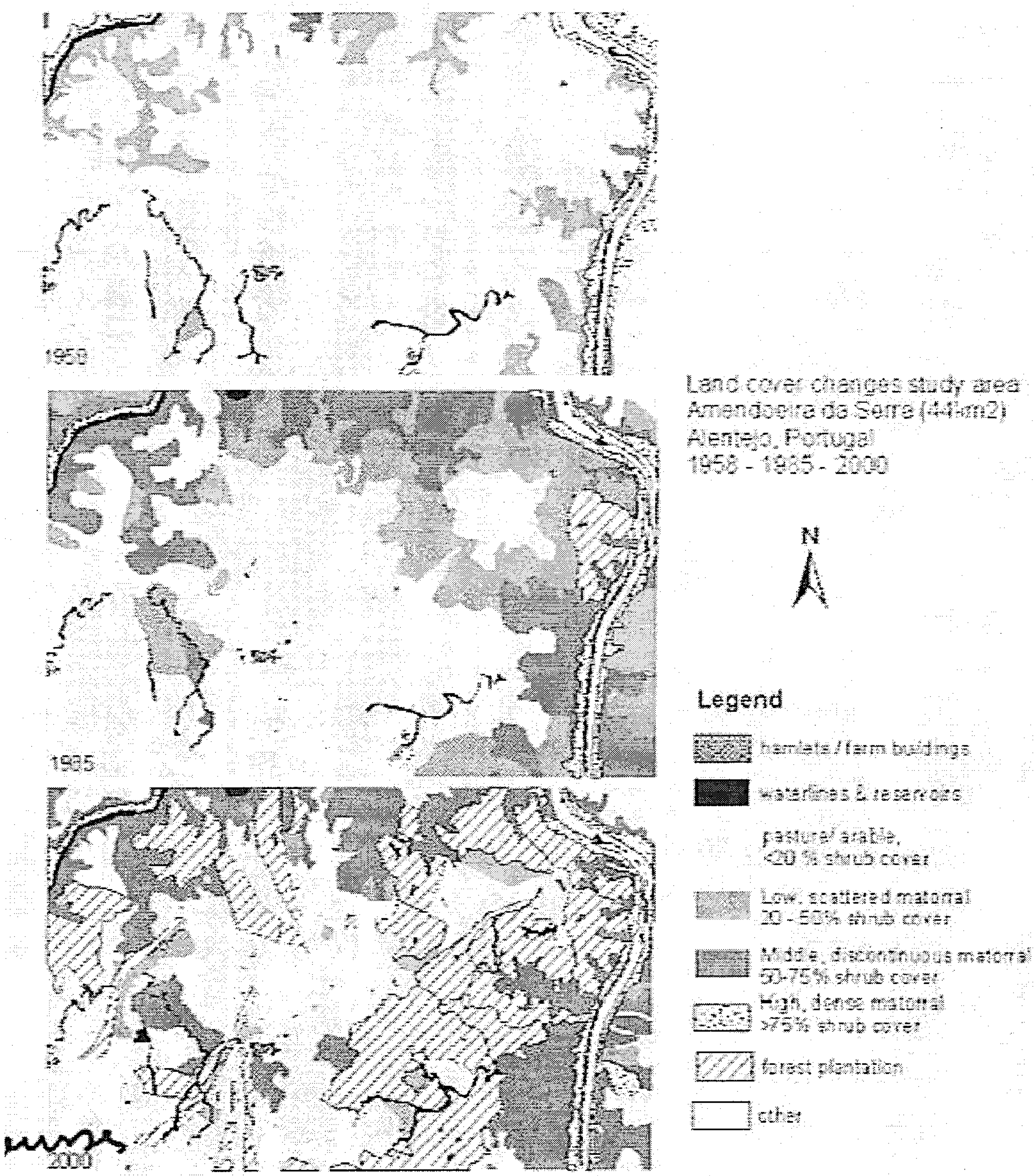

Figure 2. Land cover changes 1958 - 2000 in the study area of Amendoeira da Serra.

In 1958 most of the scrub present in the area could be found along the water courses. High *matorral* accounted for 4% of the area, low *matorral* covers 3% and middle *matorral* 7% of the study area. Linking these data on land cover with the physical conditions showed that the presence of scrub was related to the steep and stony slopes, on which cultivation is hardly possible. The scrub formations in thee areas on the banks of the water courses stays stable throughout the time period, see Figure 3, clearly because of the difficult physical pattern conditions, nothing else but scrub growth is possible here.

The absence of scrubs in a great part of the area in the first year can be explained by the policy incentives for maximizing cereal production. Large areas, also those with unfavourable conditions were cultivated, leading to a rapid degradation of the soil in some areas. Scrub was therefore rare. The agricultural area occupied for over 80% of the area in this year.

From 1958 to 1985 the area of scrub has clearly been growing at the expense of agricultural land, which declined to 52% in 1985. Large parts of the agricultural area, also those with favourable conditions, turned into low, scattered *matorral*, and areas of low, scattered *matorral* have turned into middle, discontinuous *matorral*. Both low and middle *matorral* account for almost 20% of the area. This indicates a gradual succession of agricultural area and low *matorral*.

In 2000 the area with middle *matorral* has decreased, and occupies only 13%, this also accounts for low *matorral*, which also declined to 11% of the area. Most of the scrub areas has been replaced by new forest plantations, which are planted within the framework of the CAP. The agricultural area is still in decline, and currently corresponds to 39% of the area.

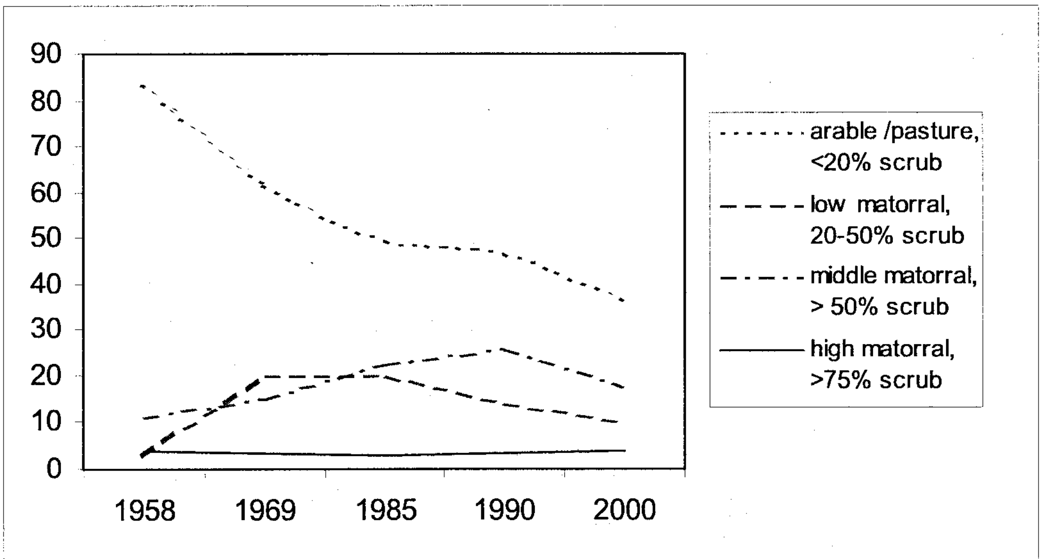

Figure 3. Trends in scrub cover.

Interviews

44 landowners were interviewed, corresponding to 56% of the landowner population, and covering 81% of the study area. Based on main source of income and age, four groups of farmers could be distinguished. 32% of the interviewees were involved with extensive livestock breeding, sheep and cattle, as their main agricultural activity and have an average property size of 380 ha. These are the dynamic and expansive farmers, still maintaining farming systems, which is their main income source. They are thus interested in using all the land that is available.

A similar percentage, 23%, are retired peasant farmers, no longer actively practicing agriculture but still possessing land in the area, which is often rented out. The average property size of these farmers is 89 ha. A third group of 30% which can be distinguished among the interviewees are the landowners who do not live in the area, but manage their property from a distance. Forestry is the main type of land use for these landowners, with an average property size of 200 ha. The remaining 15% corresponds to landowners, associations or individuals, who have mixed farm management.

In response to questions about the regime of fallow, 57% of the respondents still maintain a fallow period, which ranges from six months to three years, whilst formerly this was between five and six years. This intensification is related to the tendency to profit form EU cereal subsidies. The reason behind the fallow regime is partly because of soil recovery and partly because it is obligatory. After being fallow the soil is ploughed and sowed with wheat.

The other 43% do not consider pastures as fallow land, since they stopped cultivating cereals only recently, and thus no longer practice the traditional rotation system, with ploughing every third or fourth year. Or as a farmer said: 'actually I always have fallow land now i.e. he uses his land only for extensive livestock grazing, which was formerly the only use during periods of fallow.

More than 70% of the respondents, mostly those owning large properties, had some part of their property outside agricultural production, often with scrub cover varying from less than one hectare up to 160 ha per property. These parts are often not cultivated due to physical constraints like steep slopes, stoniness or inaccessibility. Sometimes, patches are left because of lack of means or labour or because of external restrictions e.g. regulations of the natural park. In half of the cases the areas, which do not have a productive function at present, were formerly used for cereal growing (peripheral parts), vegetation gardens (along the small water courses) and goat grazing (steep slopes).

The majority of respondents (66%) think the scrub area will not increase, and a minority expecting the opposite: i.e. the scrub area will decline, since they just started cleaning their property from scrub. Only a few people, belonging to the group of the retired peasant farmers, think that the scrub area on their property will increase in the near future.

The potential of the areas that are at present outside the agricultural production is considered as varied. Only a few landowners, retired farmers, consider these areas as worthless: 'it is just stones there', 'it does not serve for anything'. Some leave the question whether such areas are valuable or not to the responsibility of the owner of that particular area: the area might have an agricultural density but it depends on the strategy of its owner. From this point of view some refer to the possibility that 'machines can always clean the area' and as such offer possibilities for cultivation. The majority, however, considers the areas without agricultural production on their property as valuable, referring to a lack of scrub in another region close by. Some value these areas because of the function of shelter place for livestock as well as for game animals or because of the presence of valuable nutrient resources for bees. Also, the importance for the environment, regeneration of trees and recovery of species is acknowledged by some of the interviewees. This point of view explains why the majority of the interviewees does not consider areas without any agricultural production function, as 'abandoned land'.

In asking landowners what they consider as abandoned land, the answers were diverse and touch on several issues concerning the concept. Some stressed the importance of land ownership: if an area does have a landowner as laid down in the cadastral administration, then the area is not abandoned. According to this point of view land abandonment does not exist in the study region since every piece of land has an official owner.

A considerable group of 36%, often livestock farmers, referred to economic profitability; land is abandoned when the owner does not exploit the area, some mentioned explicitly cultivating, they consider a land as abandoned when it is not ploughed, not sowed nor grazed. Some respondents specify this statement by arguing that an area can only be considered as abandoned when it does not achieve its agricultural potential, i.e. a piece of land which could be cultivated but actually is not. A few farmers considered the importance of the size of the unproductive area, they mention that only 'a considerable' area which is not cultivated can be considered as abandoned. There were also some respondents, retired farmers who related the concept with expressions that might not be related with any use of the land at all: 'land where nobody takes care of' or 'land to which nobody is related'.

However, a major group of 39% refers when dealing with abandonment to the absence of *any* type of use or profit of an area, including hunting, honey production, soil and nature conservation and wild fruit collection, So, even when an area does not show any agricultural activity they still consider it not being abandoned, but useful for other types of activities.

Implications for Conceptualisation of abandonment

From cartography an irregular trend in scrub cover and open areas was observed. A part of the scrub area, the high *matorral* area, was stable throughout the study period. The stability of the *matorral* is related to the physical conditions because nothing else than scrub encroachment could take place. Other scrub areas were on more favourable areas and are highly dynamic, they increase and decrease during the study period, depending on activities of individual farmers. These areas do not show a gradual process of invading scrub on formerly cultivated areas.

The interviews made clear that landowners in the study area did not consider the areas within their property without agricultural production, as abandoned. The same applied to scrub areas in general. The majority attributes other uses or profits than cultivation and grazing from these areas. Consequently, in the case study area scrub does not indicate non-use of an area, on the contrary: often it has a multiple use.

Combining the outcome of the aerial photo interpretation, with the data of the interviews and the concept definition given in the introduction, the results have complications in understanding the relation between land cover, land use, and the concept of land abandonment. These three concepts are often used in the same way, but from the study it is concluded that they are not necessarily exchangeable.

Figure 4 makes this clear; the continuous arrows indicate an unambiguous connection between concepts. The interrupted arrows indicate that an indicator might not directly be derived from another. The arrow between the concept of land abandonment and land cover indicates a direct connection: when areas are subject to land abandonment, i.e. the soil stops being used and managed, secondary succession is taking place, resulting in scrub encroachment. However, the other way around, when an area is covered by scrub, one might not conclude directly that the area is subject to land abandonment, because a number of land use activities e.g.

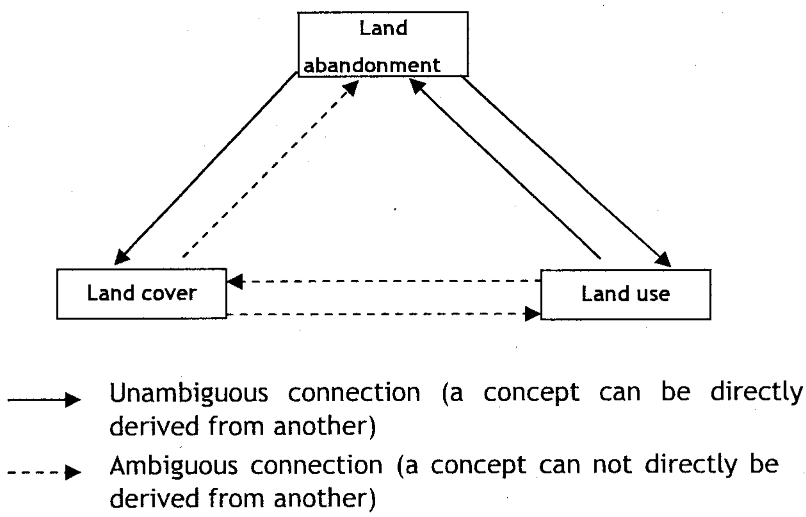

Figure 4. Connections between concepts dealing with land abandonment on local scale Mediterranean landscapes.

hunting, beekeeping and extensive livestock breeding are still possible

The arrows between land use and the concept of land abandonment are both continuous. Since the concept is dealing with the land use in a particular area, one can only determine if an area is abandoned or not, if its land use is known.

The arrows between land cover and land use are both interrupted, because they cannot be derived directly from each other when dealing with land abandonment processes. For example, when scrub invades an area, it is not clear what this means in terms of land use, since many uses are still possible in an area covered with scrub, as mentioned above. Alternatively, the associated land cover may not directly be derived since Mediterranean land use systems are mixed and can be associated with various types of land cover.

The described connections of the concept of land abandonment and its associated land cover are specific for the study area of this paper and depend on the particular type of land use system. Applying the scheme to land use systems of north-west Europe for example, more direct connections might be made, where land uses are less intermixed, and the differences between arable land, grassland and forest are more clear.

According to Figure 4 the utility of the use of scrub as an indicator of land abandonment depends on the concept definition. If land abandonment is defined as the total withdrawal of *all* human activities, then scrub cover can be used as an indicator. In all other cases one has to be careful with drawing conclusions on basis of land cover data only because it does not provide enough information on the actual use of the land.

The observed multifunctionality of scrub area coexists with an active rural population in the region. If the process of population decline continues in the next decades, it is doubtful whether this multifunctionality will be maintained. Some functions e.g. honey production and fruit collection might disappear, because they require intensive and frequent involvement of the manager. Other, such as hunting, probably might gain economic importance. The management of scrub will depend on this kind of land use.

The study presented is carried out in two small case study areas and the number of interviewed landowners is limited. Because of the interdisciplinary approach in which aerial photo interpretation was combined with interviews with landowners the scale at which the study could be done was restricted. In spite of the limited scale the study provides a valuable contribution to the conceptualization of land abandonment processes.

Conclusions

To prevent landscapes from being abandoned, which is desirable for the maintenance of biodiversity and cultural heritage (Wascher 2000; Meeus 1995), the involvement of many ecological and socio-economic aspects is required and remains a complicated issue.

This study shows the importance of monitoring land use as well as land cover in areas threatened by land abandonment. The method used in the study, combining cartography with interviews with landowners has proven to be suitable in showing that scrub does not always correspond to land that is subject to land abandonment. However, the method may only be applicable in small case study areas.

The definition of abandoned land relates in many cases not to agricultural abandonment, since other types of land uses are practiced in the area. The connections between land cover, land use and the concept of land abandonment and agricultural abandonment depend on the land use system and should be established in future research on processes of land abandonment which aim at understanding and improving land management and related policies.

For landscape planning and policy making in areas threatened by abandonment it is of importance to take into account the activities still carried out by local people.

References

Acacio, V. (2005). The dynamics of cork oak systems in Portugal: the role of ecological and land use factors. Presentation, European IALE Congress, Faro 2005.

Alves, A.L., Siqueira de Carvalho, N., Castel-Branco da Silveira, S., Marques, J.P., Costa, Z. & Horta, A.L.L.O. (2003). O abandono da actividade agrícola. Ministério da Agricultura, do Desenvolvimento Rural e das Pescas, Lisbon, Portugal.

Bandarra, N.J. (1993). What land use for a sustainable agriculture? *The situation of agriculture in Mediterranean countries. Soils in the Mediterranean region: use, management and future trends*. Pp. 135-153. Zaragoza, Spain.

Breman, B. & Pinto Correia, T. (2003). Coping with marginalization and multifunctional land use in Porgugal. Eurolan-report.

Brum Ferreira, D. (1999). Os incultos na dinâmica da paisagem do Alentejo. In: Cavaco, Carminda (eds.), *Desenvolvimento Rural Desafio e Utopia*, Estudos para o Planeamento Regional e Urbano pp. 235-242. Centro de Estudos Geograficos da Universidade de Lisboa, Portugal.

Burel, F. & Baudry, J. (1995). Species biodiversity in changing agricultural landscapes: A case study in the Pays d'Auge, France. *Agriculture, Ecosystems & Environment* 55(3): 193-200.

Coppola, A. (2004). An economic perspective on land abandonment processes. Working paper presented on AVEC workshop on Effects of Land Abandonment and Global change on plant and animal communities.

Dunjo, G., Pardini, G. & Gispert, M. (2003). Land use change effects on abandoned terraced soils in a Mediterranean catchment, NE Spain. *Catena* 52: 23-37.

Feio, M. (1998). *A evolução da agricultura do Alentejo Meridional: as cartas agricolas de G. Pery*. Edições Colibri.

Fernandez Ales, R. & Matin, A. (1992). Recent changes in landscape structure and function in a Mediterranean region of South West Spain. *Landscape Ecology* 7: 3-18.

Gonzalez Bernaldez, F. (1989). Ecological consequences of the abandonment of traditional land use systems in central Spain. In: Baudry, J. & Bunce, R.G.H., *Options Mediterranéenes, Serie Seminaires*, Land abandonment and its role in conservation: 23-29. Zaragoza, Spain, CIHEAM.

GPPAA (2004). Desenvolvimento e ruralidade em Portugal, uma análise empirica. Ministerio da Agricultura, do Desenvolvimento Rural e das Pescas, Lisboa.

Instituto do Ambiente and IGEOE (2005). CORINE Land Cover 2000 em Portugal.

Instituto Nacional de Estatistica (2001). Recenseamentos Gerais da Agricultura, Dados comparatives 1989 - 1999.

Meeus, J.H.A. (1995). Pan-European landscapes. *Landscape and Urban Planning* 31: 57-79.

Moreira, F., Rego, F.C. & Ferreira, P.G. (2001). Temporal (1958-1995) pattern of change in a cultural landscape of north-western Portugal: implications for fire occurrence. *Landscape Ecology* 16: 557-567.

Pinto Correia, T. (1993a). Threatened landscape in Alentejo, Portugal: the 'Montado' and other 'agro-silvo-pastoral' systems. *Landscape and Urban Planning* 24: 43-48.

Pinto Correia, T. (1993b). Land abandonment: Changes in the land use patterns around the Mediterranean basin. In: Baudry, J. & Bunce, R.G.H. (Eds.), *Options Mediterranéennes,* The situation of agriculture in Mediterranean countries: 97-112. Zaragoza, Spain, CIHEAM.

Romero-Calcerrada, R. & Perry, G.L.W. (2004). The role of abandonment in landscape dynamics in the SPA 'Encinares del rio Alberche y Cofio', Central Spain, 1984-1999. *Landscape and Urban Planning* 66: 217-232.

Roxo, M.J., Mourão, J.M. & Casimiro, P.C. (1998). Políticas agrícolas, mudanças de uso do solo e degradação dos recursos naturais - Baixo Alentejo Interior. *Mediterrâneo* 12/13: 167-189. Lisbon, Portugal, Instituto Mediterranico.

Tomaselli, R. (1981). Main physiognomic types and geographic distribution of shrub systems related to Mediterranean climates. In: Di Castri, F., Goodall, D.W. & Specht, R.L. (eds.), Ecosystems of the World II, *Mediterranean-type shrub lands*, pp. 95-106.

Wascher, D.M. (2000). *The Face of Europe, Policy perspectives for European Landscapes*. ECNC, Tilburg, The Netherlands.

Chapter 3 Paper B

Differences in land cover interpretation in landscapes rich in cover gradients: reflections based on the montado of South Portugal

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Abstract

This paper contributes to the discussion on current issues in methodologies of mapping land cover in the agro-silvo-pastoral landscapes of the Mediterranean. These landscapes, characterized by intermixed land use and indefinite boundaries, require particular attention in applying the patch-corridor-matrix model when classifying patches and their delineation. In a case study area in southeast Portugal, mainly characterized by agro-silvo pastoral systems, the land cover for 1990 has been mapped. The paper discusses the consequences of the complexity of some Mediterranean land use systems for land cover mapping dealing with detailed landscape dynamics. Within this scope a land cover mapping project in a small case study area is compared with the mapping undertaken within a national land cover database. Both studies were carried out on the same scale and through visual interpretation of aerial photographs. Differences in land cover classification and allocation are explored using matrix with levels of agreement. Recommendations for future land cover mapping projects are: the application of fuzzy approaches to land cover mapping in agro-silvo-pastoral landscapes should be explored and land cover classifications should be standardized in order to enhance consistency between databases. On the other hand, the fuzziness of the boundaries in this kind of landscapes is inherent to the system and should be accepted as such. The accompanying uncertainties should be taken into account when undertaking landscape analysis on the basis of land cover data.

Keywords

Land cover classification, montado / dehesa, Thematic cartography, Visual aerial photo interpretation.

1 Introduction

In landscape ecology the patch-corridor-matrix model of Forman (1995) is widely adopted. In this model, landscapes are represented as matrices, which are constructed of 1) mosaics, consisting of collections of discrete patches and 2) networks, consisting of collections of corridors. Many fundamental ideas as well as tools and methodologies within landscape ecology are constructed upon this paradigm (McGarigal and Cushman 2005). These concepts are mainly based on studies of North America (Forman 1995) and northwest Europe (Zonneveld 1995), and not of the Mediterranean or other complex landscapes. Land cover maps, derived from aerial photographs or satellite image, are usually categorical maps, in which the land cover is classified into discrete, non-overlapping land cover classes. Subsequently, patches are delineated qualitatively according to the land cover classification, assuming homogeneity throughout the whole patch. Although the discrete land cover categories have been set up artificially as well as the boundaries of the patches, this approach applies well to landscapes, monitored on a regional or local scale, which display a clear matrix. This is the case in landscapes where the boundary between two areas, for example pasture and forest, is fixed, because is coincides with a clearly defined line on the ground: e.g. a vegetation border, a fence, a hedgerow or a watercourse. Examples can be found in the landscapes of e.g. the Netherlands, Denmark, New Zealand etc.

However, other landscapes contain continuous gradients in terms of land cover, e.g. the agro-silvo-pastoral landscapes on the Iberian Peninsula, also known as *montado*s (Pt.) and *dehesas* (Es.). Delineating patches in these landscapes is currently more a matter of judgement (interpretation) than based on strict rules as defined in the patch-corridor-matrix model. Moreover, categories of forest cover are often created in different ways, using different rules. Consequently, the classification and the delineation of the land cover patches poorly represents true heterogeneity of the landscape (McGarigal and Cushman 2005). Efficient classification and mapping methods are important for systematic collection of information of *montado*s and dehesas. At present, reliable data on trends in agro-silvo-pastoral systems are still lacking (Eichhorn, Paris et al. 2006).

The main goal of the paper is to discuss the issues regarding classification and mapping of land cover in Mediterranean agro-silvo-pastoral landscapes using aerial photographs. The paper stresses the risk of important imprecision and different representations of reality when land cover maps, originating from different sources and created by using different rules for classification and mapping, are compared. The paper has two objectives:

- To discuss the issues involved in the classification of land cover in European Mediterranean landscapes
- To discuss the delineation of land cover units in landscapes rich in land cover gradient.

The land cover mapping done within the VISTA-project (EVK2-2001-000356) was compared with a already existing land cover map, which is the national land cover database COS'90 (Instituto Geográfico Português 1990), to illustrate the differences in approaches of classification and delineation of patches and the accompanying problems. The paper aims at understanding the differences between these two representations of one real world situation. Weaknesses and uncertainties are inherent to representations, and create differences between the geographic models and the real world. These differences are inevitable, but understanding them helps us to cope with this uncertainty (Longley *et al.* 2005).

2 Land cover mapping of Mediterranean landscapes at different scales

In parts of the Mediterranean a highly diversified landscape pattern emerged, still in existence today, through mixed land use and agro-forestry practices. This resulted in some of the most diverse ecosystems in Europe (Council of Europe 1992). The landscape is often characterized by continuous gradients of shrub and tree densities, a result of variable, extensive land use practices. For the purpose of this paper extensive land use practices are defined as land use practices that are characterised by low levels of inputs per unit area of land (EEA 2006). The presence of many continuous gradients of shrub and tree densities deserves extra attention when one starts to classify and map land cover and is in particular relevant for landscapes characterized by agro-silvo-pastoral systems e.g. the *dehesas,* in Spain and *montados,* in Portugal.

Figure 1: Different classes of *montado*, above: *montado*, between 5 - 10% tree cover and less than 20% shrub cover; middle: *montado*, 5-10% tree cover and 20-50% shrub cover; below: *montado*, more than 30% tree cover and less than 20% shrub cover

According to the description of the European Environment Agency (2005), the agro-silvo pastoral landscapes constitute 'a characteristic landscape in which crops, pasture land or Mediterranean scrub, in juxtaposition or rotation, are shaded by a fairly closed to very open canopy of native oaks, (*Quercus suber, Quercus rotundifolia, Quercus pyrenaica, Quercus faginea*)'. This definition indicates that there are many possible variations within this single term. Figure 1 shows some examples of variations of the *montado* system.

Mapping land cover requires mapping methods that differ when the scale of mapping differs. At a national or international level, a single designation as dehesa / *montado*, or a distinction between the four main life-forms in Mediterranean regions: trees, shrubs, dwarf shrubs and herbaceous vegetation maybe be adequate. However, when an area is mapped in more detail at a regional or local scale, with a minimal mapping unit (m.m.u.) of e.g. 1 ha, more divisions on the classification tree are desirable to represent subtle transitions in vegetation types. This is because small differences within the agro-silvo-pastoral systems in terms of tree density and shrub cover reflect important differences in the abiotic factors (Joffre 1999), the type of management in the past and present (Joffre 1999; Pinto-Correia 1993), and levels of biodiversity (Ojeda *et al.* 1995). These differences might also indicate different potentials for other complementary uses as hunting, beekeeping, collection of natural products, recreation, and are thus of importance for landscape multifunctionality (Pinto-Correia and Vos 2004).

Visual interpretation of aerial photographs for landscape cartography carried out in agro-silvo pastoral landscapes on regional level, are done by Fernandez Ales *et al.* (1992), Santos Pérez and Remmers (1997) and Plieninger (2004). In these papers one land cover category covers the agro-silvo-pastoral system, and the total number of categories often does not exceed seven. The number of categories is limited to enhance the legibility of the maps, despite the complex nature of the landscape. However, when comparing this approach to the heterogeneity and complexity of the system itself, using only one land cover class for agro-silvo-pastoral system in research carried out on regional to sub-local level, oversimplifies the real life situation and neglects important differences. This is especially true when land cover mapping is done aiming at identifying detailed landscape dynamics, making use of case studies that operate on a scale ≤ 1 : 25.000. Moreover, in order to understand landscape dynamics and its associated factors, relations between land cover and land use have to be established. Small differences in land cover might indicate significant differences in land use and / or management regimes. Therefore a careful assessment of the land cover classification is required.

3 Study area & Materials

3.1 Study area

The case study area, of 44km2, is located in the southeast of Portugal (37° 40' N, 7° 47' E, datum WGS-1984), and is shown in Figure 2. A gently sloping relief and a mosaic of varied land cover, with arable land, grassland, shrubs and open oak forest in varying mixtures characterize the landscape.

The dominant soil type is a poor and shallow litho-soil of non-calcareous schist (Roxo et al. 1998) The climate is typically Mediterranean, with most precipitation concentrated during the mild winter months, with on average 500 - 650 mm rainfall a year, followed by approximately four months of drought during the hot summer, when the temperatures often attain 30 - 40 degrees (Perez1990)

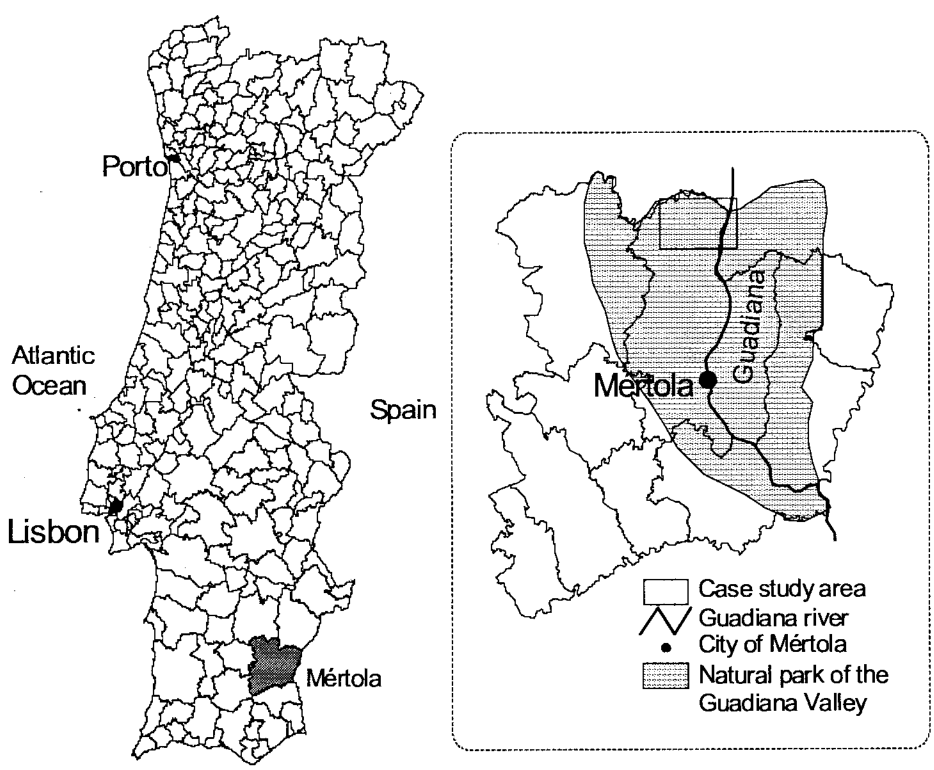

Figure 2. Location of the study area

In the past intensive cereal growing has taken place, as a result of a national policy searching for self-sufficiency in food-production, and reached a maximum of production in the first decades of the 20th century. This exploitation of the soil caused many problems with erosion and land degradation. Because of declining production and rural exodus cereal growing diminished from the 1950's, leaving behind highly degraded soils (Roxo *et al* 1998).

Due to this severe soil degradation, the unfavourable biophysical conditions and socio-economical aspects, the land use is at present dominated by extensive farming systems. The main land use activities are livestock raising and some cereal production, mainly for fodder production. Most land owners normally practise a rotation cycle of three years, with one year of cereal growing and two years of fallow in combination with grazing. Others do not grow cereals and only have livestock. There are also some landowners who do not practise agriculture but use their land for hunting reserves or new forest plantations supported by legislations of the Common Agricultural Policy of the European Union.

The extensive use of the soil, in combination with heterogeneous physical conditions, has resulted in various densities of shrub cover, representing different degrees of the intensity and type of management. As a result, the borders between arable land, pasture, scrub and forest are fuzzy transitions rather than discrete edges and therefore not clearly visible. This gradient-like aspect is strengthened because some parts of the arable land, grasslands and natural pastures are covered with dispersed oak trees that are part of the land use system, the *montado* (Pinto-Correia 1993, Pereira and Pires da Fonseca 2003).

3.2 Material

Although the application of satellite images has become more common in landscape research, aerial photographs remain indispensable for detailed surveying (Fuller 1981; Longley *et al.* 2005). The pan chromatic aerial photographs of 1990 (Centro Nacional de Informação Geográfica 1990) were used to carry out the visual interpretation of the land cover. These photographs were made during the summer months (June - September). In this period pastures are dry, and appear as white fields, the trees appear as dark dots, as do the scrub formations, though the latter are more greyish. In this way tree and shrub cover contrast clearly with the understorey that makes identification easier.

The aerial photographs have a 1: 25.000 scale. The hard copies were scanned, using 600 dpi, resulting in a pixel dimension on ground level of 1 m. Next, the visual interpretation was carried out on screen.

4 Land cover classification and mapping

4.1 Land cover classification

On aerial photographs one can interpret visually land cover categories (Lillesand and Kiefer 1994). These land cover categories should be thematically consistent, not including land use or environmental conditions (Loveland *et al.* 2005). The composition of a land cover classification depends mainly on (1) the type of landscape, (2) the spatial scale, (3) the purpose of the study and (4) the available data sources. Because the tools for the adoption of a gradient approach for mapping land cover are currently unavailable, a discrete classification for land cover was adopted, using the patch-mosaic model of Forman (1995).

In order to relate land cover to land use in a later stage of the research the classes in the land cover classification should correspond to different management regimes, as far as the differences can be observed through the land cover. On basis the previous discussion, the local scale of the study, and previous work done in the area, a land cover classification has been constructed for the VISTA-project, which is displayed in table 1, also showing the accompanying main land uses per land cover category.

The land cover classification consists of 14 categories and are mainly separated on the basis of physiognomy. Category 1, 2 and 3 are widely used and can be clearly recognised on aerial photographs. Categories 5, 6, 7 (*matorral*) and 9 - 14 (*montado*) are the land cover classes on which the paper focuses on.

Category 4 arable / grass land includes those areas that are characterized by the absence of trees and shrubs and might correspond to arable land as well as pasture. The main agricultural activities are cereal growing in a 3-5 year rotation with fallow in combination with extensive livestock breeding of sheep, cattle and, less frequently, goats or pigs. Some dominant plant species in this land cover category are: *Agrostis pouretii, Carlina corymbosa, Tolpis barbata* and *Chamaemelum mixtum.*

Categories 5 - 7 are the categories of the different types of scrub, that are present in areas with less or no agricultural activities. Depending on the biophysical conditions and the type and intensity of land use the types of scrub vegetation differ in height and density of the shrubs and in species composition. Because local names of these different scrub types cause confusion we decided to apply the standardized nomenclature of Tomaselli (1981) for *matorral*. *Matorral* is defined as a shrubby formation of woody plants related to Mediterranean climates. Three categories of *matorral* are distinguished:

Land cover classification			**Land use**
1	hamlets / farm buildings horticulture / orchards /		residential
2	waterlines / reservoirs		wildfire prevention, hunting, fishing, watering place for livestock,
3	olive grooves		production of fruit and vegetables for home consumption
4	arable / grass land, s.c. < 20%		livestock grazing, cereal production, hunting
5	low, scattered *matorral*, s.c. 20-50%		livestock grazing, hunting
6	middle, discont. *matorral*, s.c.50-75%		hunting, honey production
7	high, dense *matorral*, s.c. >75%		hunting, beekeeping, nature conservation.
8	forest plantations		wood / cork production
9	*montado*, c.c. <10%	s.c. <20%	cereal growing, sheep and cattle grazing, hunting,
10	c.c. <10%	s.c. >20%	sheep and cattle grazing, hunting,
11	c.c. 10-30%	s.c. <20%	cereal growing, sheep and cattle grazing, wood, acorn, cork production, hunting.
12	c.c. 10-30%	s.c. >20%	sheep and cattle grazing, wood, acorn, cork production, hunting,
13	c.c. >30%	s.c. <20%	cereal growing, sheep and cattle grazing, wood, acorn and cork production, hunting,
14	c.c. >30%	s.c. >20%	sheep and cattle grazing, wood, acorn and cork production, hunting,

Table 1. Land cover classification used for the interpretation of the aerial photographs in the VISTA-project

Category 5 is low, scattered *matorral* and corresponds to natural pasture where sparse shrub covers 20 - 50% of the surface. The shrubs have a maximum height of 0,6 m. and common species are *Lavendula stoechas, Genista hirsute, Carlina corymbosa, Helichrysum stoechas*. These areas are not subject to a rotational management. There is grazing but no crop growing, the area stays open through grazing but due to the low grazing intensity small shrubs can germinate.

Category 6 is middle discontinuous *matorral* . This type is between 0,6 and 2 meters high and the shrub cover between 50-75% of the surface. It a homogeneous formation of *Cistus ladaniferus*, but also *Quercus ilex, Lavandula stoechas, Genista hirsute* can be found. Middle, discontinuous matorral grows mainly on former cultivated lands or recently burned areas, since *Cistus ladaniferus* is an active pyrophyte. This type of *matorral* might represent an alternative stable state, which is highly persistent in the absence of human intervention, because seed establishment of *Quercus* species is difficult in this kind of scrub formation (Acacio 2005).

Category 7 is high, dense *matorral* (cat. 7), which can reach a height of more than 2 m., and can especially be found on the steep slopes along the waterlines. It is a heterogeneous formation, rich in species like *Arbutus unedo, Olea oleaster, Pistacia lentiscus* and *Quercus rotundifolia*. The structure of this type of *matorral* is more granular than the middle *matorral*, and thus as such recognisable on aerial photographs, since the vegetation composition is more varied and consists of bushes and small trees.

Category 8 includes the forest plantations, which are defined as areas where trees are recently planted or sowed in a process of forestation, or those areas where trees have been planted artificially less recently but still only have a forestry goal.
The selected species can be either native or exotic. In the first case it will be cork oak (*Quercus suber*) or holm oak (*Quercus rotundifolia*) and the forest plantation might develop into a *montado*. In the case of exotic species, the species that are selected for their wood and cellulose producing properties e.g. *Pinus* and *Eucalyptus*.

The land cover categories 9 - 14 deal with the agro-silvo-pastoral system, here after called *montado*. The *montado* distinguishes from the arable / grass land category and from the *matorral* categories, because of the presence of a tree cover of cork or holm Oak trees of more than 5%. In the case study area the dominant species is holm oak (*Quercus rotundifolia*), but also patches of cork oak (*Quercus* *suber*) can be observed. The trees are visible as such on aerial photographs when they are more than 10 years old.

The *montado* classification is set up as a combination between tree density and shrub cover, resulting in 7 categories, which should reflect different options and intensities of management. The tree density can be estimated in numbers of trees per hectare or in crown cover percentage. In recent studies dealing with *dehesas* and *montado*s the number of trees per hectare is often used (Pereira and Pires da Fonseca 2003, Casimiro 2002, Joffre 1999) while international land cover data bases like CORINE and methodologies for habitat mapping like BioHab (Bunce *et al.* 2005) use the crown cover (c.c.) percentage. A drawback of a classification based on the number of trees is that it does not take into account the difference between trees with large canopies and those with smaller ones, i.e. every tree counts equally. For this reason a classification based on the crown cover percentage was used.

Concerning CORINE and BioHAb (Bunce *et al.* 2005) the minimum crown cover for forest is 30%. For this reason those *montado* areas with a crown cover superior to 30% should be considered separately, since they represent 'real' forest.

The minimal tree density for the *montado* is in Portugal by law established at 10 trees ha^{-1} (*Decreto lei nº 11/97 de 14 de Janeiro*). In which way the number of trees is related to crown cover percentage depends on the crown perimeter of the trees. Figure 3 displays a detail of the aerial photograph of 1995 of the case study area. The black square represents 1 ha, within the square there are 23 trees, which are outlined in white. The total crown cover of the trees is calculated using the X-tools extension in ArcView and corresponds to 0,073ha, which means the corresponding crown cover is 7,3 %. So 20 trees ha^{-1} might represent less than 10% c.c. To make a distinction between this very scattered type of *montado* and the more open forest type two classes were distinguished: the open forest class with a c.c. between 10 -30% and the scattered *montado* with less than 10% c.c., but with a lower limit of 5%. These limits coincide with Bunce *et al.* (2005).

The second division within the *montado* classification is made on the type of understorey that is closely related to the type of short-term management and levels of disturbance. When the shrub cover (s.c.) is less than 20%, it is assumed that the area is frequently grazed and once in a while ploughed. A shrub cover of more than

20% corresponds to scattered, discontinuous or dense matorral and indicates much less intensive use of the soil.

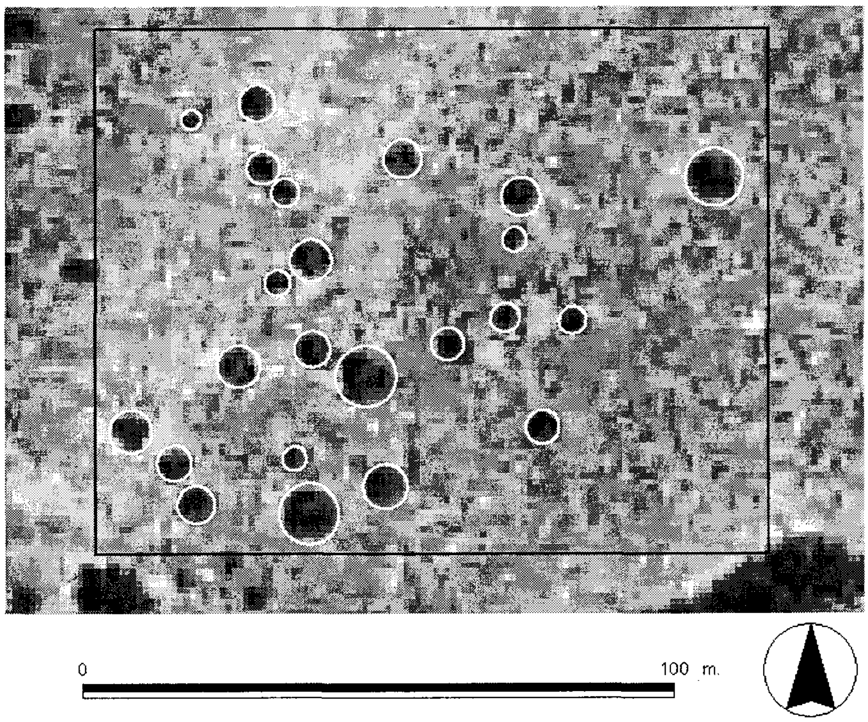

Figure 3: Detail of aerial photograph with tree cover estimation

4.2 Land cover mapping

Visual interpretation of aerial photographs is a qualitative approach that starts from the image characteristics as perceived on the printed version or on screen. Because it is a qualitative process there is no single "absolute" way to approach the interpretation process (Lillesand and Kiefer 1994). According to the same authors the basic characteristics of the aerial photo used when carrying out a visual interpretation are: shape, size, pattern, tone or hue, texture, shadows, geographic or topographic site and associations between features .

The interpretation and delineation started with most easy classes to identify, e.g. groups of houses, water courses and forest plantations, and subsequently the more complex ones like the different categories of *matorral* and *montado.* The minimum mapping unit (m.m.u.) varied with the type of land cover class. For reservoirs, groups of houses, olive grooves and waterlines it was 0.25 ha, for the other classes 0.5 ha.

The different types of *montado* according to crown cover and shrub densities were also relatively easy to recognize. In a couple of areas the crown cover was calculated as shown in Figure 3. Because of efficiency reasons this was not done for the whole area but rather to develop an expert eye on estimating percentages of crown cover.

To avoid observer bias, resulting from differences in opinion about the delineation of the fuzzy boundaries, only one observer did the interpretation.

After this preliminary phase of interpretation, fieldwork was carried out in the spring of 2003. This was mainly when doubts were registered in the aerial photo interpretation. The objective was to check the photos because they were old and sometimes unclear. Based on the occasional field work in combination with recent aerial photographs their information was corrected.

5 Comparison with the national land cover database COS'90

5.1 Land cover data base COS'90

The VISTA land cover map has been compared with the land cover map of COS'90, which is the national land cover database (Instituto Geográfico Português 1990) on a 1: 25.000 scale covering the entire continental part of Portugal. The database is widely used for monitoring land cover changes. The maps were produced through visual interpretation of false-colour aerial photographs, 28.000 in total, taken in the summer of 1990, using a m.m.u. of 1 hectare (Instituto Florestal 1994).

Because of the national wide coverage and the detailed mapping scale, the land cover classification is comprehensive, and contains 78 categories. The *montado* areas are covered by a number of forest classes. These classes are composed of the combination of crown cover percentage and the dominant tree species. Crown cover percentage is subdivided into four classes, ranging from less than 10% to more than 50%. The minimum limit of tree density for agro-forestry areas is considered to be 5 trees ha-1 or 5% tree cover of the area. In terms of species, two types of trees are important: cork oak and holm oak. In total 16 classes of *montado* are used, which are exclusively based on the composition of the tree cover, without considering different types of understorey.

A comparison between the VISTA and the COS'90 categories for *montado* and matorral and some other land cover categories is displayed in the 1st and 3rd column of table 2.

5.2 *Comparison between the two land cover maps*

Although the land cover classes of both approaches are slightly different, one can compare the differences in mapping by adapting both classifications to each other. Because COS'90 does not take into account shrub densities, we aggregated the *montado* classes of VISTA to 3 classes based on tree cover percentages: <10%, 10-30% and >30%. Because there was no further distinction in tree cover for > 30% within the VISTA classification, the categories of COS'90 of 30-50% and >50% were aggregated. Also the sub categories of COS'90 on the basis of tree species (holm or cork oak), were aggregated. The final categories of the categories of *montado* and matorral to be compared are displayed in the 2nd column of table 2. Because the COS'90 map only displays two categories of scrub (*matorral*) vegetation, it was decided to merge the classes of middle and high matorral of the VISTA-map Besides the *montado* and matorral categories, which are characterized with fuzzy borders, 4 categories with clear boundaries were chosen for the comparison of the two land So, in the end a comparison was made of the areas of arable land, horticulture, forestations, olive grooves, three categories of *montado* and two categories of *matorral*, see table 2.

The consistency between the two maps can be evaluated according to the two basic errors of land cover maps: the misallocation of boundaries and the misclassification of areas (Longley *et al.* 2005). Since it is impossible to judge in this kind of complex landscapes which interpretation is the right one, or which limit represents the 'true' boundary, they can rather be mentioned as *differences* instead of as *errors*. To assess the difference in misallocation of a boundary, a rule of thumb can been used, as recommended by Longley *et al.* (2005): features, patches, lines or dots, might be subject to errors of up to 0.5 mm on the map at a scale of 1 : 20.000 or smaller. So, if patch boundaries differ more than 0.5 mm on the map, they are significantly different.

The misclassification of areas was assessed by a systematic comparison of both maps. To make this comparison both polygon maps were rasterized with one raster cell representing 1 hectare. A sample area of 22 km2 in the centre of the case study area was chosen to carry out the detailed comparison between VISTA and COS'90. This was done by overlaying the two raster maps. Next, levels of agreement between the 2 land cover maps were assessed by applying the concept of the confusion matrix (Foody 2002). Normally, a confusion matrix is used to compare ground data and map data., for the purpose of this paper it was used to compare both land cover maps. Percentages of overlap of the categories for comparison (table 2) on the COS'90 map in relation to these categories on the VISTA-map were calculated and listed in a matrix.

VISTA		**Categories for comparison**	**COS'90**
arable / grass land		**arable/ grass land**	arable land, non irrigated
olive grooves		**olive groove**	olive groove
forest plantation		**forestations**	forest plantations
low, scattered *matorral*, s.c. 20-50%		**low matorral**	low shrub
middle, discont. *matorral*, s.c.50-75%		**high matorral**	high shrub and degraded forest
high, dense *matorral*, s.c. >75%			
montado, c.c. <10%	s.c. <20%	**montado c.c. < 10 %**	arable land + holm oak c.c.<10%
			arable land + cork c.c.<10%
c.c. <10%	s.c. >20%		holm oak (spontaneous)
			cork oak (spontaneous)
c.c. 10-30%	s.c. <20%	**montado c.c. 10 - 30 %**	holm oak c.c. 10 - 30%
			cork oak c.c. 10 - 30%
c.c. 10-30%	s.c. >20%		holm oak + cork oak c.c. 10-30%
c.c. >30%	s.c. <20%	**montado c.c. > 30 %**	holm oak > c.c. 30%
			cork oak > c.c. 30%
c.c. >30%	s.c. >20%		holm oak > c.c. 50%
			cork oak c.c.> c.c. 50%
			holm oak + cork oak c.c. 30- 50%

Table 2. The different classes of matorral and Montado of the classifications of VISTA and COS'90

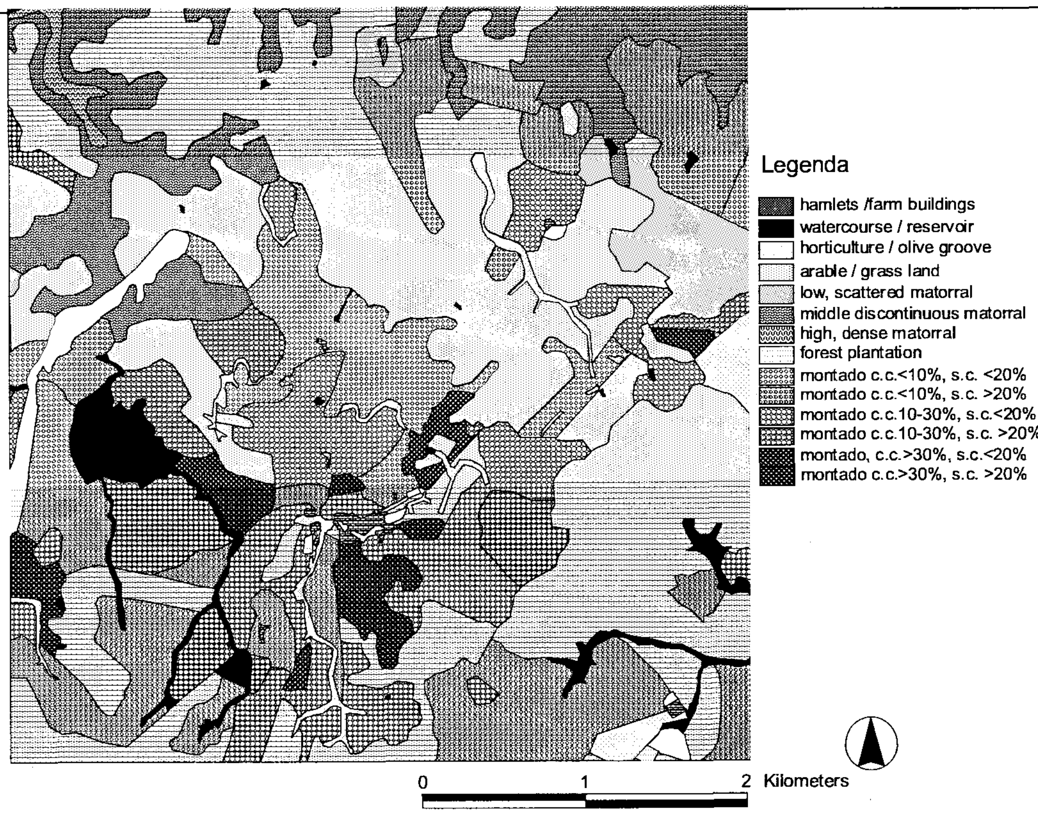

Figure 4 Land cover map elaborated within the framework of the VISTA-project.

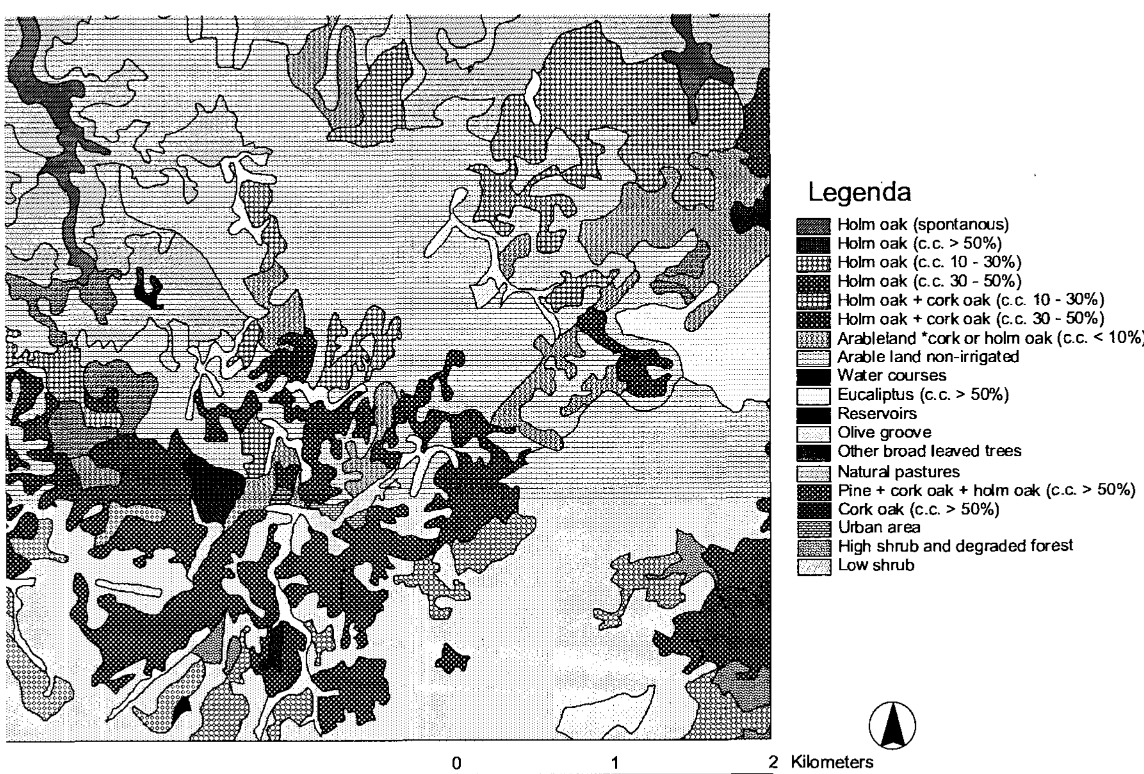

Figure 5 Land cover map according to COS'90.

6 Results of the VISTA land cover mapping and comparison between VISTA and COS'90

6.1 The VISTA land cover map and the COS'90 map

Figure 4 shows the results of the land cover mapping according the aerial photo interpretation carried out within the VISTA-project for the sample area of 22 km2. Figure 5 shows for the same area the COS'90 map. The *montado* is mostly concentrated around the settlements, while the arable/grassland, the forest plantations and the *matorral* areas are located in the periphery.

The differences between the proportion of land cover categories, as percentage of the total study area, of both land cover maps are displayed in figure 6. Clearly visible are the significant differences for the land cover categories of *montado* and *matorral*. The area of *montado* with >30% c.c. covers according to COS'90 14% of the sample area, while this is for VISTA only 4%. Almost the opposite ratio can be found for *montado* with < 10% c.c. COS'90: 9% and VISTA 22%. More close but still distinct are the numbers for the *montado* with 10-30% tree cover, COS'90 11% and VISTA 17%.

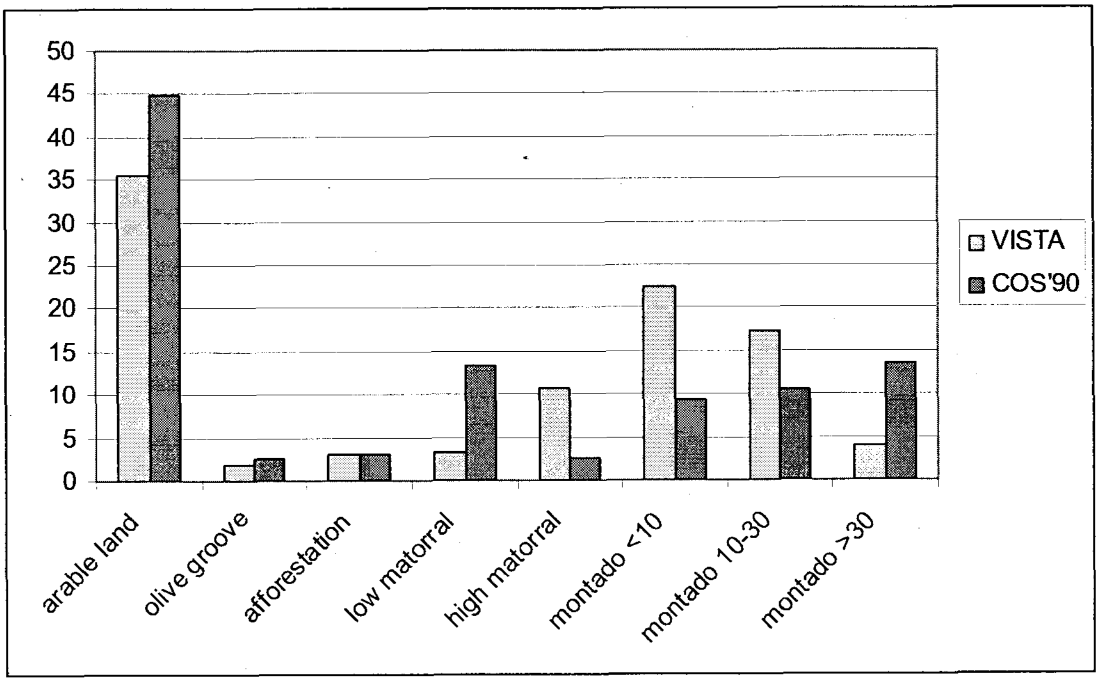

Figure 6 Comparison between COS'90 and VISTA of proportions of land cover classes

Also for *matorral* there are large differences: according to COS'90 only 2% of the area is covered by high *matorral*, but the VISTA map this is 11 %. The category arable / grass land shows similar percentages of coverage, as well as the categories of forest plantation and olive grooves.

6.2 *Differences in classification and delineation.*

When comparing the aerial photo interpretation of COS with the interpretation carried out within the VISTA project, the personal influence of the cartographer becomes clear. Figure 7 shows a detail of the aerial photograph of 1990 with the delineation between two land cover classes (A and B) for both land cover interpretations. The continuous line is the boundary between two patches identified in the case study, the stacked line is the boundary between two patches identified by COS'90. Although the boundary is in a different place, the significance of this difference needs to be assessed.

The assessment of the misallocation of the boundaries has been done for the boundaries displayed on the detail of the aerial photograph of figure 7. With a scale of 1: 3250, the rule of thumb corresponds to a ground distance of 1.63 m. The differences in boundaries in figure 7 are larger than 0.5 mm on the map, in some cases even corresponding to more than 70 m. ground distance.

Except for the misallocation of an areas boundary, there are also differences in classification of land cover. For example, COS'90 classifies area A in Figure 7 as holm oak forest with a crown cover of 35-50%, while the photo interpretation of the case study classified the area as *montado* area with 10-30% c.c.

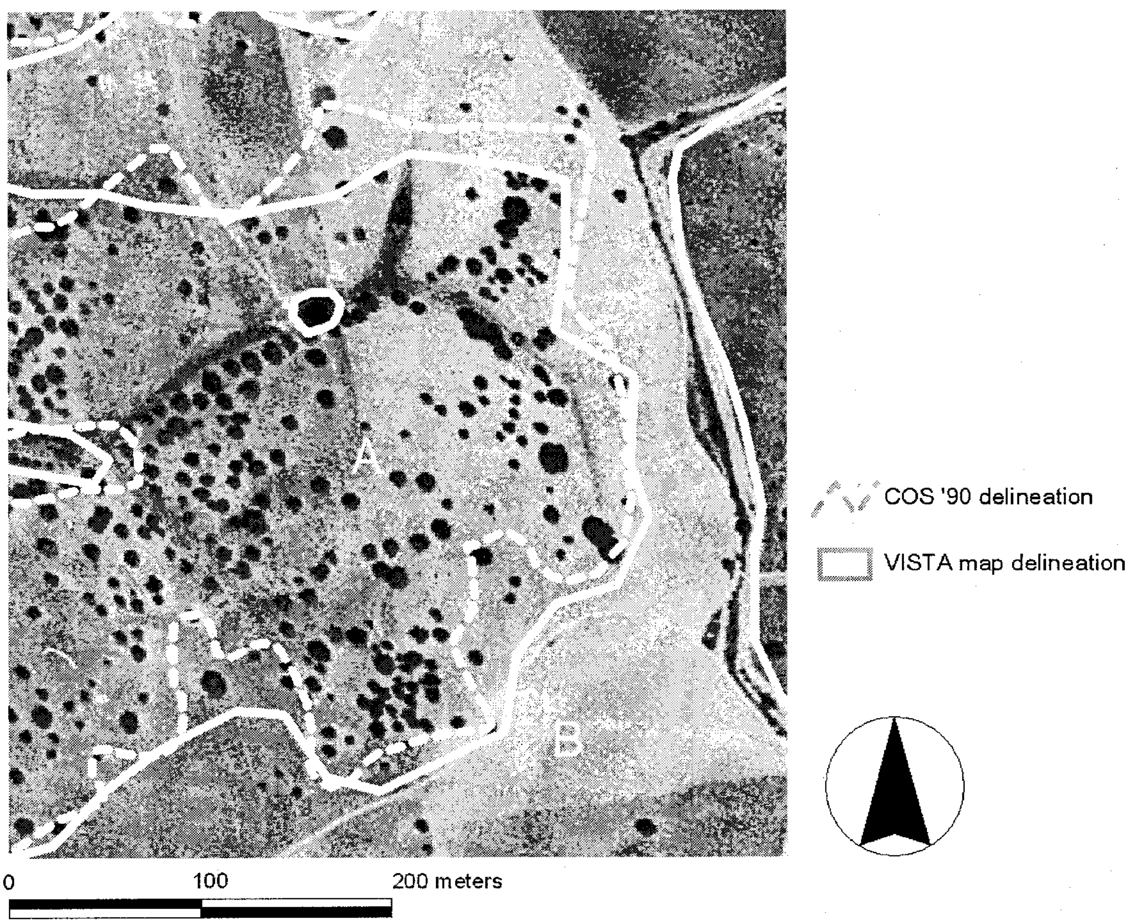

Figure 7 Delineation of land cover classes according to COS'90 (stacked line) and photo interpretation work carried out within the VISTA project (continuous line).

6.3 The VISTA and COS'90 approach compared: percentages of agreement

Table 3 displays a matrix with the percentages of agreement between the two maps for the land cover categories that were selected for comparison. On the diagonal the percentages of agreement can be read, i.e. how many percent of the area of a land cover category on the VISTA map was mapped according to the same category on the COS'90 map. The values off the diagonal reflect the percentages that were differently classified on the COS'90 map.

The land cover categories with clear borders, like the forestations, olive grooves and arable land show high levels of agreement (> 70%). This is also true for the *montado* c.c.> 30% category. For the *montado* category with c.c.< 10% there is only 13 % agreement. On the COS'90 map 24% of this category is mapped as *montado* with 10-30% crown cover or even as *montado* with c.c.> 30% (14%). On the other hand 39% of the category *montado* < 10% c.c. is mapped in COS'90 as arable / grass land. For the *montado* category with c.c.10-30% there is 16% agreement. Comparing with COS'90, 41% is mapped as *montado* c.c > 30%., while 22% of this category is mapped as arable / grass land.

		VISTA								
		arable/ grass land	olive groove	forest plantation	low matorral	high matorral	montado cc <10 %	montado cc 10-30%	montado cc >30%	other
COS'90	arable/ grass land	84	16	2	35	4	39	22	12	55
	olive groove	1	73	0	0	0	1	4	4	8
	forestations	1	0	71	0	0	0	3	6	5
	low matorral	8	4	9	6	69	4	4	0	0
	high matorral	0	0	6	6	4	4	4	0	5
	montado cc <10%	3	2	3	47	14	13	5	5	0
	montado cc 10-30%	2	3	3	4	8	24	16	0	5
	montado cc >30 %	1	0	6	1	0	14	41	74	18
	others	0	2	0	0	0	0	0	0	5
		100	100	100	100	100	100	100	100	100

Table 3: Matrix with percentages of agreement between the land cover map of COS'90 and VISTA

According to the *matorral* categories the levels of agreement are very low, only 6% for low *matorral* and 4 % for high *matorral*. The category of *low matorral* is on the COS'90 map for 47% classified as *montado* c.c. < 10% and for 35% as arable / grass land. The category of *high matorral* is on the COS'90 map classified for 69% classified as *low matorral*.

7 Discussion

Major differences exist between both land cover maps regarding the *montado* and *matorral* categories, while the categories with clear boundaries, as olive grooves and forest plantations show higher percentages of overlap. These differences between the VISTA land cover map and the one of COS'90 point out that the two approaches reflect different representations of the same reality and thus mean important imprecision. Both differences in classification and allocation are the cause of the observed differences between both land cover maps.

Differences in classifying the land cover as observed on the aerial photograph, are not only due to the application of different land cover classifications but also to dissimilarities in the estimations of crown cover by the different interpreters. Differences also emerge because in the COS'90 classification no distinction is made between trees and shrub. The recognition of the understorey of the Montado in the VISTA-classification results in the distinguishing between montado 10-30%cc without shrubs and montado <10%cc with shrubs. In the COS'90 map it is likely that both land cover types are classified as montado 10-30%cc

Differences in allocation, location of boundaries, can be related to the fact that in this gradient rich landscapes, clear boundaries between the land cover types are hardly present. While it might be easy to recognise a type of *montado* in the core area, the identification on the boundary is more problematic. This results in problems in outlining the boundaries between two different land cover classes because these are not discrete edges but rather indeterminate boundaries, representing a gradual transition from one category of *matorral* or *montado* to another one.

Dealing with such a fuzziness, the aerial photo interpretation is rather intuitive and the result heavily depends on the point of view and personal preference of the cartographer. Especially because the borders of the patches are outlined in a qualitative way, every time questioning until what extent the spatial variation in terms of tree and shrub density within the patch could be ignored (Gustafson 1998). Within this respect the application of the minimal mapping unit (m.m.u.) is important. On basis of a priori defined m.m.u.. the interpreter decides to include or exclude a couple of dispersed trees when outlining a *montado* area. Because of the irregular tree pattern of most *montado* areas, the influence of the size of the m.m.u. is considerable.

As we see, in the gradient rich landscape of the study area it is hard to define patches according to a discrete land cover classification. Rules for classification and delineation of land cover patches are hard to define and even harder to apply in practice. It is likely that both differences in allocation and classification, occur frequently in complex landscapes as the agro-silvo-pastoral ones. It is also likely that the occurrence of these differences increase when the map scale decreases and the number of land cover categories increase, because accuracy errors tend to increase when maps become more complex.

Differences in representation of the same reality do not have to be a problem if databases are used independently. However, in landscape research, different data bases are often combined in order to trace landscape dynamics. In this way, dissimilarities in classification, interpretation and delineation between databases are likely to cause false differences or similarities in land cover and consequently one runs the risk to draw false conclusions about the tendencies of land cover change.

Concluding from the study presented, there are several issues to be dealt with.. In order to facilitate comparison among land cover data bases of agro-silvo-pastoral landscapes of the Mediterranean, there should be comparability between classification and consistency in applying rules for delineating patches. In terms of classification, one of the efforts to be made is to create standardized rules and common criteria to classify the different appearances of the *montado / dehesas* systems. Standard categories of tree cover percentages should be introduced in combination with information about the vegetation of the understorey. In this point of view the BioHab project developed a promising methodology to map habitats throughout Europe in a systematic way (Bunce *et al.* 2005). Though the methodology is designed for monitoring habitats through fieldwork and not primarily by aerial photo interpretation, its framework of classification might be useful to standardize land cover cartography.

The pan-European standardized land cover classification system CORINE is applied in Portugal (Instituto do Ambiente and IGEOE 2005), and causes confusion in identifying the agro-silvo pastoral systems. These are categorized into one class: *2.4.4. Heterogeneous agricultural areas / agro-forestry systems*. Yet, class *3.1.1 Broad-leaved forest*, *3.2.3. Sclerophyllous vegetation* and *3.2.4 Transitional woodland and scrub* might also cover some types of *montado* systems, but it is doubtful if they are likely to be recognised as such in databases based of CORINE.

In terms of allocation, the m.m.u. should be applied in a strict way in order to make clear decision about including or excluding trees on the border of the *montado*. However, whilst a concerted attempt can be made to maintain the decision rules consistent, like the application of the m.m.u, the differences in interpretation can still be considerable (Loveland *et al.* 2005)

The observer bias of the qualitative interpretation of aerial photographs can be diminished by making use of automatic classification methods. They are only useful when just a few land cover classes for trees, shrubs and herbs are involved (Carmel and Kadmon 1998), but such methods are constantly improving and can be useful in the near future.

Other solutions can be found in advanced remote sensing techniques that are able to deal with real world fuzziness. These techniques are elaborated mainly in suburban areas of North West Europe (Zhang and Stuart 2001). Although developed in another context, it could be promising for mapping the *montado*. A central concept is a fuzzy map of land cover, on which a location can have partial or multiple memberships of all the candidate land cover classes (Zhang and Kirby 1997). The polygon boundaries are rather seen as a transitional zone with a degree of uncertainty. The degree of uncertainty decreases when moving to the centre of a patch and increases when moving to the boundary. In this way the probabilities of belonging to one land cover category or to another change. The pattern of change can be modelled by using a range of different interpolation methods. Application of such methods for detailed land cover mapping in the agro-silvo pastoral systems of the Mediterranean deserves further research, for further technical information we refer to Zhang and Kirby (1997), Zhang and Kirby (1999), Zhang and Stuart (2001), Anderson and Cob (2004). However, within the scope of this paper, it is important to stress that such technical solutions could be way to solve the problems, but it will not result in the same representation of reality as in the more homogenous and simple landscapes.

Besides these considerations about standardized rules and common criteria to classify and map the *montado* and *dehesa* systems, one should take into account that the fuzziness of the presented landscape is an inherent part of the system. It is directly related with the characteristic extensive land use forms that permanently are being adapted by farmers to the resources available in different patches of land cover. This complexity with its indeterminate boundaries corresponds to specific land use systems, and thus should be accepted and represented in the maps obtained. Therefore land cover databases dealing with this type of landscapes should not be compared in their construction or accuracy with databases referring to intensively used landscapes. They should be treated with care, and one should take into account the resulting inconsistencies when carrying out landscape analysis.

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8 References

Acacio V (2005) The dynamics of cork oak systems in Portugal: the role of ecological and land use factors. In: Abstracts of the European congress of the International Association for Landscape Ecology, Faro, Portugal, 29 March - 2 April 2005

Anderson J J and Cob N S (2004) Tree cover discrimination in pan-chromatic aerial imagery of pinyon-juniper woodlands. Photogramm Eng Rem S 70(9): 1063-1068

Bunce R G H, Groom G B, Jongman R H G and Padoa-Schioppa E (2005). BioHab, Handbook for Surveillance and Monitoring of European Habitats, Alterra-report 1219, Alterra, Wageningen

Burel F and Baudry J (2003) Landscape Ecology. Concepts, Methods and Applications. Science Publishers, New Hampshire

Carmel Y and Kadmon R (1998) Computerized classification of Mediterranean vegetation using panchromatic aerial photographs. J Veg Sci **9**: 445-454.

Casimiro P C (2002) Uso do solo, Teledetecção e Estrutura da Paisagem. Dissertation New University of Lisbon

Centro Nacional de Informação Geográfica (1990) Portugal continental, image 4460 and 4462 Lisbon.

Council of Europe (1992) Council Directive 92/43 EEC of 21 March 1992 on the conservation of Natural Habitats and Wild Flora and Fauna. Brussels.

EEA (European Environmental Agency) (2005) EUNIS - European Nature Information System, http://eunis.eea.eu.int/index.jsp. Cited 11 Oct 2006

Eichhorn M P, Paris P, et al. (2006) Silvo-arable Systems in Europe: Past, Present and Future Prospects. Agroforestry Systems 67(1): 29-50

Fernandez Ales R, Martin A, Ortega F, Enrique E A (1992) Recent changes in landscape structure and function in a Mediterranean region of South West Spain. Landscape Ecol 7: 3-18

Forman R T T (1995) Land mosaics, the ecology of landscapes and regions. Cambridge university press, Cambridge

Foody G M (2002) Status of land cover classification accuracy assessment. Remote Sens Environ 80: 185-201

Gustafson E J (1998) Minireview: Quantifying Landscape Spatial Pattern: What Is the State of the Art? Ecosystems 1: 143-156

Instituto do Ambiente and IGEOE (2005) Corine Land cover 2000 em Portugal. Lisbon.

Instituto Florestal (1994) Fotointerpretação no Âmbito do 'Projecto Nacional de Cartografia de Ocupação do Solo'. Lisbon

Instituto Geográfico Português (1990) Carta de Ocupação do Solo - COS'90. Lisbon.

Joffre R (1999) The *dehesa* system of southern Spain and Portugal as a natural ecosystem mimic. Agroforestry systems 45: 57-79

Lillesand T and Kiefer R (1994) Remote sensing and image interpretation. Wiley, New York

Longley P A, Goodchild M F, Maguire D J, Richardson D M (2005) Geographic Information Systems and Science. Wiley, New York

Loveland T R, Gallant A L, Vogelmann J E (2005) Perspectives on the use of land-cover data for ecological investigations. In: Wiens J, Moss M (eds) Issues and Perspectives in Landscape Ecology. Cambridge University press, Cambridge, p 120

McGarigal, K. and Cushman, S.A. 2005. The gradient concept of landscape structure. In: Wiens J, Moss M (eds) Issues and perspectives in Landscape Ecology Cambridge University press, Cambridge, p. 112

Ojeda F, Arroyo J, Maranon T (1995) Biodiversity components and conservation of Mediterranean heath lands in Southern Spain. Biol Conserv **72:** 61-72

Pereira P M, Pires da Fonseca M (2003) Nature vs. Nurture: the making of the *montado* Ecosystem. Conservation Ecol **7.**

Perez M R (1990) Development of Mediterranean Agriculture: An ecological approach. Landscape Urban Plan 18: 211-220

Pinto-Correia T (1993) Threatened landscape in Alentejo, Portugal: the '*Montado*' and other 'agro-silvo-pastoral' systems. Landscape Urban Plan 24: 43-48

Pinto-Correia, T and Vos W (2004) Multifunctionality in Mediterranean Landscapes - past and future. In: Jongman, R.H.G (ed) The new dimensions of the European Landscape. Springer, Dordrecht.

Plieninger T (2004) Built to last? The continuity of holm oak (Quercus ilex) regeneration in a traditional agroforestry system in Spain. Culterra 39: 5-62

Roxo M J, Mourão J M, Casimiro, P C (1998) Políticas agrícolas, mudanças de uso do solo e degradação dos recursos naturais - Baixo Alentejo Interior. Mediterraneo 12/13: 167-189

Santos Pérez A, Remmers G A (1997) A landscape in transition: an historical perspective on a Spanish latifundist farm. Agr Ecosys Environ 63: 91-105

Tomaselli R (1981) Main physiognomic types and geographic distribution of shrub systems related to Mediterranean climates. In: Di Castri F, Goodall D W, Specht R L(eds) Mediterranean-type scrublands. Elsevier, Amsterdam.

Zhang J and Kirby R P (1997) An evaluation of fuzzy approaches to mapping land cover from aerial photographs. J Photogramm Rem S 52(5): 193-201.

Zhang J and Kirby R P (1999). Alternative criteria for defining fuzzy boundaries based on fuzzy classification of aerial photographs and satellite images. Photogramm Eng Rem S 65(12): 1379-1387.

Zhang J and Stuart N (2001) Fuzzy methods for categorical mapping with image-based land-cover data. Int J Inform Sci 15(2): 175- 195.

Zonneveld I S (1995) Land Ecology. SPB Academic publishers, Amsterdam.

Chapter 4 Paper C

Extensification trends in Mediterranean landscapes: holds the landscape homogenization dogma in any case?
A landscape change study (1958 - 2000) in the Portuguese Alentejo

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Abstract

This paper explores the landscape dynamics of two areas in the south east of the Portuguese Alentejo region by systematic comparisons of land cover maps of 1958, 1985 and 2000, which were for this purpose derived from aerial photographs.

The study consists of 2 separate analysis: 1) detection of processes of extensification through analysis of land cover class transitions with the use of transition matrices; 2) monitoring landscape composition and configuration through the application of a set of landscape metrics.

The results show clear changes during the past forty years in landscape composition and configuration. The landscape metrics display a trend towards a more fragmented, complex, fine-grained landscape. Most widespread land cover changes were transformations from arable / grassland to other land cover categories, such as montado, forest plantations and matorral. The shift from arable/grassland to land cover classes dominated by woody species suggests an extensification of agricultural practices. The results are partly consistent with the generally assumed trends in Mediterranean landscapes: extensification of land use being a main process. However, contrary to what is often observed and assumed, this process is associated with a trend towards a more fine grained and fragmented landscape.

Keywords

Heterogeneity; montado; landscape change; landscape metrics; transition matrices.

Introduction

As is inherent to their dynamic nature, landscapes continuously change, though the pace and magnitude of these processes have been increasing in many rural landscapes in Europe, especially during the 20th century (Vos and Stortelder 1992; Wood and Handley 2001; Antrop 2005). Intensification of agricultural production caused rapid changes in traditional landscape structures, mainly in the areas with most favourable conditions for cultivation. In less favourable areas (LFA's) extensification of agricultural activities is an important process driving landscape change. Both processes often result in a loss of biodiversity and of cultural heritage, and consequently most of the landscape changes are seen as a threat (Jongman 1996; Antrop 2005).

Mediterranean European landscapes comprise a wide variety of ecosystems and habitats that accommodate a diverse flora and fauna (Blondel and Aronson 1995). Many of them have been shaped through the centuries by traditional low-input farming, with extensive grazing and agro-silvo-pastoral practices, a type of management which is in balance with the natural resources, which had high levels of biodiversity as unplanned by-products. Many Mediterranean landscapes are subject to profound landscape changes (Naveh 1982), which occur very fast at a large scale, and destroy most traditional structures (Baudry and Tatoni 1993; Pinto-Correia and Mascarenhas 1999). These changes are caused by both intensification and extensification of agriculture. In the less favoured areas (LFA) marginalisation and extensification are common processes, with afforestation with fast-growing trees and land abandonment being the main ones. These trends cause increased risk of wild fires (Moreira et al. 2001), degradation of cultural values (Vos 1993) and loss of biodiversity (Burel and Baudry 1995).

For the prevention of negative landscape impact of these changes, new forms of management are of outermost importance. These should be based on conclusive knowledge of patterns and processes of landscape change. Empirical research by monitoring is a growing concern of today's landscape research. Within landscape ecology concepts, tools and methods are applied and developed to quantify patterns of change and link them to processes (Naveh and Lieberman 1994). Procedures for the analysis of changes in landscape pattern through remotely sensed images have been reported, e.g. by Kienast (1993), Dunn et al. (1991) and Bender et al. (2003). As will be discussed, Geographical Information Systems, landscape metrics and transition matrices are of increasing importance in today's landscape change research (e.g Romero-Calcerrada and Perry 2004; Pan et al.1999; Poudevigne and Alard 1997).

The present study deals with landscape change in the Alentejo region in Southeast Portugal. Up to now the number of (international) research papers dealing with landscape change in South Portugal is limited (Roxo, Mourão, et al. 1998 , Casimiro 2002) and none of these addressed landscape changes at the local level. This lack of knowledge at the local level contrasts sharply with the urgency of landscape research since, in the Alentejo and the Algarve landscapes, dramatic changes are taking place (Pinto-Correia 1995). For example, an analysis of Corine land cover data (Breman and Pinto-Correia 2003) shows that 16% of the territory of the municipality of Mertola has undergone land cover change in the period 1990 - 2000. These changes are especially dominated by afforestation of agricultural land and extensification.

The processes of extensification are often associated with a simplification and homogenisation of Mediterranean landscapes (Fernandez Ales et al. 1992; Pinto-Correia 1993b; Lehouerou 1993). In other words, extensification leads to a loss of fine grained landscape structures. Also recent publications (Rounsevell et al. 2005) predict this trend for the near future. However, it remains to be seen if extensification of agricultural activities associated with homogenisation applies to every landscape in Mediterranean agro-silvo-pastoral land use systems.

The study consists of 2 separate parts: 1) to identify processes of extensification, by analizing land cover transitions with transition matrixes; 2) to monitor the changes in landscape structure over the period 1958 - 2000, using a set of landscape metrics.

Both analyses contribute eventually to question whether extensification processes are in any case associated with homogenisation of the rural landscape, as is generally assumed in the literature.

The present study starts with a short literature review and a discussion of conceptual and methodological aspects of landscape change studies.

Studying landscape change: conceptual and methodological considerations

In this paper the definition of Forman (1986) of the concept landscape is adopted and is as follows: 'A landscape is a mosaic where the mix of local ecosystems or land uses is repeated in similar form over a kilometres wide area'.

The holistic aspect of the concept of landscape, is by some considered to be a fundamental topic in landscape research (Naveh and Lieberman 1994). However, studying the overall change of a landscape as a holistic entity, including aesthetical, historical and cultural considerations, it is a rather complex process, if possible at all (Antrop and Van Eetvelde 2000). The majority of papers published dealing with landscape change base their analysis on the change of landscape elements, like land cover patches. But the study of landscape change is related to, but not co-extensive with, land cover change (Wood and Handley 2001), being a change in individual elements, within a landscape, not necessarily linked with an overall landscape change(Antrop 1998; Golley2000). Describing a landscape in terms of land cover is a simple and aggregated way, representing the interface between natural conditions and human influence. As such, it is regularly used to quantify landscape change, as in the patch-corridor-matrix model of Forman and Godron (1986). The spatial configuration and composition of land cover patches is often applied to describe landscape structures and patterns. Landscape structure is an important factor in the study of ecological processes. O'Neill et al. (1988) introduced indices of landscape patterns, also known as 'landscape metrics', as a useful tool for an objective description and quantification of the landscape structure, as has been used successfully in studies of landscape structure at different scales by McGarigal and Marks (1995) and Lausch and Herzog (2002).

Depending on the objective of the study, one has to choose carefully the size of the study area, time frame of the study, tools and data sources, in order to constitute a reliable spatial-temporal data model (Burgi and Russell 2001).

As in many other Mediterranean landscapes, land cover changes in the Alentejo region originate mostly at a local scale, this implies that monitoring of the changes should be done rather on a local scale than on a regional scale (Antrop 1993). The choice of scale and the size of the pilot area is a trade-off between the reliability of the representation of the rural landscape under study and, on the other hand, the logistical effort with respect to the detailed photo interpretation.

The timeframe of this type of study depends strongly on the available data sources. Detailed spatially explicit land cover data are at present widely available through satellite images. However, for historic information, historical maps and cadastral archives should supply the data, but in Portugal these rarely date back earlier than 1800, and cause many problems in geo-referencing and interpretation. When these data are also lacking, as in the present case, one is restricted to the oldest available information, which are here aerial photographs from the 1950's.

Although aerial photographs may have potential drawbacks, like doubtful quality and problems with registration and distortion (Dunn et al. 1991), they remain a valuable data source in landscape research (Longley et al. 2005).

Material and methods

Study area

The municipality of Mertola is located in the southeast of the Portuguese region of the Alentejo. Within the municipality two sample areas of both 44 square km have been selected: Amendoeira da Serra (37° 40' N, 7° 47' E, datum WGS-1984) and João Serra (37° 40' N, 7° 50' E, datum WGS-1984). Previous studies (e.g. Oliveira 1998) indicated that these areas are representative for landscape changes in this region.

Mertola is located on the Guadiana river and ranges from 50 to 300 m a.s.l. The prevailing rock is schist, on which shallow and poor soils occur. The area has a typical Mediterranean climate, with averagely 700 mm rainfall a year, concentrated during the winter months. Periods of drought from two to eight months occur during the hot summers (Perez 1990).

Mediterranean-type vegetation dominates the area, with, as dominating species, Quercus rotundifolia and Cistus spp. High, dense matorral, a typical Mediterranean scrub type (Tomaselli 1981) occurs along the watercourses, with species like *Arbutus unedo, Nerium oleander, Tamarix hispanica* and *Securinega buxifolia*. A lower, dispersed type of matorral hosts a richness of aromatic plant species, like *Rosmarinus officinalis, Lavendula* spp., *Thymus cephalotus* etc.

Due to its peripheral location, specific history and socio-cultural conditions, the municipality is considered as a marginal agricultural area (Oliveira 1998; Roxo et al. 1998). The agro-silvo-pastoral system of the montado (Pinto-Correia 1993a) is one of the typical management systems, especially in the study area of Amendoeira da Serra. Main agricultural activity is sheep breeding, but there are also some cattle, goats and pigs. Besides extensive livestock breeding, there is cereal growing, especially in the area of Joao Serra, and forest plantations are recently spreading.

The landscapes of the two sample areas are slightly different. The landscape of the area of Amendoeira da Serra is described by Cancela d'Abreu et al. (2004) as follows: 'In spite of its homogenous character the landscape presents variations in the landscape pattern, based on the spots of holm oak Montado, together with open fields or with a scarce presence of trees. Besides the variation in land cover, like agriculture, forestry and pastoralism or dense shrub formations, the rolling slopes are the other determinative element of the landscape, some times interrupted by the hidden valleys of the watercourses'. High natural values especially occur along the watercourses, with formations of Juniperus and wealth of aromatic herbs and medicinal plants'.

The landscape of the second study area, João Serra, is much more plain and open, with the absence of the agro silvo pastoral system. Cancela d'Abreu et al. (2004) writes about this landscape: 'the character of this landscape results essentially from its slightly undulating cereal fields, pastures and fallow land, where trees are absent, and the open space dominates'.

The agro-silvo pastoral area, and the matorral vegetation in the area of Amendoeira, constitute habitats for different wildlife species like *Felix silvestris, Genetta Genetta, Aegypus manclus* and *Falco naumanni*. The recognition of this important role has been formalized in 1995 with the constitution of the natural park of the Guadiana valley.

The open, steppe-like landscape of the area of Joao Serra has an important role in steppe-bird conservation, with species like *Otis tarda, Tetrax tetrax,* and *Falco naumanni*. As such, the area is subject to special habitat regulations since 1993, aiming at preserving bird populations.

The general historic land use changes in the municipality of Mértola are described by Roxo et al. (1998). In the beginning of the 18th century most of the area was covered with montado and matorral that were used as commons ('baldios') for hunting and collecting of honey and firewood. The baldios were mainly the most remote areas, hilly and with difficult access. Apart from the mentioned activities, also livestock breeding was important (sheep, pigs and goats that were kept pastorally). At the end of the 18th century the population of the municipality almost doubled, and there was a necessity to enlarge the area under cultivation of cereals and the pastures for livestock. This enlargement happened at the expense of the natural vegetation. The end of the 19th century was a decisive period in the development of the agriculture in the Alentejo. Policies were focused on the enlargement of the agricultural production. Agriculture was the most important economical sector, and all action was focused on it, which had severe effects on the natural resources. Large areas of uncultivated land were seen as potentially to be cultivated. In order to improve the national production of wheat, under the fascist regime of Salazar a wheat campaign started in 1926, and lasted until the late 60's.

The policies were urging the farmers to produce more cereals in order to attain national self-sufficiency of food production. The national production of wheat doubled in these decades from 306 427 tons in 1918 up to 649 320 tons in 1950.
After the revolution of the early 1970's the protectionist cereal campaigns stopped and in the most peripheral areas the cultivation of wheat and other arable crops was abandoned. In some areas, where soil degradation was most severe, extensive Eucalyptus-stands were planted.

After Portugal's entrance of the EU in 1985, financial support from the Common Agricultural Policy (CAP) became available for the Portuguese agriculture, also for revival of livestock breeding (especially sheep), and cereal cultivation. Later on, afforestation programs for less favoured areas as part of the second pillar measures of the CAP gained importance for some areas in the Alentejo.
Still, at present aging and depopulation are significant processes, and given the limited employment opportunities, the human population decline is expected to continue in the near future. Distant landowners tend to switch their management to less intensive practices, this process is clearly visible in our study areas, e.g. with in the significant increase of forest plantations during the last decade.

Land cover data

Data on land cover were derived from grey-scale (8-bit) aerial photographs of 1958 (scale 1: 26.000), 1985 (scale 1: 15.000) and digital ortho photo-maps of 2000 (1: 22.000). The hard-copies of the aerial photographs were scanned (600 dpi) and georeferenced, using the ortho photo-maps of 2000 as the reference.
A land cover classification with 21 classes was used (see legend of figure 1). The classification distinguishes different types of the Montado and matorral based on differences in tree and shrub densities, since these might imply different types of land use or regimes of management. Also various types of forest plantations with different dominant tree species were considered, since they require different kinds of maintenance and serve different goals.

The visual interpretation of the aerial photographs was done on screen and the land cover patches were manually digitised using a minimal mapping unit of 0,5 ha. For the most recent time period also field work was done. All work was done by the same person to avoid different judgement in the interpretation, and carried out with the software package for geographical information systems ArcView 3.2.

Our two analyses are based on an aggregated version of the land cover classification: the 6 classes of montado are aggregated to 3, defined by their tree cover. The 4 forest plantations are aggregated into one, without a distinction between the tree species. These aggregations facilitated the identification of the main trends in land cover transition and landscape change.

Transition matrices

The land cover database of the two sample areas was used for the diachronic analysis of land cover change with Markov-type transition matrices. In these matrices rows and columns represent land cover classes, and the entries rates of change from one land cover category to the other category. Transition matrices are frequently used to explore the dynamics of land cover categories (Romero-Calcerrada and Perry 2004; Poudevigne and Alard 1997). An extensive analysis of transition matrixes in terms of gains, losses, persistence, net change, swap and systematic transitions among the categories has been proposed by Pontius et al. (2004). A net change in the quantity of a specific land cover category indicates the definite change of that land cover class. A swap change indicates a change in the location of a category, while the quantity remains the same. The concept of swap change allows avoiding underestimations of the total change on the landscape.

In order to properly identify the most systematic transitions of the land cover categories, the transitions should be interpreted relative to the size of the categories. By deducting the observed proportions with the expected proportions of change, systematic transitions were identified. Large positive deviations from zero indicate that systematic transitions between two land cover categories occurred, rather than random transitions. For details on the methodology see Pontius et al. (2004). All calculations were carried out in Excel 2000.

Landscape metrics

Useful indicators for landscape change in terms of composition and configuration are quantitative landscape indices or landscape metrics. This is a tool for the quantification of specific spatial attributes of patches, classes of patches and larger mosaics (McGarigal and Marks 1995), and are widely applied and discussed (e.g. Botequilha Leitao and Ahern 2002; Gustafson 1998; Romero-Calcerrada and

Perry 2004). The combination of an analysis of statistical land cover change and the use of landscape metrics is considered to be indispensable for the analysis of landscapes and their changes (Herzog and Lausch 2001; Lausch and Herzog 2002). Albeit, the use of landscape metrics, and especially the choice of which ones to use, is a matter of controversy.

Therefore we choose to use four metrics which are widely used and understood, being simple and suitable indicators to measure landscape heterogeneity (Herzog and Lausch 2001; Gustafson 1998): the mean patch size (MPS), the Landscape Shape Index (LSI), the Simpson diversity index (SIDI) and contagion. The MPS is an indicator of the grain of the landscape and the LSI is an indicator of landscape complexity: when the LSI decreases, the patches in the landscape simplify. The Simpson Diversity Index (SIDI) is a diversity index, which is recommended when richness, in this case corresponding to the number of land cover classes, is smaller than 100 (Herzog and Lausch 2001). A representative and most commonly used indicator of spatial configuration is contagion. This measures the degree of spatial aggregation or clumping of different spatial units (Gustafson 1998).

Based on the vector maps, the metrics were calculated, using Fragstats 1.0 for ArcView.

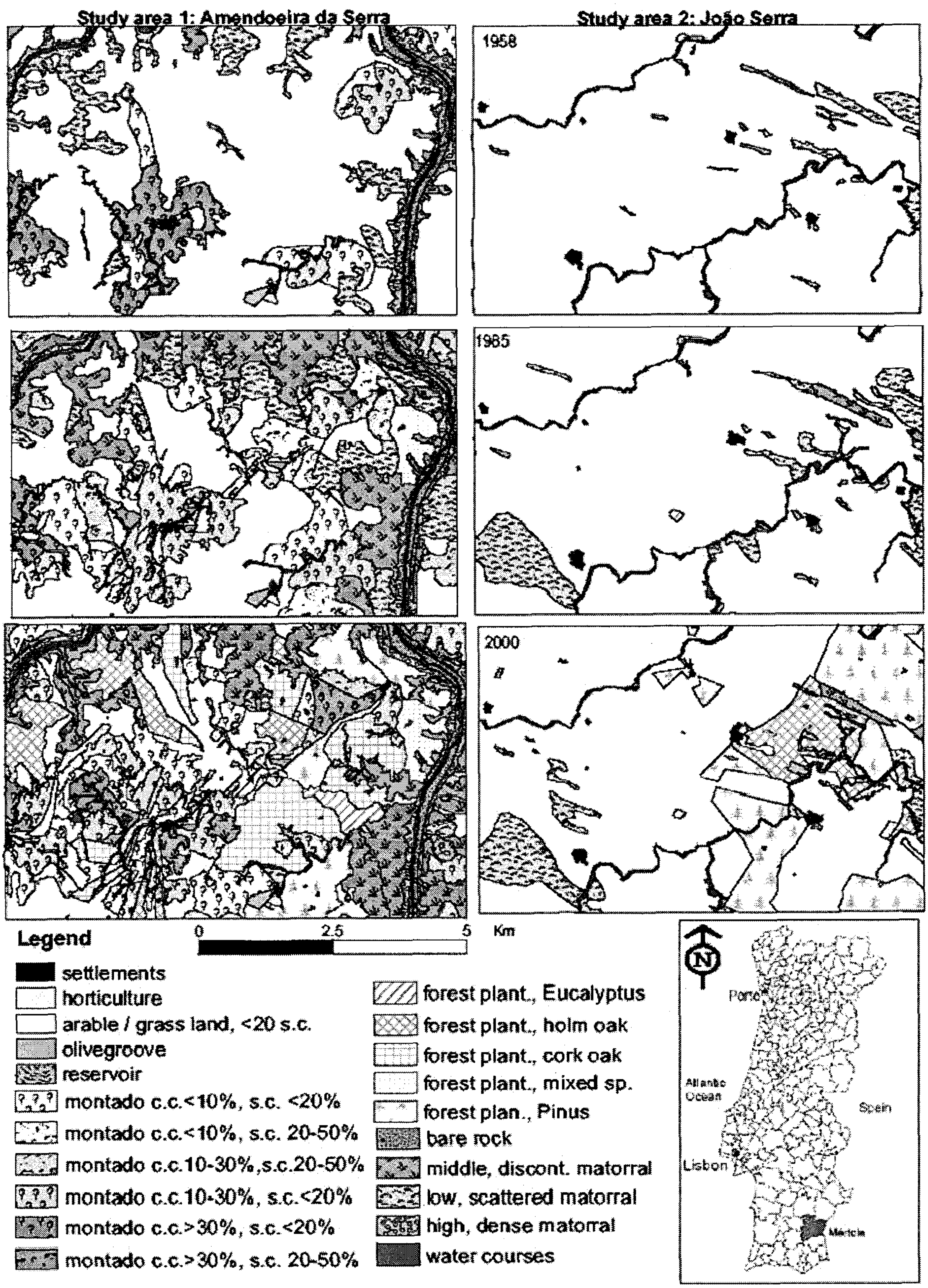


Figure 1: Land cover maps of 1958, 1985 and 2000, derived from aerial photographs for sample areas of 44 square km at Amendoeira da Serra and João Serra (municipality of Mértola)

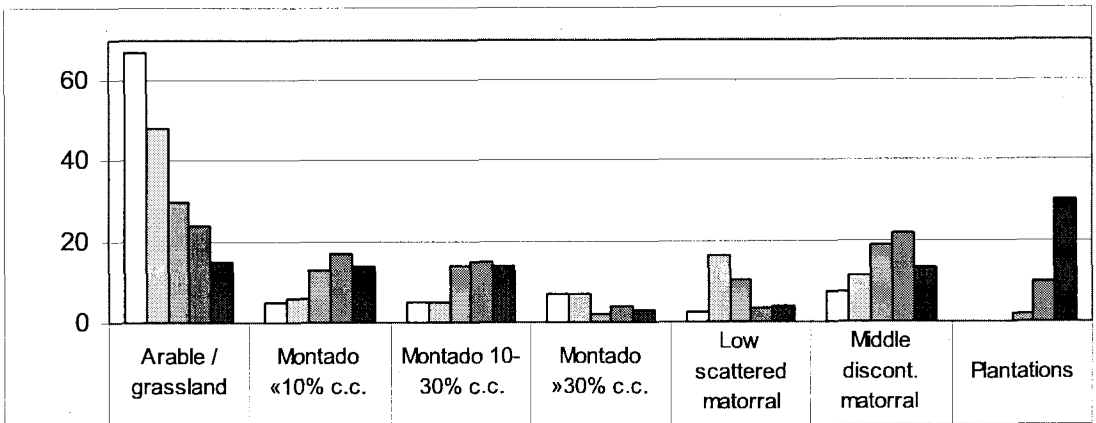
Results

Land cover maps

The land cover maps of the sample areas are shown in figure 1, while figure 2 and 3 depict the percentages of area per land cover class for the three study periods. In 1958 arable/ grassland is dominating the study area of Amendoeira, accounting for 66% of the area, which is a result of the cereal growing promotion in the beginning of the 20th century. Around the settlements there is some montado (16%), mostly with a tree cover of more than 30% and without shrub in the understorey. On the steep banks of the rivers high dense matorral occurs, which obviously reflects the difficult physical conditions, which do not allow any cultivation.

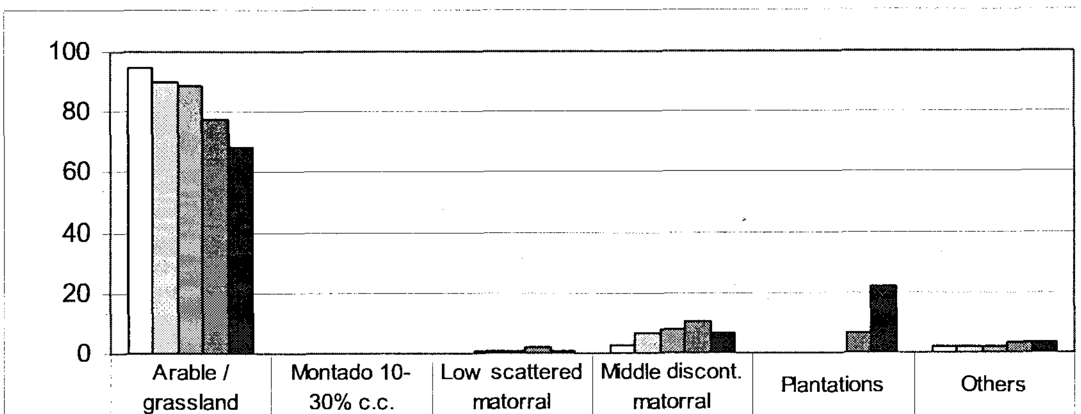
The land cover map of 1985 shows a gradual increase of matorral and montado. A shift from open arable/grass land without trees, to a more closed landscape with open oak forest and shrubs is taking place. The montado is getting more varied in terms of tree and shrub densities. The matorral does not only appear on the steep slopes along the watercourses, but also at the suitable areas for agriculture, in these areas it is low and scattered. Also the first forest plantation appears in the northeast corner of the area.

At the land cover map of 2000 a significant occupation of forest plantations has developed, accounting for 30% of the whole area. Different tree species are planted; being Quercus suber and Quercus rotundifolia the most frequent ones.
At present, arable/grassland (15%), montado (21%), matorral (17%) and the new forestations (30%) are the main land cover categories in the area of Amendoeira.
In the area of Joao Serra, arable/grassland is much more dominant, at present accounting for 69% of the area. Forest plantations are also here an increasingly dominant land cover class, at present occupying 22% of the area. The area of matorral is relatively small, mainly concentrated on the rocky areas and steep slopes. In the past the open agricultural area dominated even more, in 1958 accounting for 95%.



	Arable / grassland	Montado «10% c.c.	Montado 10-30% c.c.	Montado »30% c.c.	Low scattered matorral	Middle discont. matorral	Plantations
□ 1958	67	5	5	7	3	7	0
□ 1969	48	6	5	7	16	12	0
▨ 1985	30	13	14	2	10	19	2
▨ 1990	24	17	15	4	4	22	10
■ 2000	15	14	14	3	4	13	30

Figure 2: Changes in land cover of the Amendoeira da Serra sample area (in % of the whole sample area); only most dynamic classes area shown.



	Arable / grassland	Montado 10-30% c.c.	Low scattered matorral	Middle discont. matorral	Plantations	Others
□ 1958	95	0	0	2	0	2
□ 1969	90	0	1	6	0	2
▨ 1985	89	0	1	8	0	2
▨ 1990	78	0	2	11	7	3
■ 2000	68	0	1	6	22	3

Figure 3: Changes in land cover of the João Serra sample area (in % of the whole sample area); only most dynamic classes area shown.

Transition matrices

We did not include the full transition matrices. Instead, tables 1 to 5 show the most important information derived from the full matrices. Table 1 (sample area of Amendoeira da Serra, period 1958 - 1985) and 4 (sample area of João Serra, period 1985 - 2000) show the persistence, losses, gains, the total change, swap and the net change for the most dynamic land cover classes. Tables 2 and 3 include the most systematic land cover transitions for the Amendoeira area for both time periods.

<u>Study area 1 Amendoeira da Serra</u>

Period 1958 - 1985

The total persistence for the period accounts for the 41%, which means that only this percentage of the land cover did not change over this period. Arable/grassland accounted for the great part of this percentage, only 27% of that area did not change. Still, almost 60% of the total sample area changed. For example 11% switched from arable/grassland to montado with less than 10% tree cover, and whereas in 1958 69% of the area was arable/grassland, this was only 30% in 1985.

	loss	gain	tot. change	swap	net. change
A	39,0	1,3	40,4	2,7	37,7
Ss	8,7	10,2	18,9	17,4	1,4
F	0,0	1,8	1,8	0	1,8
M<10	3,5	11,8	15,3	7,1	8,2
M 10-30	0,8	13,8	14,6	1,7	12,9
M>30	5,3	0,5	5,8	0,9	4,9
Sd	0,2	18,2	18,4	0,3	18,1
M	1,1	0,4	1,4	0,7	0,7

Table 1: Gains, losses, swap and net change of land cover in percentages of the whole Amendoeira da Serra sample area (1958 - 1985).
A= arable land / pasture; Ss= low, scattered matorral; F= forest plantations; M<10= montado, c.c.<10%; M10-30= montado, c.c.10-30%; M>30= montado, c.c.>30%; Sd= middle discontinuous matorral; M=high, dense matorral.

For the Amendoeira area the calculations of losses and gains for the period 1958 - 1985 are shown in table 1, which includes also the total change, swap and absolute value of net change area. The values are relative to the whole area.

According to table 1, the largest loss is that of arable/grassland, which declines with 39 %. Most of this change is a net change, only 2.67% is swap.
Middle discontinuous matorral increases most in this period, as do montado <10% c.c., montado 10-30 % c.c. and low scattered matorral. The gain of low scattered matorral is merely a swap change, montado with <10% c.c. is partly a swap change partly a net change, while the gains of the montado 10-30% tree cover and middle, discontinuous matorral are net changes.
Table 2 shows the most systematic land cover transitions in the period. Large positive values in the 'O-E column' (the observed proportion minus the expected proportion) indicate systematic transitions between two land cover classes. Large negative values indicate that the transition between categories occurred less than expected with a random process.

transition from 1958 - 1985	**O-E**	**interpretation**
arable/grassland -> *montado* <10%	2.93	*montado* <10% replaces arable/grassland
arable/grassland -> low *matorral*	2.3	low *matorral* replaces arable/grassland
low *matorral* -> middle *matorral*	6.64	middle *matorral* replaces low *matorral*
montado<10% -> *montado* 10-30%	1.96	*montado* 10-30% replaces *montado* <10%
montado >30% -> *montado* 10-30%	3.18	*montado* 10-30% replaces *montado* >30%
arable grassland -> *montado* 10-30%	-3.76	*montado* 10-30% does not replace arable/grassland
montado >30% -> middle matorral	-1.25	middle *matorral* does not replace *montado* >30%

Table 2: Main land cover transitions in the Amendoeira da Serra sample area (1958 - 1985)

The overall trend in land cover change from 1958 to 1985, is the transition from arable/grassland to montado <10% c.c. and low, scattered matorral, which respectively develop gradually to montado 10-30% c.c. and intermediately high, discontinuous matorral. This explains the swap change in low, scattered matorral: on the one hand it gains from arable/grassland, and on the other it looses to intermediately high discontinuous matorral, a sequence like a normal secondary succession. The increase of land cover classes dominated by woody species reflects an extensification in cultivation, with declining activities like ploughing and other types of soil tillage.

Period 1985 - 2000

In the next time period (1985 -2000) the total percentage of area that persists its land cover class is 42,5 %, which is slightly higher than in the first study period. Only 10% of arable/grassland stayed like that, and 19% was lost to other classes. It is the land cover class, which has the largest decline, and again most of this is a net change (table 4). Also low, scattered matorral, montado <10% c.c. and montado 10-30% c.c. lost area. For the last two this loss is mainly a swap change, whereas for low scattered matorral it is half swap and half net change, which also accounts for intermediately high, discontinuous matorral.

The new forest plantations are a definite change, at least until they are cut. They gained most area in this period, together with montado <10% c.c. and montado 10-30% c.c.

transition from 1985 - 2000	O-E	interpretation
arable/grassland -> montado <10%	1.31	montado <10% replaces arable/grassland
arable/grassland -> forest plantations	2.78	forest plantations replace arable/grassland
low matorral -> middle matorral	1.26	middle matorral replaces low matorral
montado<10% -> forest plantations	2.24	forest plantations replace montado <10%
montado >30% -> montado 10-30%	1.07	montado 10-30% replaces montado >30%
low matorral -> forest plantations	2.18	forest plantations replace low matorral
middle matorral -> forest plantation	-2.23	forest plantations do not replace middle matorral

Table 3: Main land cover transitions in the Amendoeira da Serra sample area (1985-2000)

The most systematic transitions are shown in table 3. New forest stands are predominantly planted on arable/grassland, low, scattered matorral and areas with montado <10%c.c. Intermediately high, discontinuous matorral is not substituted by new forest plantations. This is caused by 1) the steep slopes, 2) the EU regulation 2080, which only gives subsidies for plantings on agricultural land, and not on land that is abandoned for more than six years. Like the period 1958 - 1985, the systematic transitions in this period also suggest processes of extensification in agricultural activities. A graphic representation of these results is displayed in figure 4.

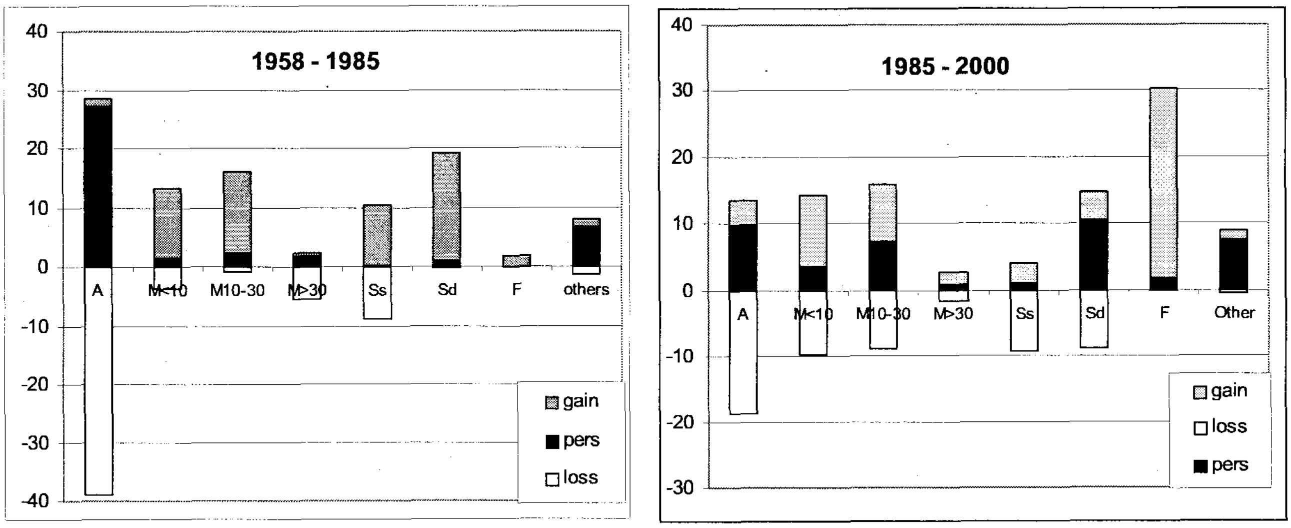


Figure 4: Persistence, gain and losses of land cover in the Amendoeira da Serra sample area (1958 - 1985 and 1985 - 2000) in percentages of the whole area. A= arable land / pasture; M<10= Montado, c.c.<10%; M10-30= Montado, c.c.10-30%; M>30= Montado, c.c.>30%; Ss= low, scattered matorral; Sd= middle discontinuous matorral; F= forest plantations.

Study area 2 Joao Serra

Period 1958 – 1985

The level of persistence in the João Serra area for 1958-1985 is 93%, which is mainly caused by the continuation of arable land/grassland, which accounts for 89% of the area. Most important changes are those from arable/grassland to low, scattered matorral (7%), from low, scattered matorral to a somewhat higher, discontinuous matorral (0.55%), and from arable/grassland to Eucalyptus plantation. There were hardly any changes in the land cover categories urban area, lakes, olive grooves and watercourses.

The largest loss is that of arable/grassland; most of its loss is a net change, only 1.83% is a swap. Also the land cover classes with the greatest gain, the low scattered matorral, have a loss which is mostly a net change (5,97% net change; 2,29 % swap change).

In short, the only systematic change is the transition from arable/grassland to low scattered matorral, suggesting extensification of land use. The difference between the observed proportion and the expected proportion is 1.75, indicating a systematic transition between these land cover categories, rather than a random process.

Period 1985 - 2000

In contrast with the previous period, from 1985 to 2000 the level of persistence fell to 74%. In this period only 70% of the arable/grassland remained. A part of this area changed to low scattered matorral (2,1%), a larger part changed to pine plantation (13.5%) and plantation of holm oak (5.4%). Also some areas of low, scattered matorral were turned to pine (1,7%) or holm oak (0.5%) plantation. For the other land cover classes like montado, olive grooves and watercourses there are hardly any land cover changes observed.

Gains, losses, swap and net change are shown in table 5. The loss of arable/grassland is mostly a net change, whereas changes of low, scattered matorral are mostly a swap change. The gains of forest plantations are net changes.

Thus, most systematic transition in the Joao Serra area in this period is the change from arable/grassland to forest plantation, either pine or holm oak (with respectively

	loss	gain	tot. change	swap	net change
A	21,8	1,4	23,1	2,7	20,4
SS	3,7	2,1	5,8	4,3	1,6
F	0	22	22	0	22
M10-30C	0	0	0	0	0
SD	0,1	0,2	0,3	0,1	0,1

Table 4: Gains, losses, swap and net change of land cover in percentages of the whole João Serra sample unit (1985 - 2000).
A= arable land / pasture; Ss= low, scattered matorral; F= forest plantations; M10-30= montado, c.c.10-30%; Sd= middle discontinuous matorral.

values for obs - exp 3 and 1.3). In contrast with the earlier study period, arable/grassland is less probable to be replaced by low scattered matorral (obs - exp= -2.2). Another systematic change is the transition from low scattered matorral to forest plantation of pine (obs-exp= 1.13).

Summarizing, for both study areas in both study periods, the identified systematic land cover transitions concern changes from arable/grassland to land cover classes dominated by woody species like matorral, forest plantation and montado. This suggests an ongoing process of extensification in land use.

Changes in landscape metrics

Figure 5 and 6 display the graphics of four landscape metrics, representing the dynamics of the spatial configuration of the landscapes of the sample areas.

The area of Amendoeira shows clearly a decreasing mean patch size (MPS), this indicates that the landscape has become more fine-grained. This reflects that the large area of arable land in 1958 turned into a more varied area with different shrub and tree densities. In the Amendoeira area, the LSI increases, which means that the shapes of the patches become more complex and irregular.

Over the study period the Simpson Diversity Index (SIDI) increases in the Amendoeira area, because the dominant area of arable land in 1958 becomes more balanced by the increasing area of montado, matorral and forest plantations. But in contrast, contagion decreases, which means that the landscape mosaic of the study area has become less aggregated and more fragmented.

The area of Joao Serra displays more or less similar trends (figure 5): the LSI and SIDI increase, while the MPS and contagion decrease, indicating a shift towards a more complex, fragmented and fine grained landscape.

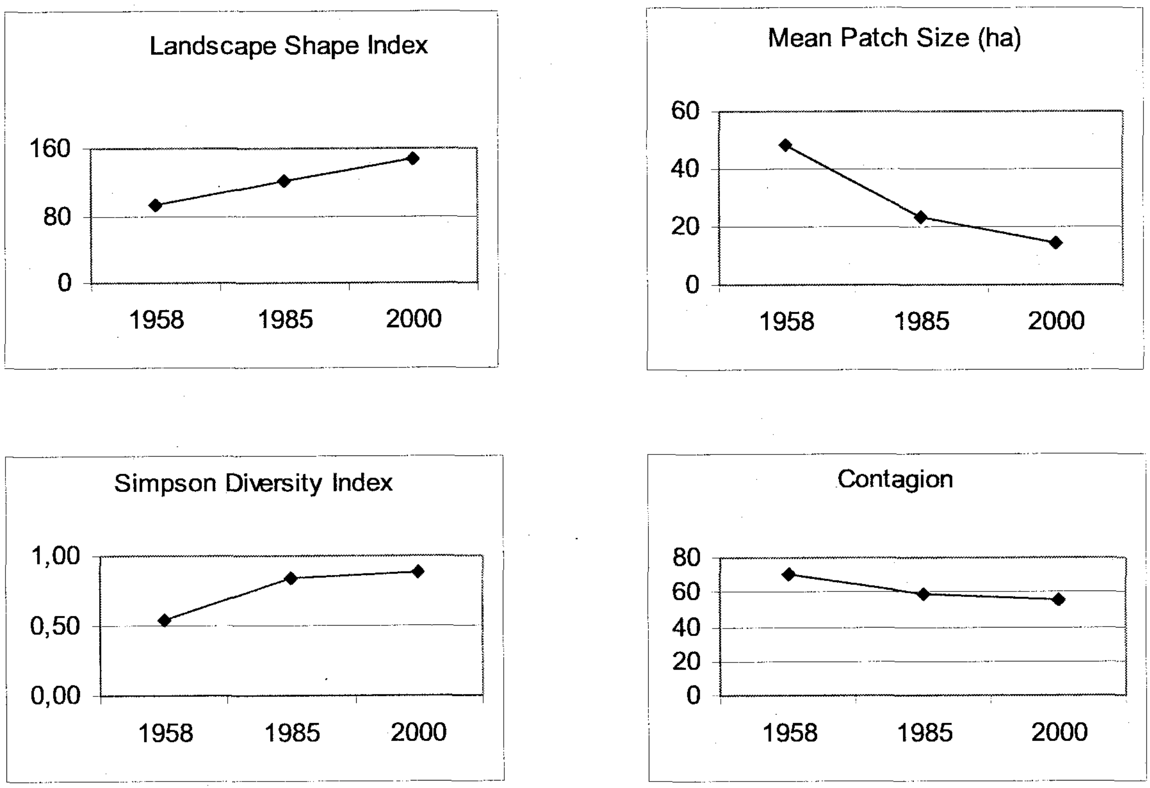


Figure 5: Changes in landscape metrics, representing changes in landscape configuration in the Amendoeira da Serra sample area (1958 - 2000)

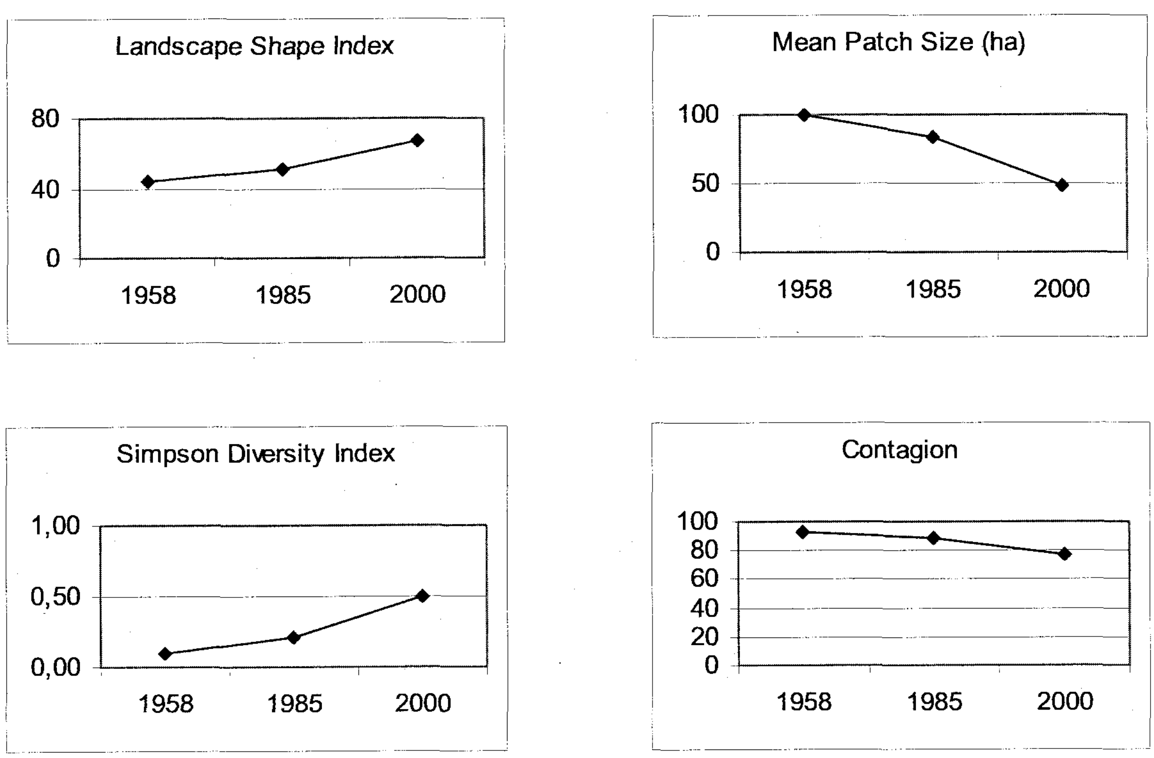


Figure 6: Changes in landscape metrics, representing changes in landscape configuration in the João Serra sample area (1958 - 2000)

Discussion

The present study shows that in both sample areas: 1) an ongoing process of extensification of land use is taking place; 2) the landscape structure became more fine grained and fragmented: there is a trend towards increasing heterogeneity.
The general trend of invading shrubs and trees, either through natural succession or artificially planted, corresponds with a main land use change trend in the Mediterranean: the relaxation of land use. Several authors, like Vos (1993), Pinto Correia (1995) and more recently Romero-Calcerrada and Perry (2004), observed comparable trends in Mediterranean landscapes.

The second observation, a trend towards a more fragmented and complex landscape by the invasion of shrubs and trees, does not correspond with other observed trends in dehesa / montado landscape of the Iberian Peninsula. These studies, on the contrary, show that through extensification, this type of landscape becomes more homogenous. For example, the studies carried out by Fernandez Ales et al. (1992) and Romero-Calcerrada and Perry (2004), both analysing structural changes in Spanish dehesa-landscapes, stress the risk of homogenisation of the landscapes under study through extensification of the land use. Closely related with this process are some problems as increasing fire risk, decreasing biodiversity and loss of cultural values.

Within the timeframe and at the spatial scale of our study, the landscapes of the sample areas show a trend towards increasing heterogeneity. A fundamental element in this discussion is the issue of scale. Whereas trends towards heterogenisation can be found at local level, this might be towards homogenisation on the regional level. Evidence from literature of research carried out at the regional level could elucidate this issue. However, as has been stated in the introduction, studies on landscape change in this region are up to now rare, which complicates comparison of the results. Nevertheless, the only landscape change study carried in the region reveals similar trends (Casimiro 2003). In this study, the landscape structure analysis is based on satellite images of 1985, 1995 and 2001. A number of landscape indices are used, also the MPS, LSI, SIDI and contagion. Each index shows in the study of Casimiro the same trend found in the present paper: towards more heterogeneity. However, more evidence should be gained through landscape change study on regional and (sub) national level.

In the specific case of our study areas, an explanation of the trend observed can be found in the starting period of the study: after the cereal campaigns in the beginning of the 20th century the landscape was very homogenous, dominated by arable / grassland without tree cover. Next, the extensification processes, that started at the beginning of the 1970's, differed at each property. The differences between properties are closely related with the different types of land owners. Each landowner copes in a different way with the biophysical constraints of the area, and profits in a different way of the available CAP-subsidies. One can choose e.g. for production subsidies on livestock or cereals, but one can also choose in the region of the case study area for special LFA-regulations, as are the subsidies for forest plantations. Hence, the farmers' choice depends on a complex set of socio-economic factors, has an important impact on the landscape structure.

As the results show, especially the forest plantation gained recently importance and are an important factor in the increasing landscape heterogeneity. The forest plantation itself is, in general, rather homogenous, with a mono-species stand planted in rows. But because of the dispersed parcel structure, with only some parcels being planted, the landscape pattern becomes more heterogenous.

Besides the starting period of the study and the spatial processes going on, the short period of observation may play a role as well in explaining the trend towards heterogeneity. As the study area is still in a dynamic transition, with from the 1970's on different approaches in different stages of development on different properties. When the forest plantations are more developed and extensification trends progress, it may look different, perhaps eventually evolving towards homogenisation.

Nevertheless, the trend towards a more heterogeneous landscape is unmistakable, and is often related to a greater change for biologic diversity and at the same time floristic, faunistic and structural vegetation diversity enhances ecological heterogeneity (Naveh 2001). Whether the landscapes of the sample areas will indeed continue to follow this direction depends very much on management decision, especially those of the new forest plantations, and this aspect deserves further monitoring and research.

References

Antrop, M., 1993. The transformation of the Mediterranean landscape: experience of 25 years of observations. Landscape and Urban Planning. 24, 3-13.

Antrop, M., 2005. Why landscapes of the past are important for the future. Landscape and Urban Planning. 70, 21-34.

Antrop, M. and Van Eetvelde, V., 2000. Holistic aspects of suburban landscapes: visual image interpretation and landscape metrics. Landscape and Urban Planning. 50, 43-58.

Baudry, J., and Tatoni, T., 1993. Changes in landscape patterns and vegetation dynamics in Provence, France. Landscape and Urban Planning. 24, 153-159.

Bender, O., Boehmer, J.A., Jens, D. and Schumacher, K., 2005. Using GIS to analyse long-term cultural landscape change in Southern Germany. Landscape and Urban Planning 70, 111-125.

Blondel, A. and Aronson, J., 1995. Biodiversity and ecosystem function in the Mediterranean Basin: Human and Non-Human Determinants, in: Davis, G. W. and Richardson, D. M. (Eds.), Mediterranean-Type Ecosystems, the functions of biodiversity. Springer verlag, Berlin, pp 43-119.

Botequilha Leitao, A. and Ahern, J., 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning. 59, 65-93.

Breman, B. and Pinto-Correia, T. 2003. Coping with marginalisation and Multifunctional Land use in Portugal. Research report, University of Évora, Portugal .

Burel, F. and Baudry, J., 1995. Species biodiversity in changing agricultural landscapes: A case study in the Pays d'Auge, France. Agriculture, Ecosystems and Environment 55, 193-200.

Burgi, M. and Russell, E. W. B., 2001. Integrative methods to study landscape changes. Land Use Policy 18, 9-16.

Cancela d'Abreu, A., Pinto-Correia, T. and Oliveira, R. 2004. Contributos para a identificação e caracterização da Paisagem em Portugal Continental. Direcção -Geral do Ordenamento do Território e Desenvolvimento Urbano, Lisboa.

Casimiro, P. C., 2002. Uso do solo, Teledetecção e Estrutura da Paisagem. Phd-thesis New University of Lisbon, Faculty of Social and Human sciences, Lisbon. pp. 572

Casimiro, P. C. 2003. Análise Quantitativa da Paisagem, Evolução Temporal de Padrões Espaciais - Concelho de Mértola. GeoInova - 6, 59-84.

Council of Europe, 2000. The European Landscape Convention. Strassbourg.

Dunn, C. P., Sharpe, D. M., Guntenspergen, G. R., Stearns, F. and Yang, Z., 1991 Methods for analysing temporal changes in Landscape Pattern. in: Turner, M. G. and Gardner, R. H. (Eds.) Quantitative Methods in Landscape Ecology. Springer, New York, pp 173-198.

Fernandez Ales, R., Martin, A., Ortega, F. and Enrique, E. A., 1992. Recent changes in landscape structure and function in a Mediterranean region of South West Spain. Landscape Ecology 7, 3-18.

Forman, R. T. T. and Godron, M., 1986. Landscape Ecology. Willey, New York.

Golley, F., 2000. Analysis of the concept of landscape change. in: Mander, U. and Jongman, R. H. G. (Eds.) Consequences of land use changes. WIT Press. Southampton. pp 3-10.

Gómez-Sal, A., Alvarez, J., Muñoz-Yanguas, M. A. and Rebollo, S. 1993. Patterns of change in the agrarian landscape in an area of the Cantabrian Mountains (Spain) - Assessment by transition Probabilities. in: Paoletti M G. (Eds) Landscape Ecology and Agroecosystems. pp 141-151.

Gustafson, E. J., 1998. Minireview: Quantifying Landscape Spatial Pattern: What Is the State of the Art? Ecosystems 1, 143-156.

Herzog, F. and Lausch, A. 2001. Supplementing Land-Use Statistics with Landscape Metrics: Some Methodological Considerations. Environmental Monitoring Assessment 72, 37-50.

Jongman, R. H. G., 1996. Ecological and landscape consequences of land use change in Europe. ECNC, Tilburg.

Kienast, F., 1993. Analysis of historic landscape patterns with a Geographical Information System - a methodological outline. Landscape Ecology. 8, 103-118.

Lausch, A. and Herzog, F., 2002. Applicability of landscape metrics for the monitoring of landscape change: issues of scale, resolution and interpretability. Ecological Indicators 2, 3-15.

Lehouerou, H., 1993. Land degradation in Mediterranean Europe - Can agro forestry be a part of the solution- a prospective review. Agroforestry systems 21, 43-61.

Longley, P. A., Goodchild, M. F., Maguire, D. J. and Richardson, D. M., 2005. Geographic Information Systems and Science. Wiley, New York.

Lourenço, N., Pinto-Correia, T., Jorge, M. and Machado, C., 1998. Farming strategies and land use changes in southern Portugal: land abandonment or extensification of the traditional systems? Mediterrâneo 12/13, 191-208.

McGarigal, K. and Marks, B. J., 1995. FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure.

Moreira, F., Rego, F. C. and Ferreira, P. G., 2001. Temporal (1958-1995) pattern of change in a cultural landscape of north-western Portugal: implications for fire occurrence. Landscape Ecology. 16, 557-567.

Naveh, Z., 1982. Mediterranean landscape evolution and degradation as multivariate biofunctions: Theoretical and practical implications. Landscape Planning 9, 125-146.

Naveh, Z., 2001. Ten major premises for a holistic conception of multifunctional landscapes. Landscape and Urban Planning 57, 269-284.

Naveh, Z. and Lieberman, A., 1994. Landscape Ecology: Theory and application. Springer Verlag, New York .

O'Neill, R. V., Krummel, J. R., Gardner, R. H., Sugihara, G., Jackson, B., DeAngelis, D. L., Milne, B. T., Turner, M. G., Zygmunt, B., Christensen, S. W., Dale, V. H. and Graham, R. L., 1988. Indices of landscape pattern. Landscape Ecol. 1, 153-162.

Oliveira, R. 1998. Causas para a desflorestação e degradação da floresta - estudo-caso para o concelho de Mértola- Portugal. Catena 12-13, 75-93.

Pan, D., Domon, G., de Blois, S. and Bouchard, A., 1999. Temporal (1958-1993) and spatial patterns of land use changes in Haut-Saint-Laurent (Quebec, Canada) and their relation to landscape physical attributes. Landscape Ecology 14, 35-52.

Perez, M. R., 1990. Development of Mediterranean Agriculture: An ecological approach. Landscape and Urban Planning 18, 211-220.

Pinto-Correia, T., 1993a. Threatened landscape in Alentejo, Portugal: the 'Montado' and other 'agro-silvo-pastoral' systems. Landscape Urban Plann. 24, 43-48.

Pinto-Correia, T., 1993b Land abandonment: Changes in the land use patterns around the Mediterranean basin. in: Baudry, J., and Bunce, R. H. G., Options Méditerranéennes, The situation of agriculture in Mediterranean countries. CIHEAM. Zaragoza, Spain. pp. 97-112.

Pinto-Correia, T. and Mascarenhas, J., 1999. Contribution to the extensification/intensification debate: new trends in the Portuguese montado. Landscape and Urban Planning 46, 125-131.

Pinto-Correia T. 1995. Land marginalisation in Portuguese rural areas: a general view over the actual process and the foreseeable trends for the near future. in: Bethe, F., and Bolsius, E. C. A.. Marginalisation of agricultural land in Europe, essays and country studies. The Spatial Planning Agency, The Hague, 103-118.

Pontius, J., Shusas, E. and McEachern, M., 2004. Detecting important categorical land changes while accounting for persistence. Agriculture, Ecosystems and Environment 101, 251-268.

Poudevigne, I. and Alard, D., 1997. Landscape and Agricultural Patterns in Rural Areas: a Case Study in the Brionne Basin, Normandy, France. Journal of Environmental Management 50, 335-349.

Regato Pajares, P., Castejón, M., Tella, G., Giménez-Caballero, S., Barera, I. and Elena-Rosello, R., 1995. Analysis of changes in Mediterranean mountain regions of Spain: seven study cases. in: Jongman R. (Eds.) Landscape changes in Europe. ECNC, Tilburg.

Romero-Calcerrada, R. and Perry, G., 2004. The role of land abandonment in landscape dynamics in the SPA 'Encinares del río Alberche y Cofio', Central Spain, 1984-1999. Landscape and Urban Planning 66, 217-232.

Rounsevell, M., Reginster, I., Araujo, M. B., Carter, T. R., Dendoncker, N., Ewert, F., House, J. L., Kankaanpaa, S., Leemans, R., Metzger, M.J., Schmit, C., Smith, P. and Tuck, G., 2005. A coherent set of future land use change scenarios for Europe. Agriculture, Ecosystems and Environment in press.

Roxo, M. J., Mourão, J. M. and Casimiro, P. C. 1998. Políticas agrícolas, mudanças de uso do solo e degradação dos recursos naturais - Baixo Alentejo Interior. Mediterraneo 12/13, 167-189.

Tomaselli, R., 1981. Main physiognomic types and geographic distribution of shrub systems related to Mediterranean climates. in: Di Castri F, Goodall D W and Specht R L. (Eds.) Mediterranean-type shrublands. pp 95-106.

Vos, W., 1993. Recent landscape transformation in the Tuscan Apennines caused by changing land use. Landscape Urban Planning 24, 63-68.

Vos, W. and Stortelder, A. H. F., 1992. Vanishing Tuscan Landscapes: landscape ecology of a Submediterranean Montane area (Solano basin, Tuscany, Italy). Pudoc, Wageningen.

Wood, R. and Handley, J., 2001. Landscape Dynamics and the management of change. Landscape Research 26, 45-54.

Chapter 5 Paper D

The destination of arable land in a marginal agricultural landscape in South Portugal: an exploration of land use change determinants

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Abstract

This research attempts to investigate what drives three conversions of arable land during the period 1985 - 2000 in a marginal agricultural landscape in Southern Portugal: afforestation of arable land, abandonment of arable land and regeneration of the agro-silvo-pastoral system. This was done by exploring the associations between these changes and a selection of both biophysical and socio-economic variables in a study area of 44 square km. For each conversion of arable land into one of the three other land use types the descriptive power of the various independent variables were evaluated using logistic regression. By comparing different statistical models (one containing only the biophysical attributes, another model containing only the socio-economic variables and finally a model containing both types of variables) the relative importance of socio-economic and biophysical variables was evaluated. The results show that both the biophysical and socio-economic variables were significantly associated with the occurrences of the land use changes. However, the models containing only the socio-economic variables were stronger related to occurrences of afforestation and regeneration of the montado, whereas the biophysical variables were more related to land abandonment. The landowner type was a significant descriptive variable across all land use change models. The results suggest that local socio-economic factors are significant in explaining the pattern of the conversion of arable land in the study area and for this reason the variety of landowners' response to the physical conditions deserves more attention in land use change modelling.

Keywords:

Descriptive variables; logistic regression; socio-economic drivers; landowner typology; Mediterranean landscapes

1 Introduction.

The changing rural landscape of Europe is the topic of a number of publications in contemporary landscape research (Fernandez Ales et al 1992; Jongman 1997; Kristensen et al 2004). One of the main land use trends of the last decades in marginal agricultural areas of Mediterranean Europe is the decline of arable land (Baudry and Tatoni 1993; Alados et al 2004). Under influence of economy, policy, social and physical processes that act on global, national and local level, the land use in these areas changes to less intensive uses. In this way former cultivated land converts often to shrub and forest. Such changes are often associated with the increased occurrence of wildfires (Moreira et al 2001), a decline of biodiversity (Gonzalez Bernaldez 1991), and a threat to cultural historic values (Pinto-Correia 1993a). Since a further decline of arable land in these areas is expected (Rounsevell et al 2005) it is desirable to enhance the understanding of the process of land use change regarding arable land.

Understanding the underlying processes and identification of driving forces of land use changes is an important subject of research (Burgi et al 2004). In this respect the importance of the socio-economic environment, e.g. political and economical regimes, in relation to land use change is generally acknowledged (Brandt et al 1999; Baudry et al 1999). At the same time, relating socio-economic variables to patterns of land use in combination with an assessment of biophysical variables continues to be a challenging area of landscape ecological research (Burgi et al 2004), especially when integration of different types of data is hindered due to lack of geo-referenced data. As for the socio-economic factors, several authors stressed that the local level should not be underestimated (Pan et al 1999). Integrating socio-economic data at the individual decision-maker's level seems indispensable for explaining change patterns in rural landscapes. While a number of papers has been written about the social factors influencing land use change (Kristensen et al 2001; Bender et al 2005; Mottet et al 2006), a deeper understanding of the role of different local socio-economic factors in generating land use change patterns is needed, especially on the level of individual landowners (Lambin et al 2001).

In this paper the occurrence of land use changes from arable to other land use types in the period 1985-2001 in a local case-study area will be explained by using a set of local biophysical and socio-economic factors. The level of the individual landowner is integrated by means of a landowner typology, assuming that each type of landowner decides in a different way about his land management. The analysis of land use change focuses on the variation of the transformations of arable land in space, which is expected to enhance our understanding of the processes underlying the changes. It is assumed that land use change shows a certain spatially structured pattern that is closely related to a complex of descriptive factors.

2 Materials and Methods.

2.1 Study area

A good example of a region where the decline of arable land has been dramatic over the last decades is the municipality of Mértola in the province of the Alentejo in South Portugal (figure 1). The area has a Mediterranean climate, an undulating relief with poor and shallow soils and is located in a peripheral part of the country. Due to these conditions the area can be considered marginal in terms of agricultural production, although agriculture is a relatively important source of income for the sparsely distributed population (Pinto-Correia et al 2006). Extensive livestock breeding, mainly sheep, and cereal growing are the main agricultural activities, although they suffer from decreasing market importance. Since the Portuguese entrance into the European Union, subsidies and regulations of the Common Agricultural Policy are increasingly determining land use practices in the area, one of the most visible articulations being the introduction of forest plantations, subsidized by successive instruments but mainly in the 1990s through the EU Reg.2080/92. Most of the land is privately owned. Property sizes are relatively large, on average about 100 ha. A rural exodus has taken place and still continues, mainly because of the poor conditions for agriculture, the peripheral location of the area, and the lack of alternative employment sectors.

Within this municipality a sample area of 44 square km is chosen (figure 1). The area is named after the local village, Amendoeira da Serra, and is situated close to the Guadiana River. It is a hilly area with some steep slopes, especially near the river. Agro-silvo-pastoral systems, open holm oak forest with agricultural practices in the understorey, the so-called montado (Pinto-Correia 1993b), dominate the area. This land use system combines forestry with agriculture and pastoralism. The trees are destined for cork production in the case of cork oak (*Quercus suber*) or production of firewood and fodder in the case of holm oak (*Q. rotundifolia*). The alternating densities of holm oak in combination with meadows; arable land, and dispersed shrub create a complex landscape pattern. The remaining area is occupied by new forest plantations, with cork or holm oak and pine (*Pinus spp*)being the preferred species, and by different types of typical Mediterranean scrublands, dominated by *Cistus spp*, also known as matorral;.

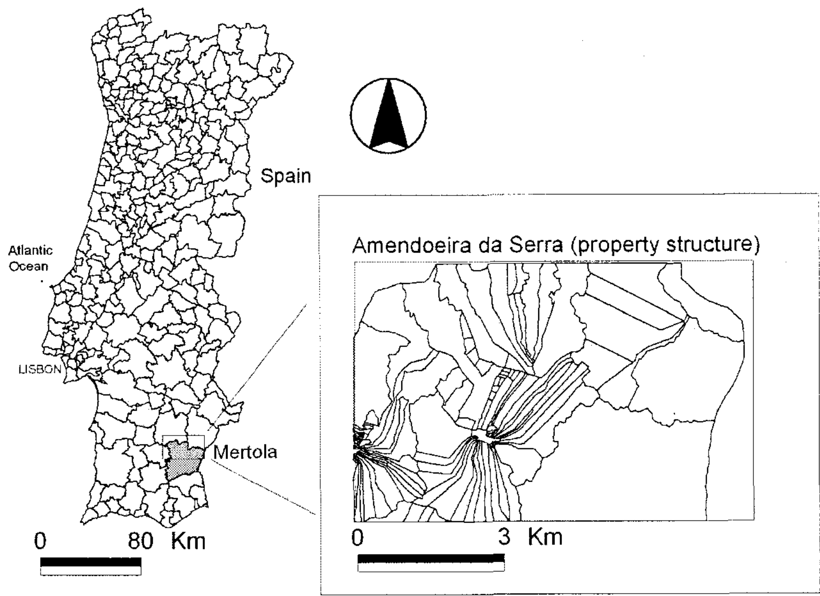

Figure 1: Location of the study area and the property structure of sample area.

Other studies (Roxo et al 1998; Casimiro 2003; Doorn and Pinto Correia, in press) dealing with land use dynamics of the region reveal that most severe changes in agricultural management and landscape in the study area have taken place in the last 50 years (figure 2). Important changes in arable land are afforestation, regeneration of montado and abandonment. Afforestation is a drastic land use change, with severe soil mobilization and often a complete removal of the existing vegetation. While the intervention itself is rather drastic, the direction of land use change is, eventually, towards a less intensive way of land use. With financial support coming from the CAP, the young trees (holm oak, cork oak and pine are the preferred species) are sown or planted in high densities (625 trees ha-1). Regeneration of the montado, is a gradual process of natural regeneration of holm oak. This results from land use extensification, for example decline of soil tillage practices and decreasing grazing intensity, in combination with the support of natural regeneration of oak trees. Arable abandonment is a result of an ongoing decline of agricultural practices over a long term. Shrubs like *Cistus spp* usually establish in these areas.

Because data of the landowners were available from 1985 on, the land use changes over the period 1985 - 2000 were examined. The municipality level, which is in this region of Portugal average 100 km^2 in area, was our spatial scale because it is the appropriate scale to register a diversity of landscape changes on the one hand, and to maintain a workable scale for the collection of social data on the other hand.

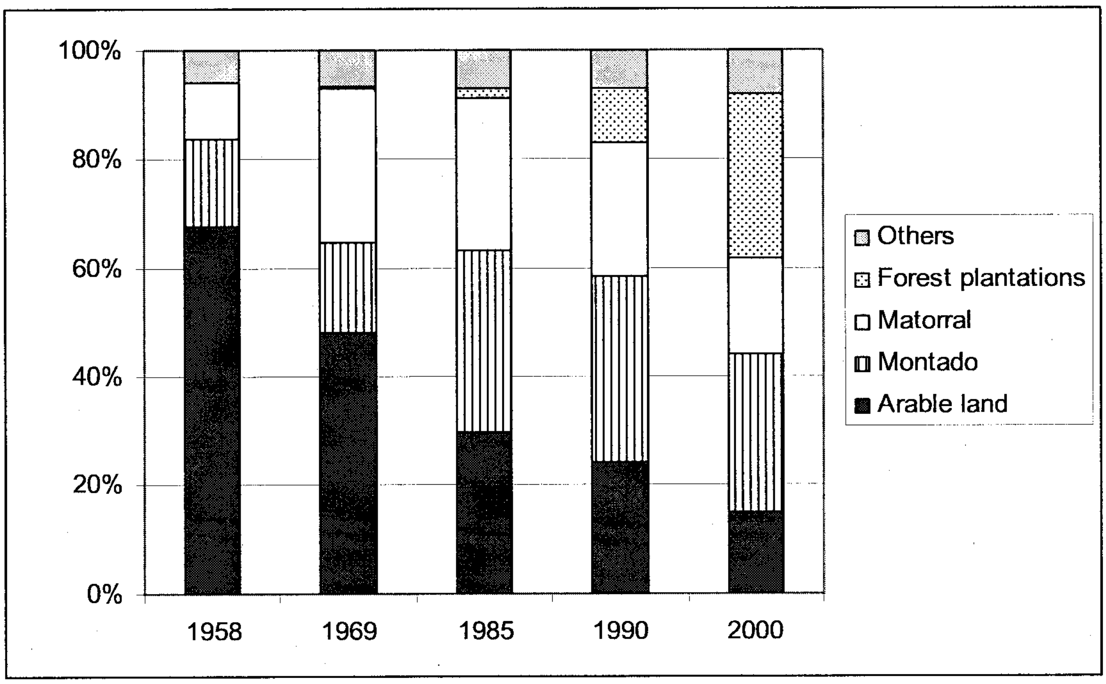

Figure 2: Changes in land cover / use over the time period 1958 -2000 in the study area of Amendoeira da Serra.

2.2 Land cover / use data

Data on land cover / use were derived from aerial photographs. Two years were studied: 1985 and 2000. For the year 2000 digital ortho-photo-maps, defined in UTM projection, with a 1 meter resolution were used. For the year 1985, hard copies of pan-chromatic aerial photographs with a scale of 1: 15 000 were scanned (600 dpi) and geo-referenced with the ArcView extension Image Warp, using at minimum 10 ground control points and the ortho-photo maps of 2000 as the base map. The distortion was at maximum 15 m. For both years the images were classified qualitatively on screen based on visual interpretation of land cover, according to the basic guidelines set out by Lillesand and Kiefer (1994), using a minimum mapping unit of 0.5 ha. Four land cover / use categories were distinguished: arable land, forest plantation, montado and matorral.

In this study arable land is a rotational system of arable with grassland, that is characterized by the absence of trees and shrubs (< 5% cover). When the land is fallow for a couple of years there is extensive livestock breeding of mainly sheep and cattle. The forest plantations are defined as areas where trees are recently planted or sown in an afforestation-scheme. The preferred species are holm and cork oak, but also plantations of *Pinus spp* and *Eucalyptus spp* occur. The montado distinguishes from the arable land and from the matorral category, because of the presence of a tree cover of cork or holm oak trees of more than 5%. Matorral is defined as a shrubby formation of woody plants (mainly *Cistus spp.*) related to Mediterranean climates.

2.3 Bio-physical variables

A topographical map of 1989, scale 1:25 000 (Instituto Geográfico do Exercito 1989), was used to construct a digital terrain model, to derive slope and south exposure. For south exposure, serving as a proxy for moisture and solar radiation, a continuous scale was used, ranging from 0 (N) to 180° (S), without distinguishing between east and west.

The available information on soil consisted of a soil map from 1959, scale 1: 50.000, which provided data on soil types. On this map four classes of soil are distinguished: 1) Rock outcrop of schist; 2) Litho-soils of sub humid and semi arid climates of schist; 3) Red or yellow Mediterranean soils of non-calcareous material or schist and 4) Grey Mediterranean soils of non-calcareous material or schist. Yet, the four classes showed high levels of correlation (significance at 0.01 level) with the other biophysical variables as slope and aspect. For this reason the four classes were reduced to two types with respect to their agricultural qualities, based on soil depth and percentage of organic matter. Soil type 1) the rock outcrop and soil type 2) the litho-soils are both characterized by less than 10 cm soil depth and a low percentage of organic matter (1.4%). These two types were aggregated to soil type A, that represents soils that have a low quality for agricultural. Soil type 3) the red or yellow Mediterranean soils and soil type 4) the grey Mediterranean soils have both a soil depth up to 30 cm and have a higher percentage of organic matter (4.6%). These two types are aggregated to soil type B that represents the relatively better agricultural quality soils. Correlation tests with the aggregated soil variables and the other bio-physical variables did not show significant correlation levels.

2.4 Socio-economic database and property structure

One socio-economic variable concerned the accessibility of farmland. By creating buffer zones of 10 m around the (dirt) roads in ArcView, a raster map with a 10m resolution was made in which each cell of map contained a value corresponding to the distance to the nearest road.

The other socio-economic variable concerned the individual landowner. Quantitative and qualitative data of the landowners were collected at the household level. This level allows a representation of the heterogeneity of landowners in a certain area, and serves to capture the actual level of decision-making (Lambin 2004). From cadastral archives, information of the regional agricultural administration and oral information of the local population, the property structure, i.e. structure of land tenure, could be mapped (figure 1) and the landowners identified. The interview data showed that the average period of ownership, and thus responsibility of the land management was 32 years, a period that is much longer than the study period (1985-2000). Consequently, the property structure, including the property size and structure, as well as number of farms and ownership, was assumed to be stable from 1985-2000 and the interviewed landowners representative for the land management during the study period.

Structured interviews with landowners were carried out in the spring/summer of 2004. To make the sample consistent, only the landowners who were responsible for managing the land at present were interviewed. To obtain a good representation of the diversity of landowners and land use, the sample of landowners to be interviewed had to represent a wide range of different types of landowners and had to cover a representative part of the study area. In practice, a lot depended on the accessibility of the landowners, as some are untraceable, while others refused an interview. Eventually, 28 landowners were interviewed, corresponding to 56% of the landowner population, owning together 81% of the area.

The data at the household level were combined into groups of landowners. According to the framework of Kristensen et al (2001), policies oriented towards regulation of landscapes do not have a direct impact on the landscape, but rather are implemented by actors. Their individual decisions are influenced by a variety of considerations originating from owners' and producers' perspectives. This variety of attitudes was captured and simplified in a landowner typology, as an appropriate method to articulate the different perspectives of landowner behaviour and response to the biophysical and socio-economic environment. So information of individual households was aggregated by types of landowners, distinguished on a set of various social, economic, and cultural factors.

Developing typologies of landowners can be defined in terms of scale, intensity, products etc. and is a research challenge originating from rural sociology (Van der Ploeg 1994). More specifically, for landscape change studies, several authors have successfully made use of landowners typologies (Poudevigne and Alard 1997; Kristensen et al 2001)

2.5 Data analysis

2.5.1 Land use changes

The changes in arable land were assessed by overlaying the two land use maps from 1985 and 2000. The areas that had undergone a change in arable land as well as those where the arable land stayed stable, were selected, which resulted in the map of land use change.

2.5.2 Landowner clustering

Household data were aggregated to groups of landowners through cluster analysis. The interview data that were assumed to be important in determining the typical management methods entered the analysis and were transformed to categorical data (table 1). A hierarchical cluster analysis was performed using average linkage with between groups selection, which is an agglomerative clustering method (Jongman 1995). This clustering method consecutively groups those objects that are the most similar into clusters. Next, these clusters are grouped into larger clusters of a higher rank. To eventually determine the membership of each landowner to a cluster, the cut-off level was established in proportion to sample size and size of clusters, which resulted in the differentiation of four clusters.

For the logistic regression the landowner types entered the equation as a nominal variable that was transformed into a dummy variable for each type of landowner. The dummy variable for the retired landowner takes 1 when an area belongs to a retired landowner and takes 0 when it belongs to another type of landowner.

Variable	Categories
Main agricultural activities	1) Cereals, 2) Livestock, 3) Cork production, 4) Hunting, 5) None, 6) Other, mix.
Distance property - residence	1) < 20 km, 2) 20 - 50 km, 3) > 50 km.
Age	1) 30 - 50 yr, 2) 50 - 65 yr, 3) > 65 yr
Education	1) < 5 yr, 2) 5 - 10 yr, 3) > 10 yr
Property size	1) < 50 ha, 2) 50 - 200 ha, 3) 200 - 500 ha, 4) > 500 ha
# Gross Cattle Unit	1) 0, 2) < 50, 3) > 50

Table 1. Variables used in the hierarchical clustering of the landowners

2.5.3 *Statistical analysis*

From the raster maps, 4400 sample points were systematically sampled, based on a regular grid that was projected on the maps, with a density of 1 sample point per hectare. This density was chosen based upon the assumption that 1 ha corresponds to the unit of decision making for agricultural management In this way an artificial increase of the significance levels by having more statistical observations than 'true' observations, which would occur when sampling more than once from one single observation (i.e. a parcel), was minimized. Each sample point contained attribute data on presence/absence of a land use change, biophysical and socio-economic variables (table 2).

The descriptive variables were checked for multi-colinearity with the Pearson correlation coefficient.

To associate land use changes with socio-economical and biophysical variables a binary logistic regression was carried out. Each land use change (the response variable) was converted into a binary variable representing the presence / absence of the change, whereby the zeroes are observations of arable land that has not changed. The aim of the regression technique is twofold: 1) to identify the contribution of individual descriptive variables as well as groups of descriptive variables (i.e. socio-economical and bio-physical) to the description of the three investigated land use changes; and 2) to assess nature of the relationship between response and individual descriptive variables.

Response variables	type	Descriptive variables	type
Land use change:		1. Soil quality	binary
- Afforestation - Regeneration of montado - Abandonment	binary (presence /absence)	2. Slope	continuous (°)
		4. Aspect	continuous (°)
		5. Distance to road	continuous (m)
		6. Land owner type	categorical

Table 2. Variables used for the logistic regression

Goodness of fit is evaluated by the chi-square test, applied to the difference in the (-2Log) maximum likelihood of a model with descriptive variables to a model with less or no descriptive variables. One of the aims of the analysis is to identify the relative importance of the biophysical and socio-economical variables. For this purpose three models for every land use change were tested and the goodness of fit was evaluated: 1) a full model including both biophysical and socio-economical variables, 2) a model including only bio-physical variables and 3) a model including only the socio-economic variables. To assess the descriptive power of the variables, the chi-square values of the three models were compared. The greater the chi-square value the stronger the land use change is associated with the set of descriptive variables. Furthermore, when the sum of chi-squares of models 2 and 3 is higher than the chi-square of the full model (model 1), it can be concluded that there exists an overlap between the descriptive power of the two groups of variables (Bakker et al 2005a). Within the overlap it is not possible to assign the descriptive power to one of the groups.

To accomplish the second aim of the regression technique, the evaluation of the descriptive power of each individual variable, 7 models for each land use change were tested, each model including just one variable. Since a quantitative analysis of the regression coefficients is in this case less relevant due to the complexity of the descriptive variables and to confounding between the variables (Bakker et al 2005b), the significance of the contribution to the model of each variable and the sign of the regression coefficient are especially interesting.

To avoid an erroneous fit of the model, it was sometimes necessary to remove data points when the ratio 0/1 observations for the response variable was out of proportion, meaning an excess of 0's compared to 1's or the other way around. By random sampling out of the most abundant category a maximum skewness of 1/3 vs 2/3 of the total sample was enforced.

3 Results

3.1 Changes in arable land use.

The overlay of the land use maps of 1985 and 2000 (figure 3), resulted in a land use change map (figure 4). Three land use changes that involved the decrease of arable land were identified: 1) Afforestation, 2) Regeneration of the montado and 3) Abandonment, leading to the establishment of matorral. The descriptive statistics for the biophysical characteristics of the land undergoing these changes are given in table 3. The average for soil quality represents the average of the binary variable and values closer to 0 correspond to quality type B soils (the soils with higher quality in relation to agriculture) and values closer to 1 correspond to quality type A soils (the soils with a low quality in relation to agriculture).

According to table 3 the areas where the arable land did not changed ('stable arable') have in general type B soils (mean = 0.69) and gentle slopes (mean = 5.1 °). On average Afforestation occurs far away from infrastructures (mean distance = 585 m.) and on type A soils (mean = 0.97). Regeneration of montado is located the closest to infrastructure (mean distance = 492 m) and has the most gentle slopes (mean slope = 4.9°). Abandonment of arable land occurs on the steepest slopes (mean slope = 8.5 °) and the soils of type A (mean = 1.00)

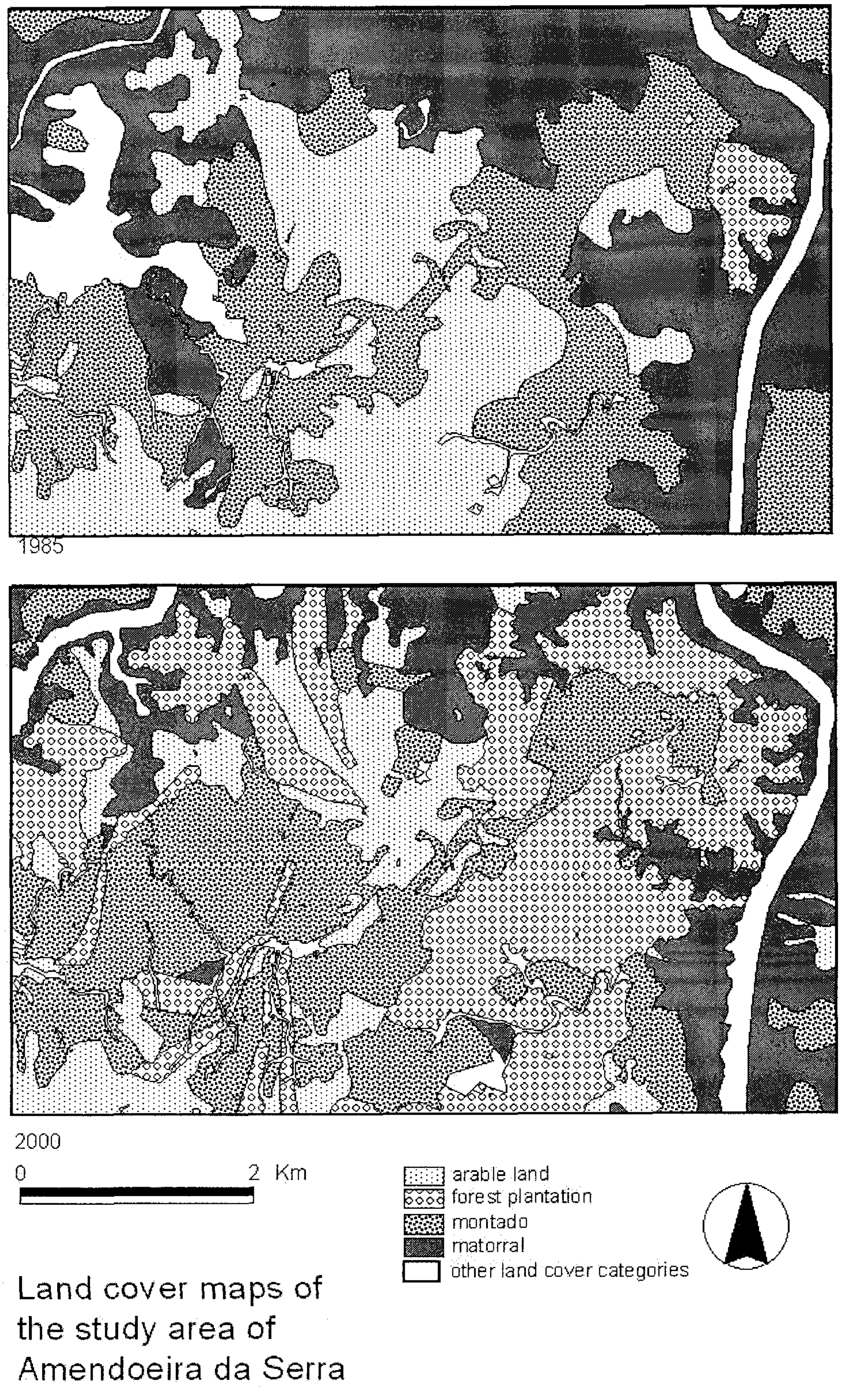

Figure 3: Land cover maps from 1985 and 2000, derived from aerial photographs of the sample area of 44 square km at Amendoeira da Serra , municipality of Mértola.

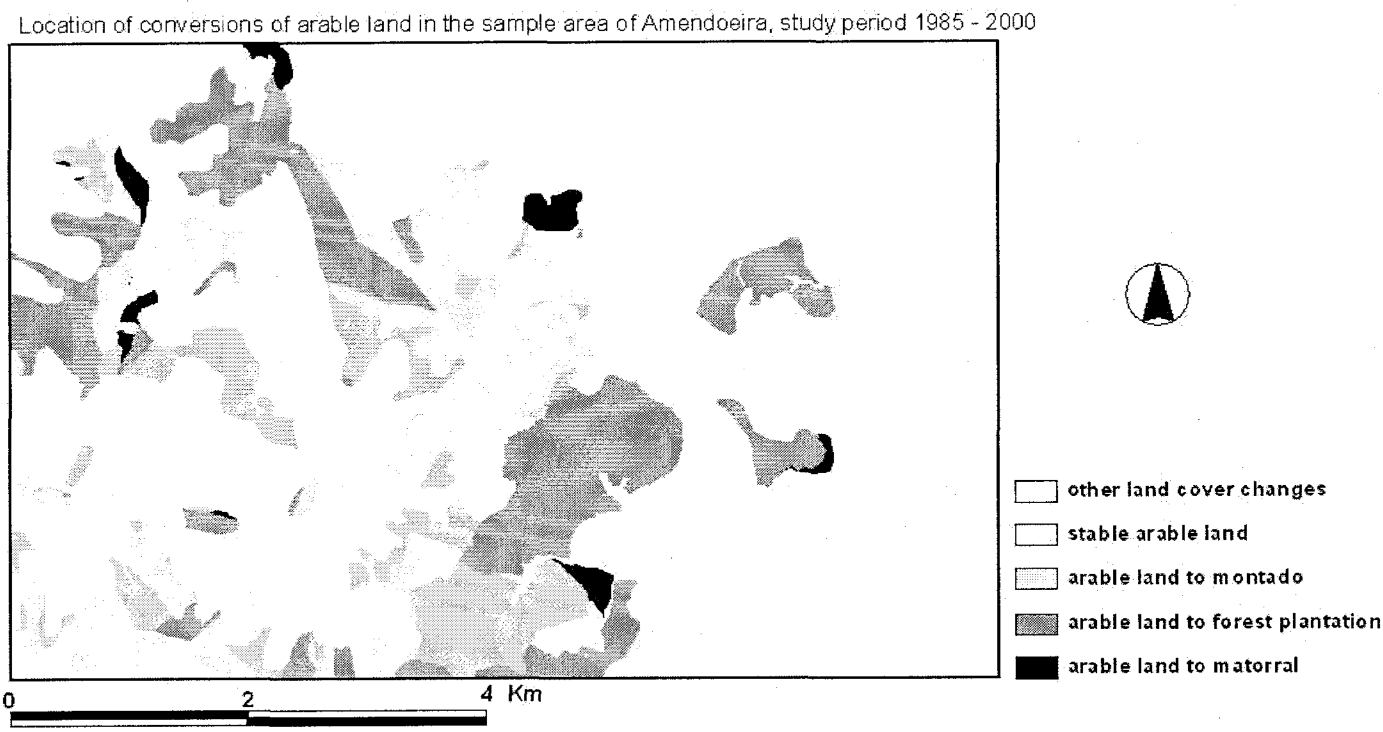

Figure 4: Map of changes of arable land 1985 - 2000

	ha	%	slope (°)	aspect (°)	soil quality	dist_infra (m)
Stable arable	433	10	5.1	86.1	0.69	571
Afforestation	492	11	6.1	88.5	0.97	585
Regeneration of montado	269	6	4.9	74.9	0.83	492
Abandonment	47	1	8.5	77.65	1.00	591

Table 3: Land use change in hectares and percentages of the total study area and their average biophysical attributes.

3.2 Landowners clustering

The cluster analysis of the household data resulted in four groups of landowners. The characteristics of each group are summarized in table 4.

The retired landowner has the highest age: 65+; and the lowest education: less than 4 years. In general they live close to their properties, which is in most cases inherited. From the interviews it became clear that most of them have left agriculture or will do so in the near future. Their agricultural practices are reduced to subsistence farming. In consequence, their holding does not generate much income; some earn money for renting out their land. When they die or leave their property the land is normally divided among the inheritors, but rarely do those start practicing agriculture. So usually the land is afforested, rented out to the active landowners in the area or, less frequently, will be sold to neighbouring landowners or to newcomers. It appeared to be too complicated to include these variations on ownership in the analysis, and, as mentioned before, only the landowners who are responsible for the present management were included in the analysis.

The active landowners are on average younger then the retired landowners and with larger properties (up to 1000 ha). They have the highest number of livestock (30-500 gross cattle units); their main agricultural activity is livestock breeding, often sheep for meat production, sometimes cows or pigs and cereal growing. Presumably, they will continue farming in the near future, some of them have a successor for their holding, nevertheless it is expected that the overall number of active landowners will decrease. Continuation of farming will, most probably, be extensive livestock breeding in combination with some cereal growing. A future prospect for the 'active landowner'-type of landowner will be the survival of a few large landowners that are taking over an increasing part of the area, by renting or buying land.

The smallest group of landowners are 'diversified landowners', they have large properties (up to 1000 ha). Their land management practices are characterized by a variety of activities: livestock breeding, hunting, forestry, nature protection etcetera. This type of landowners can either be individuals or cooperatives and foundations; in general they have a high level of education and are relatively young. Because of spread sources of income it is expected that these landowners will continue to manage the land in a diverse way.

Finally, landowners who live far away from their land, more than 60 km, rarely have livestock and are called the 'absentee landowner'. This type includes landowners who are usually middle-aged and possess medium sized properties (100 - 500 ha). They want to keep the land that they normally inherited, because of the family connection and / or the investment of capital. They are not occupied with the daily management of the land; often a neighbouring landowner is in charge of that.

Because of this labour-poor long distance management, there are few requirements for continuation, and it is expected that most of the landowners of this type will pursue with this type of management.

Landowner type	age (yrs.)	education (yrs.)	distance home - property (km.)	property size (ha.)	nr. of animals	main agr.activity
Retired	> 65	<4	<10	<100	<30	none
Active	40-65	2-9	<30	100-1000	30-500	livestock
Diversified	30-40	>5	>30	100-1000	50-100	mixed
Absentee	>35	>4	>30	100-500	0	cork prod.

Table 4: Landowners typology and associated parameters.

3.3 *Statistical analysis*

The correlation test revealed that the descriptive variables were not correlated to an extent that multi-colinearity problems would arise (i.e. Pierson r < 0.20)

The results of the logistic regression for the three land use changes are displayed in table 5. In the first column the signs of the regression coefficients of the individual variables are shown, indicating the nature of the relationship. Positive values of the regression coefficients indicate that higher values of the independent variables coincided with more occurrences of a certain land use change. The next three columns show the chi-square values for the individual variables; the two variable-groups (socio-economical and bio-physical) and the total model. The greater the chi-square value the stronger the land use change is associated with the set of descriptive variables.

For each land use change the models including both socio-economic and biophysical descriptive variables have significant chi-square values. This also applies for the models including either the biophysical variables or only the socio-economic variables. This means that the set of descriptive variables describes well the ccurrence of the changes in arable land (i.e. the hypothesis that the land use changes occur independently from the biophysical or socio-economical variables can be rejected). Furthermore, the sum of chi-squares of the socio-economic model and

	Individual variables		biophysical /socio-economical	total model
(a)	(b) direction	(c) x^2	(d) x^2	(e) x^2
AFFORESTATION				
bio-physical variables				
slope	+	11***		
south exposure			141***	
soil quality	-	134***		
socio-economical variables				507***
dist. to infrastructure				
l-o type retired	+	87***		
l-o type active	-	179***	415***	
l-o type absentee				
l-o type diversified	+	342***		
REGENERATION OF MONTADO				
bio-physical variables				
slope				
south exposure	-	6**	39***	
soil quality	-	16***		
socio-economical variables				112***
dist to infrastructure	-	13**		
l-o type retired				
l-o type active	-	36**	103**	
l-o type absentee	-	10**		
l-o type diversified	+	95**		
ABANDONMENT				
bio-physical variables				
slope	+	24***		
south exposure			78***	
soil quality	(-)†	32***		
socio-economical variables				131***
dist. infrastructure				
type retired				
type active			58***	
type absentee	-	5*		
type diversified	+	44***		

*** indicates significance at 0.001 significance level

** indicates significance at 0.05 significance level

* indicates significance at 0.1 significance level

† No convergence due to complete data separation; Chi square significant at 0,001 significance level

Table 5: Results of the logistic regression

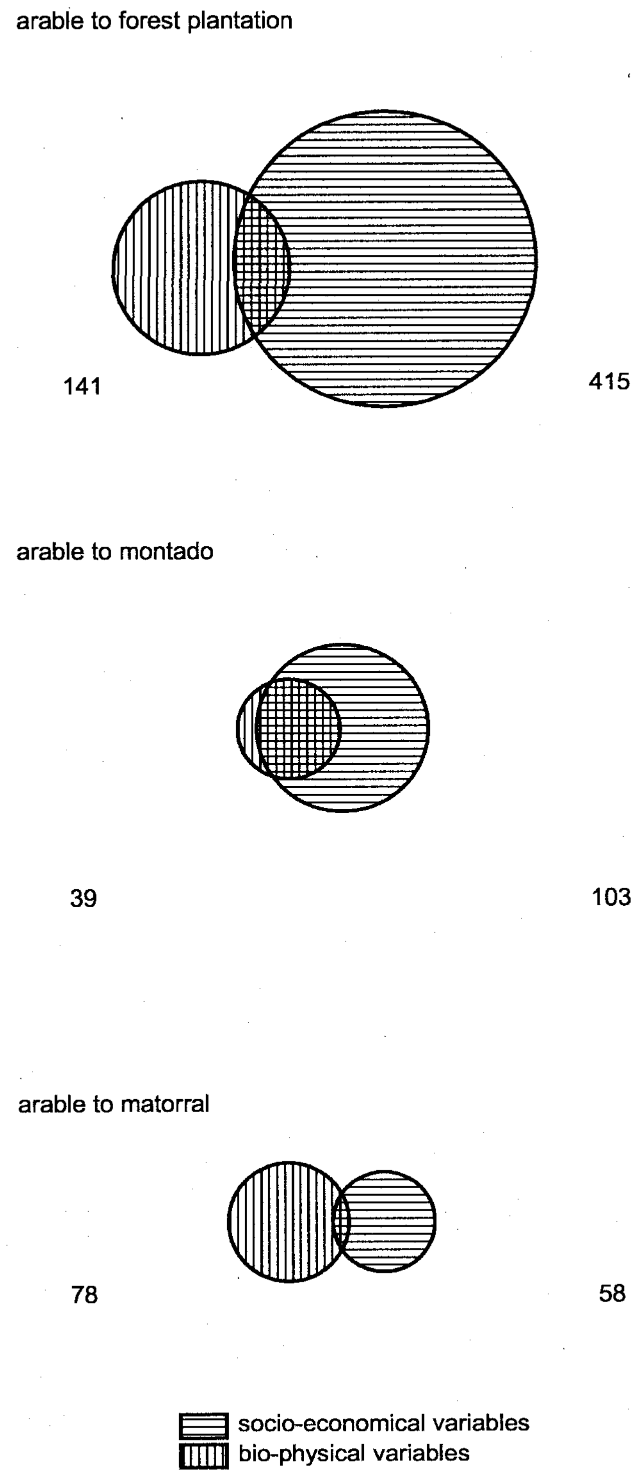

Figure 5: Visualization of the contribution and overlap of the biophysical and socio-economical variables based on the chi-square values.

the bio-physical model is for each land use change higher than the chi- square of the full model. This indicates an overlap in the descriptive power of the set of bio-physical descriptive variables and the set of socio-economic variables. The models describing afforestation and the regeneration of the montado including only the socio-economic variables have a higher chi-square value than the models including only the bio-physical variables. The portion of the chi-square values, the overlap between both sets of variables and the added value of each set is visualised in figure 5. In this figure the circles represent the descriptive power of each set of variables: the larger the circle, the larger the descriptive power.

According to the results of the models tested with the descriptive variables separately, it can be concluded that slope is significantly associated with abandonment and afforestation. In both cases the direction of the beta is positive, implying that abandonment and afforestation occurred more often on steep slopes. Soil quality is significantly associated with each land use change, in the sense that arable land is maintained on good soils, whereas alternatives are sought for the soils with low qualities for agriculture.

Concerning the socio-economical data applies that at least one or more of the landowner types contributed significantly to each land use change model. The landowner type 'diversified' has for each model a significant Chi-square value. The regression coefficient for this landowner type is positive for each model, indicating that diversified landowner generally is least inclined to maintain arable cultivation. Contrarily, the landowner type 'active' is associated negatively with two conversions, implying that the active landowner is more inclined to maintain arable cultivation.

4 Discussion

The comparison of the chi-square values showed that the models including only the socio-economic variables predict better the occurrence (because of higher chi-square values) of afforestation or the regeneration of montado than the models including only the biophysical variables. For abandonment the bio-physical variables are more important than the socio-economical variables. This implies that this land use change is much less a matter of freely chosen decision making of the landowners, but is forced by the strong bio-physical limitations.

The type of landowner appears to be an important descriptive variable for the occurrence afforestation. The results of the single variable models indicate that the 'retired' landowner and the 'diversified' landowner have positive correlation coefficients. This means that the higher the chance a landowner is of the type 'retired' or 'diversified' the greater is the probability the arable land converts to a forest plantation. Landowners of the type 'retired' will plant forest on their arable land, because they stopped their agricultural activities, but still want to earn some money from their land and to do investments for their children. Landowners of the type 'diversified' will do so too, because of the multipurpose management of their property. Instead of only focussing on agriculture, also hunting and forestry are part of their management that favours the natural regeneration of the montado system.

The interviewees of this type of landowner mention the specific management choices they made to support a particular land use, like hunting, nature education and beekeeping. This could also explain the other positive correlation coefficients for the models predicting the conversions from arable land to montado and to matorral. The association between farms with a broad range of production and land use change has also been found by Poudevigne and Alard (1997) in Normandy, France. The different reasons of the 'retired' and the 'diversified' landowner to convert the arable land into forest plantation will influence greatly the management of the forest plantation on the long term and thus the development of the land cover in the future. When a holm oak plantation is managed well and shrub growth is repressed, the plantation might evolve eventually into a montado.

The negative correlation coefficients of the 'active' landowner in the models that explain afforestation and regeneration of montado suggests that landowners of this type practice a rather stable way of agriculture. They maintain their arable land without many land use transitions. This relation between stability in land use and a narrow and stable range of production activities has also been found by Poudevigne and Alard (1997). However, according to the interviews with the active landowners in this study area there have been significant changes in management driven by the trade-off between profitability, availability of subsidies and labour demand. In particular, the type of livestock was subject to changes: there used to be many more goat and cattle, where it is at present mainly sheep. Apparently such changes are not reflected in the analysis.

Contrarily to afforestation and regeneration of montado, abandonment is more directed by the set of bio-physical variables. As can be seen from the results of the models with the single variables, especially slope and soil quality are significant variables. The probability of abandonment of arable land is higher on steep slopes with a soil that has low qualities for agriculture. Which type of landowner is in charge of the management appears to be less important. This suggests that the bio-physical constraints of these areas are that strong that it is unfavourable for all types of landowners to practice agriculture there. This is contrarily to what Mottet et al (2006) found in their case study in the French Pyrenees, where abandonment did not necessarily occur on areas with the strongest bio-physical constraints.

Nevertheless, the types of landowners are related in a different way with afforestation and regeneration of montado. Factors that constitute these differences have to be searched in specific management goals, availability of (financial and physical) resources and personal circumstances. The land use changes as described in the paper have an important impact on the landscape of the study region. The influence of the type of landowner on the past land use changes appeared to be important in explaining the pattern of these changes, and it is expected to be that this also counts for the future land use changes. A better understanding of how landowner types relate to specific land use changes can contribute to direct and specify policies for landscape management.

Demographical trends show that the portion of landowners who practice actively agriculture is diminishing strongly, while the local population is aging quickly. An increase of retired landowners could imply, according to the results, the area of forest plantations and montado will increase at the expense of arable land. A further understanding of the process of land use changes requires a profound analysis of the interaction of types of landowners and their bio-physical environment, as well as an analysis of the individual land management responses of the different landowner types to changing economic conditions and institutional factors as the regulation of the CAP. Only in this way, downscaling future scenarios of land use change will generate more reliable results. On which basis land management policies and regulations can be designed to act more specifically on local situations. In this respect land use change modelling with Agent Based Modelling (ABM) is a promising tool for exploring and modelling different groups of landowners in relation to their socio-economical and physical environment.

The methodology used has been shown to be suitable for explaining landscape change using a wide variety of different types of data, and thus is considered to be useful in research that aims to integrate spatially explicit bio-physical and socio-economic data. Although the range of descriptive factors is not complete it was possible to identify some important factors. The presented method allowed to 1) assess the descriptive power of the two sets of descriptive variables relative to one another, 2) establish functional relationships between the descriptive variables and the response variables, and 3) identify the most significant factors in explaining the pattern of change of arable land. This pattern-led approach enhanced our understanding of the process of arable land use change. What has not been done in the presented study is a validation of the three derived land use change models.

Furthermore, because the study is not process-based, questions concerning the reason why land use change has taken place can not be answered.

However, including the landowner typology raised the study beyond the level of purely analyzing spatial patterns. It allowed not only to answer the question where the land use changes occurred, but also who made the changes, making inferences possible of why they chose or chose not to make such changes. This could contribute to a deeper analysis of landowner management strategies in relation to the biophysical as well as the socio-politico-economic environment.

5 Conclusions

As a result of ongoing global developments, arable land in marginal areas in Europe is on the decline. Land that is too marginal is abandoned, and only on the best soils arable cultivation is maintained. Four different landowner types could be distinguished, who all have different attitudes towards the land use possibilities. The diversified landowners are most inclined to actively respond to policies by converting the arable land to forests and Montado, or simply let natural succession take over by which they create possibilities for hunting and beekeeping. The retired owners tend to turn their arable land into forest plantations, while the active landowners are most inclined to maintain arable cultivation.

The method of combining socio-economical and biophysical data allows for identifying the relative importance of the two groups. By comparing the model performance of three model variants (a model containing all variables; a model containing only the biophysical variables; and a model containing only the socio-economical variables) assumptions on whether the land use change is mainly biophysically driven or that it is more a matter of socio-economical aspects can be supported or rejected. In the present case it turned out that afforestation and the regeneration of the Montado system is mainly a socio-economical matter, whereby the landowner typology appears to determine whether or not a landowner is willing to respond to policies that favour these land use changes. Land abandonment, on the other hand, is mainly determined by biophysical characteristics, implying that the most marginal lands are no longer suitable for any use of the land other than extensive uses such as hunting and beekeeping.

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References

Alados CL, Pueyo Y, Barrantes O, Escos J, Giner L, Robles AB (2004) Variations in landscape patterns and vegetation cover between 1957 and 1994 in a semiarid Mediterranean ecosystem. Landscape Ecol 19: 543-559

Bakker MM, Govers G, Ewert F, Rounsevell M, Jones R (2005a) Variability in regional wheat yields as a function of climate, soil and economic variables: Assessing the risk of confounding. Agr Ecosyst Environ 110: 195-209

Bakker MM, Govers G, Kosmas C, Vanacker V, Oost Kv, Rounsevell M (2005b). Soil erosion as a driver of land-use change. Agr Ecosyst Environ 105: 467-481

Baudry J, Tatoni, T (1993) Changes in landscape patterns and vegetation dynamics in Provence, France. Landscape Urban Plan 24: 153-159

Baudry J, Laurent C, Thenail C, Denis D, Burel F, (1999) Driving factors of land-use diversity and landscape patterns at multiple scales - a case study in Normandy, France. In: Kronert R, Baudry J, Bowler IR, Reenberg A (eds) Land-use changes and their environmental impact in rural areas in Europe. UNESCO, Paris, pp. 103-120

Bender O, Boehmer JA, Jens D, Schumacher KP (2005) Using GIS to analyse long-term cultural landscape change in Southern Germany. Landscape Urban Plan 70: 111- 125

Brandt J, Primdahl J, Reenberg A, (1999). Rural land-use and landscape dynamics - analysis of 'driving forces' in space and time. In: Kronert R, Baudry J, Bowler

IR, Reenberg A (eds) Land-use changes and their environmental impact in rural areas in Europe. UNESCO, Paris, pp. 81-102

Burgi M, Hersperger AM, Schneeberger N (2004) Driving forces of landscape change - current and new directions. Landscape Ecol 19: 857 - 868

Casimiro PC (2003) Análise Quantitativa da Paisagem, Evolução Temporal de Padrões Espaciais - Concelho de Mertola. Revista Geolnova - Revista do Departamento de Geografia e Planeamento Regional 6: 59-84

Doorn v A (in press) Extensification trends in Mediterranean land use systems: does the landscape homogenisation dogma apply? A landscape change study (1958-2000) in the Portuguese Alentejo. J Mediterr Ecol (in press)

Fernandez Ales R, Martin A, Ortega F, Enrique EA (1992) Recent changes in landscape structure and function in a Mediterranean region of South West Spain. Landscape Ecol 7: 3-18

Gonzalez Bernaldez F (1991) Ecological consequences of the abandonment of traditional land use systems in central Spain. Options Méditerranéenes, Série Séminaires 15 Land abandonment and its role in conservation, pp 23-29

Instituto Geográfico do Exercito (1989) Carta Militar de Portugal 1:25K series M888 nr 541, Lisbon

Jongman RHG (1997) Ecological and landscape consequences of land use change in Europe. Proceedings of the First ECNC Seminar on Land Use Change and its Ecological Consequences. ECNC, Tilburg

Jongman RHG, Ter Braak CJF, Tongeren OFR (1995) Data analysis in community and landscape ecology. Cambridge University Press, Cambridge

Kristensen L, Thenail C, Kristensen SP (2004) Landscape changes in agrarian landscapes in the 1990s: the interaction between farmers and the farmed landscape. A case study from Jutland, Denmark. J Environ Manage 71: 231-244

Kristensen SP, Thenail C, Kristensen L (2001) Farmers' involvement in landscape activities: An analysis of the relationship between farm location, farm characteristics and landscape changes in two study areas in Jutland, Denmark. J Environ Manage 61: 301-318

Lambin EF (2004) Linking socio-economic and remote sensing data at the community or at the household level. In: Fox J (ed) People and the environment: approaches for linking household and community surveys to remote sensing and GIS. Kluwer, Dordrecht, pp. 223-240

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C (2001). The causes of land-use and land-cover change: moving beyond the myths. Global Environ Chang 11: 261-269

Lillesand TM, Kiefer RW (1994) Remote sensing and image interpretation. John Wiley & sons, New York

Moreira F, Rego FC, Ferreira PG (2001) Temporal (1958-1995) pattern of change in a cultural landscape of north western Portugal: implications for fire occurrence. Landscape Ecol 16: 557-567

Mottet A, Ladet S, Coque N, Gibon A (2006) Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees. Agr Ecosyst Environ 114: 296-310

Pan D, Domon G, de Blois S, Bouchard A (1999) Temporal (1958-1993) and spatial patterns of land use changes in Haut-Saint-Laurent (Quebec, Canada) and their relation to landscape physical attributes. Landscape Ecol 14: 35-52

Pinto-Correia T (1993a) Land abandonment: Changes in the land use patterns around the Mediterranean basin. Options Méditerranéennes, The situation of agriculture in Mediterranean countries 1 (2) pp 97-112

Pinto-Correia T (1993b) Threatened landscape in Alentejo, Portugal: the 'Montado' and other 'agro-silvo-pastoral' systems. Landscape Urban Plan 24: 43-48

Pinto-Correia T, Breman B, Jorge V, Dneboska M (2006) Estudo sobre o Abandono em Portugal Continental. Análise das dinámicas da Ocupação do Solo, do Sector Agrícola e da Comunidade Rural. Tipologia de Areas Rurais. Universidade de Évora, Évora, pp. 1-211

Poudevigne I, Alard D (1997) Landscape and Agricultural Patterns in Rural Areas: a Case Study in the Brionne Basin, Normandy, France. J Environ Manage 50: 335-349

Rounsevell MDA, Ewert F, Reginster I, Leemans R, Carter TR (2005) Future scenarios of European agricultural land use: II. Projecting changes in cropland and grassland. Agr Ecosyst Environ 107: 117-135

Roxo MJ, Mourao JM, Casimiro PC (1998) Políticas agrícolas, mudanças de uso do solo e degradação dos recursos naturais - Baixo Alentejo Interior. Mediterraneo 12/13: 167-189

Van der Ploeg JD (1994) Styles of farming: an introductory note on concepts and methodology. In: Van der Ploeg JD, Long A (Eds.) Born from within. Van Gorcum, Assen, pp. 7-30

Chapter 6

General discussion and conclusions

6.1 Initial goal and research questions.

Motivated by the fact that in rural landscapes in southern Portugal severe land use changes take place which causes, processes and consequences have been little studied, the objective of the present thesis is to monitor the structural and compositional landscape changes in case study areas (paper C) and to identify explanatory factors for the location of land cover change to contribute to the understanding of the process of landscape change (Paper D)

A secondary objective is to emphasize the importance of a clear use of concepts, methods and tools when carrying out landscape research in agro-silvo pastoral landscapes in the Mediterranean. Paper A is a contribution to the current debate on the concept of land abandonment in Portugal (Pinto Correia et al. 2006a, Pinto-Correia et al. 2006b) and addressed the following key question: How does the frequently used concept of land abandonment relate to land cover and land use in the case study area? Paper B questioned the application of commonly accepted landscape ecological paradigms and methods to agro-silvo-pastoral systems.

6.2 General discussion of the results

The results of paper A revealed that the relationships between the concept of abandoned land and the associated land cover and land use are multifaceted and far from being straightforward. Agricultural abandonment is not necessarily related to abandoned land, since other types of land uses are practiced in the area. The paper also showed that scrub areas, though having low levels of disturbance, do not always correspond to areas that are subject to land abandonment. This kind of observations suggest that when disturbance levels are lower, translating land cover into land use and subsequently connect it with concepts as land abandonment is getting less obvious and more difficult, because of the less visible traces of human activity.

As a consequence, the way land cover and land use relate depends on the land use system. Their relation should be assessed a priori in order to avoid oversimplification of the versatility of the land use and consequently of the multifunctionality of the landscape. This discussion is especially important because European scenario studies on land cover change like Eururalis (www.eururalis.nl) and also the VISTA-project (see § 6.4), forecast continuation of land abandonment in marginal areas. What this will mean in terms of land cover and land use is far from being clear and needs to be understood in more detail.

The results of paper B argued that the application of commonly accepted landscape ecological paradigms, like the patch approach, and methods, like classification and delineation of land cover, on landscapes composed of continuous patches with changing characteristics in space, like the montado, raises some issues which have hardly been discussed before in the literature. The paper argues that consistency among land cover databases is a prerequisite to facilitate comparison among land cover data basis of agro-silvo-pastoral landscapes of the Mediterranean. One of the efforts to be made is to set up guidelines for standardization of land cover classification and cartography to cover the wide range of different appearances of the *montado / dehesas* systems. The paper also stresses that the fuzziness of *montado* landscape, being directly related with the typical extensive land use, is an inherent part of the system, and thus should be accepted and represented in the maps obtained. As a consequence the land cover databases dealing with this type of landscapes should not be compared in respect to their construction and accuracy with databases referring to intensively used landscapes.

The contribution of paper A to a conceptual discussion and the contribution of paper B to a methodological discussion, are expected to be valuable for landscape research in Mediterranean landscapes. Too often these types of landscapes and its processes are oversimplified, especially in models predicting future land use according to a number of scenarios. To really understand the processes of landscape change an effort has to be made to move beyond the simplifications that still persist in much of the current literature on this subject (Lambin et al. 2001).

Paper C revealed that significant changes during the past forty years in landscape composition and configuration occurred in both case study areas. In terms of landscape composition, categories as arable /grassland diminished substantially, while the categories of forest plantation and *montado* increased. This expansion of land cover categories dominated by woody species, suggests an ongoing process of extensification of land use. In terms of landscape configuration a clear trend towards a more heterogeneous landscape can be observed. These trends of extensification of land use on the one side and heterogenisation of the landscape on the other side are usually not associated in literature, where often extensification is related to homogenisation of the landscape.

The paper also argued that the high levels of swap change within the montado are the cause of the low persistence of land cover. While this may indicate a considerable resilience of the system, where the same land use system is associated with a number of land cover categories, it also suggests that the land cover classification used may not be suitable. Although the land cover pattern may show significant changes, these do not necessarily correspond to a change in the land use or management system. This is related with the type of use of the Montado, similar to other silvo-pastoral systems but different from any other type of land use : there is a relatively stable tree cover, but the under cover is continuously changing due to changes in grazing pressure, frequency and type of shrub cleaning, presence or not of cultivation, etc. It is an extensive system, where the intensity of use varies within a large spectrum of possibilities, along time and within the same time period, within the various plots of Montado in a single holding. Thus, the land cover composition may change relatively often and significantly, without meaning a real change in the land use system.

At this point, it could be said that an interesting question emerges from the comparison between the results and conclusions of paper B and paper C. On the one hand it is supposed to be important to distinguish between different patterns of montado, since different tree and shrub densities represent different habitats, and imply different relations with landscape multifunctionality. This is valuable according to an analysis of the range of functions supported by the Montado. On the other hand however, analysing landscape changes with too many classes of montado appeared to result in low levels of land cover persistence and consequently this means a complication in the detection of the main trends in landscape change. There are changes in the land use intensity, but these changes correspond to variations that are part of the system in itself. It can be concluded that a trade-off between data quality and accuracy on the one hand should be balanced against simplification and generalization on the other hand. The identification of detailed classes of land cover may be needed, but according to the purposes of each analysis, some classes may be merged in larger classes that represent a wide ranging land cover type, mainly depending on tree cover type and density - representing the most stable factor.

A major point to be stressed is that this complexity raises the need to develop more research on the classification and analysis of this type of extensive and complex land use systems, and on their significance for the landscape pattern in place and its changes. Only in that way it will be possible to analyse the causes and consequences of land use change in many of the agro-silvo pastoral systems that are valued today for a diversity of non commodity functions.

Paper D explored the land use determinants of three conversions of arable land: afforestation, abandonment and regeneration of the Montado system.

Abandonment is in this paper understood as the soil is stopped being cultivated and grazed. The results showed that the models including only the socio-economic variables predict better the occurrence (because of higher chi-square values) of afforestation or the regeneration of montado than the models including only the biophysical variables. For abandonment the bio-physical variables are more important than the socio-economical variables. This implies that this land use change is much less a matter of freely chosen decision making of the landowners, but is forced by the strong bio-physical limitations. The landowner type was a significant descriptive variable across all land use change models. Four different landowner types could be distinguished, who all have different attitudes towards the land use possibilities. The diversified landowners are most inclined to actively respond to policies by converting the arable land to forests and Montado, or simply let natural succession take over by which they create possibilities for hunting and beekeeping. The retired owners tend to turn their arable land into forest plantations, while the active landowners are most inclined to maintain arable cultivation.

6.3 Main conclusions

The main conclusions of the thesis can be summarised as follows:

- The relationships between land cover, land use and the concept of land abandonment depend on the land use system, and should empirically be established in every research dealing with land abandonment. Particularly in the extensively managed mixed silvo-pastoral systems of the Mediterranean, this issue requires much attention and detailed analysis in order not to miss precision
- Standardized rules and common criteria for land cover classification and mapping are needed to attain greater coherence among land cover databases of agro-silvo pastoral systems on the Iberian Peninsula. The rules to be adopted for classification need to be adapted to the special conditions and land use systems of this region and can not be simply imported from regions of more regular and standardised systems
- Land cover databases of landscapes that are rich in continuous vegetation gradients, like ones of the *montado* and *dehesas*, should be treated with care,

taking into account the inconsistencies and uncertainties resulting from the landscape complexity.

- Extensification trends in Mediterranean agro-silvo-pastoral landscapes can cause an increase in landscape heterogeneity. The issue of scale is once again extremely important here; this has been observed both at farm and landscape level.
- A detailed classification of the agro-silvo pastoral system, considering different categories of crown cover and different types of under cover, which in fact are all successive stadiums of the same system, is one of the causes of observing the low level of persistence in land cover and may be non relevant for assessment of trends the land use - the purpose of the analysis has to be carefully considered before deciding on the level of detail in the classification. .
- In the present case study area afforestation and the regeneration of the Montado system is mainly a socio-economical matter, whereby the type of landowner appears to determine whether or not a landowner is willing to respond to policies that favour these land use changes. Land abandonment, on the other hand, is mainly determined by biophysical characteristics, implying that the most marginal lands are no longer suitable for any use of the land other than extensive uses such as hunting and beekeeping.
- Local socio-economic factors are significant in explaining the pattern of the conversion of arable land in the study area and for this reason the variety of landowners' response to the physical conditions deserves more attention in land use

6.4 Conclusions of the VISTA-project

In both case studies, the agricultural area is most prone to change and diminishes by between 15% and 30%. This area mostly converts into shrub area, which increases from between 23% and 129%. The work of WP3 has contributed in a number of ways to the understanding of land use change in traditional European landscapes.

Some key methodological advances have been made, that include new approaches to the reconstruction of past land use data, the development of landscape scale future scenarios (incorporating stakeholder knowledge) and the use of innovative Agent-Based modelling approaches to asses not only land use change, but also farmer vulnerability.

The work has also contributed new insights into processes of land use change based on the analysis of past land use trajectories and the location characteristics that explain these transitions. In particular, this work has demonstrated the locations that are expected to change in traditional agricultural landscapes, which may provide pointers to better (targeted) management of these landscapes.

Furthermore, the work on future land use scenarios has also demonstrated the potential for continued land abandonment into the future, especially for scenarios that are economically orientated. Clearly, if realised such changes will have profound effects on traditional agricultural landscapes and the local communities and ecology that depend upon them.

6.3 Review of used approaches and methods

6.3.1 Theoretical framework

According to the International Association of Landscape Ecology (IALE) landscape ecology is:

> the study of spatial variation in landscapes at a variety of scales. It includes the biophysical and societal causes and consequences of landscape heterogeneity. Above all, it is broadly interdisciplinary. The conceptual and theoretical core of landscape ecology links natural sciences with related human disciplines.

(Source: www.landscape-ecology.org)

In this respect the present study can be placed in 'the heart' of landscape ecology, also concerning the used methodologies and tools. It was because of the application of interpretation of aerial photographs during his work on interactions between the environment and vegetation that Troll (1939) invented the term 'landscape ecology'.

During the PhD the focus shifted slightly from analysing the landscape within the more classical paradigms of landscape ecology to analysis of drivers of land cover change, adopting tools of geography. The analysis of land cover / land use change has a strong geographical character and many useful theories, tools and methodologies are developed by researchers and research groups connected to the Land Use and Land Cover Change (LUCC) Project (1996-2005), which is a program element of the International Geosphere-Biosphere Programme and the International Human Dimensions Program on Global Environmental Change. It is an interdisciplinary program aimed at improving the understanding of the land use and land cover change dynamics and their relationships with the global environmental change (LUCC, http://www.geo.ucl.ac.be/LUCC).

During the PhD I felt a constant lack of shared concepts and paradigms between landscape ecology and the LUCC-publications. For example the concept of the landscape as a holistic entity is little acknowledged in the latter one, as well as the limitations of representing the landscape by land cover or land use. On the other hand quantitative approaches and spatial statistics are rather much developed within the LUCC literature, while landscape ecology is not a particularly quantitative discipline, and it is less concerned with theory or the formalities of hypothesis testing (Wiens 1992), Also differences in scale and approach contribute to the gap between landscape ecology and the LUCC-publications. While LUCC research aims at understanding the changes, quantifying and trying to understand factors at regional and national level. landscape ecology looks at smaller areas (m2 to km2) and tries to measure changes in order to measures impacts on species, on landscape use. I believe there is a challenge to bridge the gap between those two fields of research, because there might be a fruitful mutual benefit. On the one hand the outcome of LUCC models can be enriched by applying landscape ecological concepts and to 'translate' the indicator land cover to the wider concept of landscape. On the other hand landscape ecology can learn lessons from the quantitative techniques and modelling approaches from the LUCC-framework. Moreover, local, regional and national landscape ecological projects can be connected to global change processes, which are mainly studied within the LUCC-framework and less within landscape ecology. These two approaches are thus evidently rather complementary and more interaction should between researchers connected with the two traditions and contexts would certainly be fruitful..

6.3.2 *Interdisciplinarity*

Because all landscapes consist of both natural and cultural dimensions, research aiming at understanding landscape processes is likely to integrate knowledge from different disciplines. Recently, interdisciplinary landscape research gained much attention, mainly due to the need to solve current environmental problems that go across disciplinary boundaries (Tress et al. 2003). The present study, by focusing on landscape change in a rural area, has a strong interdisciplinary component: data from interviews are combined with biophysical and land cover data in a qualitative (paper A) as well as quantitative way (paper D). The mutual benefits gained from combining data from cartography with data fròm the interviews with farmers, result in a deeper and more complete understanding of past land cover changes, its driving forces and the present landscape. Where biophysical analysis or general socio-economic data do not sufficiently explain the observed land use changes, the data from the interviews provided adequate information to identify the driving forces behind.

The data sources used in the case study are complementary and it was possible to correct the errors that were made in the aerial photo-interpretation with the information given by the farmers during the interviews. The other way round, the information coming from interviews can also be misleading and the past and present aerial photos and cartography can help to clarify misunderstandings. Added information from the interviews, like data about past and present livestock or information about crop growing, but also on other activities like hunting and beekeeping is essential to be able to interpret land cover and land use.

There are also some constraints in combining the data. The information coming from the farmers depends strongly upon their memory. For the present day situation this is not a problem, but for detailed information of past days, the information is hard to quantify. Especially in this region of Portugal, where farmers are often illiterate and do not have an administration of the enterprise in the past.

In cartography it is possible to make sharp time slices, but the time periods are chosen quite arbitrary, namely when aerial photos were available and do not correspond necessarily with important periods in land use change. Unlike the cartography data, information coming from the memory of the farmers is usually not localizable exactly in time. There fore using clear time periods as an overarching concept between methodologies of different disciplines, might not always function.

Changes in land use, like for example an expanding area of shrub, which are very obvious on aerial photographs and maps, are often occurring gradually and for the farmer it does not appear like a change. So if the farmers are asked what kinds of changes have happened, the answer is often that nothing has been changing, while the aerial photos show something completely different.

This study shows how the two methods from different disciplines can both help to clarify irregularities in one of the methods and how through the use of qualitative interviews with stakeholders some unknown driving factors could be identified. Nevertheless, when aiming at clarifying the complex variety of factors that influences landscape change various other disciplines are required as well.

Besides the above-mentioned benefits, the interdisciplinary study contributes to the knowledge of the real life situation in the study area; this is indispensable in doing interdisciplinary research that relates to the complexity of the landscape itself.

6.3.3 Data collection and quality.

One of the most common difficulties encountered in landscape change studies is the lack of compatibility (i.e. the relation among variables or regions) and consistency (i.e. the definition, usage and measurement of variables) (Briassoulis 2001) of the databases. Often, external databases are used, of which each was built with specific procedures, concerning a specific goal and on a certain scale. Combining these databases causes problems in spatial and temporal referencing and with operational definitions. For example, a common difficulty is that land use data are available on plot level, while socio-economic data are only available on municipality level, causing problems in spatial referencing; or meteorological data are reported daily, while census data only are collected every ten years, causing problems in temporal referencing. Finally, differences in definitions of land use types can cause a lot of confusion, is 'pasture' on land cover map A the same as 'grassland' on land cover map B (problem with operational definitions)?

The strength of the present study is the high reliability of the used databases. Compatibility and consistency were maximised, because the same researcher carried out most of the data collection, with the exception of biophysical data as soil type. The historic and contemporary data on land cover were gathered following the same procedures in aerial photo interpretation hereby avoiding problems in operational definitions. The socio-economic data were gathered trough interviews with land owners within the study area carried out by the researcher, hereby assuring that land cover as well as socio economic data were available at he same scale, and thus avoiding the problem of spatial referencing. Only the problem of temporal referencing was hard to overcome, while an interpretation of aerial photographs of 1958 was carried out, it was practically impossible to interview the persons who were landowner by that time. That is the reason the analysis of the explanatory factors of land cover change (paper D) is limited to the study period of 1985 -2000.

6.4 Reflexions: Potentialities and Limitations of the study

Having a strong interdisciplinary component the study runs the risk of becoming less deep than in focused, disciplinary approaches. Because the study was aimed at integrating both biophysical and socio-economical factors in landscape change processes, it was within the resources and the time frame of the project impossible to analyse both types of factors as deep as it would be in a disciplinary study. Moreover, the study was carried out by one researcher and not by a team. On the one hand this can be seen as an advantage because no time was wasted in translating terminologies. On the other hand concepts, methodologies, and tools of different knowledge cultures had to become acquired and be combined with each other by the same person. This demands adaptation and communication skills in combination with necessary breadth to integrate the information; all this might be at the expense of a more profound disciplinary analysis. However, it is a tentative progress in new science approaches, contextualised and more related to society demand and concerns (Nowotny et al etc) The integration of various types of data is in this way both the strength and the weakness of the study.

Currently there is an ongoing debate about the demands on PhD students involved in integrative landscape studies: is it realistic for a PhD student to bridge disciplines and to develop new and integrative knowledge? In my opinion, after the experience of this PhD work, facing its demands and the required knowledge development, a PhD-project dealing with landscape research becomes more challenging and interesting when it is carried out in an interdisciplinary way. Also according to the current trend of the holistic landscape approach and landscape multifunctionality, interdisciplinarity is requisite, also for PhD-projects. Especially because in some domains of research an actual trend can be observed, following the complexity and uncertainty of modern society, to be moving from what can be called

Mode 1 (which can be considered as discipline focused, with a strict range of external factors), towards Mode 2 (which is problem focused; taking a diversity of external factors into account and strongly contextualised) (Nowotny et al. 2001).

Yet, as the theory and methods for integrative landscape research are still evolving and mostly at an early stage of development (Tress et al. 2006), a well-established theoretical framework is missing and complicated the PhD study. As interdisciplinarity is one of the research priorities for landscape ecology (Wu and Hobbs 2002) it is expected that this will be enhanced in the near future.

Another aspect that has much to do with the integrative character of the study is the size of the study area. Because data collection had to be carried out for land cover as well as the socio-economic data, the size of both study areas has been of 44 km2. Surely the outcomes of the study are not suitable to extrapolate in a quantitative way to a wider scale. However, much knowledge can be acquired from the analysis undertaken, as the area studied gathers most of the characterisics, natural and cultural, of large extensions of southern Portugal, and also other parts of Mediterranean Europe. General guidelines on landscape change processes might be derived and applied to comparable landscapes and land use systems. More over, the lessons learned from the case study area might serve as an input for landscape change models.

A third, and more personal, particular characteristic of the study is the fact the I as a researcher is a foreigner in the country where the study has taken place. Being a foreigner, and not talking in your mother tongue, can put some strong limitations to the study. Especially during the interviews with the farmers, the language barrier may have been a certain restriction to obtain sufficient and useful information.. On the other hand there are also important advantages; as an outsider one is less biased and prejudiced, and sometimes, during the interviews the respondents were strikingly open and honest, and this might be also because of the absence of any relation with a Portuguese entity from the interviewer side.

6.5 Relevance of the study

Recently some authors set up priority lists for European landscape research which aim at marking research strategies that ensure effective planning and management of future landscapes (Wu and Hobbs 2002; Klijn and Vos 2000). In their book 'From Landscape Ecology to Landscape science' Klijn and Vos (2000) recommend to extend landscape ecology to landscape science by matching research scales with relevant socio-economic processes and integrating landscape ecology with human sciences. Also Wu and Hobbs(2002) advocate the interdisciplinary path for landscape research, despite the lack of consistency and coherence in concepts and theories. The work presented is hoped to be a contribution to the further development of integrated landscape research. More specifically the output is expected to contribute to:

- the refinement of the concept of abandonment.
- direct Mediterranean landscape studies towards more unified use of mapping methodologies for agro-silvo pastoral systems.
- the development of integrative methodologies to study processes of landscape change.
- the derivation of general guidelines for composing (agent-based) landscape change models in the Mediterranean
- the provision of information for up scaling landscape change processes.
- the acknowledgement of the complexity and non-uniformity of Mediterranean landscapes in terms of processes and actors and concerning methods and tools.

This study drew attention to the fact that the Mediterranean landscape under study demonstrate non-uniformities in frequently adopted concepts (like land abandonment); methods (like land cover mapping); dogma's (like 'extensification causes landscape homogenisation'); and actors (like different types of landowners causing heterogeneity in landscape change). By taking into account these nuances the real world appears to be much more complex, and complicates the work to be done. But this complexity could also be seen as a challenge.

6.6 Reflexions on further research perspectives

Pinto-Correia(2000) advocates the landscape level to be most appropriate for the definition of integrated management for the future development of Portuguese rural areas. In a more recent paper (Pinto-Correia et al. 2006) the same author argues that there is a gap between the strategies formulated for rural landscapes at central level and the way these landscapes are evolving today. Instead of being concerned with conservation of valuable landscape by preservation, the challenge is to understand the dynamics going on, how they affect landscape multifunctionality and what they mean for the different stakeholders. Only through this understanding, visions and management strategies can be developed.

The present research contributes to the understanding of the landscape dynamics going on and supports the statement that simple answers do not provide an adequate understanding of landscape change (Lambin et al. 2001). As the study showed the different types of landowners show divergent relationships with the land cover change. The future of the landscapes of the case study areas, and in a wider sense the ones of South Portugal, is in the hands of the owners of the land. Their future management is very much directed by the regulations of the European Union and the expanding world market, and will perhaps bring about even more dramatic landscape changes.

Resulting from the output of the presented work some recommendations and improvements for further research can be given:

- To monitor the effects of the observed landscape changes on flora and fauna.
- An evaluation of the (future) impact of the forest plantations on landscape structure, wild fire risk and biodiversity.
- Further research on landscape dynamics in south Portugal might cover a larger sample area and may take into account a wider range of biophysical variables.
- A challenging subject is to carry out an analysis of landscape change over a longer time period (1870 - 2000) and focus on the differences, in terms of direction and amplitude, over time.
- An assessment of landscape multifunctionality and the influence of landscape change on multifunctionality.

References

Briassoulis, H. 2001. Policy-oriented integrated analysis of land-use change: an analysis of data needs. - Environmental Management 27: 1-11.

Klijn, J. and Vos, W. 2000. From landscape ecology to landscape science. - Kluwer.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G. and Folke, C. 2001. The causes of land-use and land-cover change: moving beyond the myths. - Global Environmental Change 11: 261-269.

Nowotny, H., Scott, P. and Gibbons, M. 2001. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. - Polity Press.

Pinto-Correia, T. 2000. Future development in Portuguese rural areas: how to manage agricultural support for landscape conservation? - Landscape and Urban Planning 50: 95-106.

Pinto-Correia, T., Breman, B., Jorge, V., Dneboska, M., 2006a. Estudo sobre o Abandono em Portugal Continental. Análise das dinámicas da Ocupação do Solo, do Sector Agrícola e da Comunidade Rural. Tipologia de Areas Rurais. In: Universidade de Évora, Évora, pp. 1-211.

Pinto-Correia, T., Gustavsson, R. and Pirnat, J. 2006b. Bridging the gap. Towards more sensitive and creative landscape approaches across various levels of decisions. - Landscape Ecology, 21: 333-346.

Tress, B., Tress, G. and Valk, A. v. d. 2003. Interdisciplinarity and transdisciplinarity in landscape studies - the Wageningen DELTA approach. - In: Tress, B, Tress, G, Valk, A. v. d and Fry, GLA (eds.), Interdisciplinary and transdisciplinary landscape studies: potential and limitations. pp. 8-15.

Tress, B., Tress, G., Fry, G. and Opdam, P. 2006. From Landscape Research to Landscape Planning. - Springer.

Wu, J. and Hobbs, R. 2002. Key issues and research priorities in landscape ecology: An idiosyncratic synthesis. - Landscape Ecology 17: 355-365.

www 1: www.eururalis.nl

www 2: www.landscape-ecology.org

www 3: www.geo.ucl.ac.be/LUCC

Extensive summary

Europe's rural landscape is changing. The causes are diverse, and so are the effects on the environment, biodiversity, cultural heritage and scenery. As the speed and impact of the changes are increasing, so is the awareness that valuable qualities associated with the rural landscape are also getting lost. This is reflected in the amount of academic literature that deals with the changing rural landscapes of Europe that has been published over the past 2 decades. Nowadays the study of causes processes and consequences of landscape, land cover and land use change is one of the key issues of landscape ecology.

An area that has been little studied is the Alentejo region in the South of Portugal, despite the fact that severe changes in land use have been and still are taking place, which have had a dramatic impact on the rural landscape . In the first half of the 20th century many areas have been subject to intensive cereal growing, followed in the 1970s'and 80's by a period of abandonment of agricultural activity. Over the past 20 years the CAP has had a very clear impact on the landscape in the region, for example by the massive emergence of forest plantations.

Macro forces such as climate change, world trade negotiations and regulations of the Common Agricultural Policy (CAP) of the European Union, are important for general assessments of trends in land use change. However, to improve the understanding of changes in land use and landscape, local level case studies are as important in order to avoid over-simplification of complex processes. Such simplifications on the one hand concern assumptions on causes and consequences of land use change, but on the other hand are also rooted more deeply in the formulation of concepts and the application of methods of data gathering. Often, the conceptualisation and the design of research methods does not correspond to the complex research issues that is being dealt with.

The key theme of the present thesis is to monitor structural and compositional land use and landscape changes and to identify the associated driving factors in case study areas in Southeast Portugal. A secondary objective is to emphasize the importance of a clear use of concepts, methods and tools when doing landscape research in agro-silvo pastoral landscapes in the Mediterranean.
The thesis addresses the following key questions:

1. How can the frequently used concept of land abandonment be defined in relation to land cover and land use? What type of land cover and land use can be an indicator when an area is considered as abandoned?
2. How do the matrix-patch-corridor paradigm and the classification and mapping of land cover apply to agro-silvo-pastoral systems? Which classification makes sense in these systems ?
3. Which structural and compositional landscape changes in the sample areas have taken place during the last 50 years?
4. What are the most explanatory factors for the location of changes in arable land?

Corresponding to the four key questions, the thesis consist of four papers, each dealing with one of the questions. The study has been carried out in 2 study areas located in the municipality of Mértola, which is part of the region of the Baixo (=lower) Alentejo. A peripheral location, characterized by a sparse distribution of the rural population and marginal conditions for agriculture (poor soils and extreme climatic conditions).

The first paper starts from the concern that for the development of integrated management policies that are aimed at dealing with the issues concerning land abandonment in the Mediterranean, there is a need to evaluate the process of change taking place. Therefore, land cover as well as land use has to be monitored in a detailed way. This is because the relationship between land cover and land use is not as direct as has often been assumed, especially in relation to the processes of land abandonment. Scrub encroachment is generally used as a proxy to monitor these processes. The question is what this indicator really means in terms of land use. To assess land use practices and the connection with the observed land cover, detailed research based on evaluation of land cover changes through aerial photo interpretation and interviews with farmers has been carried out. The study shows that areas dominated by scrub encroachment do indeed indicate areas where agricultural practices e.g. ploughing and grazing, have been declining. However, an understanding of the land use systems in place, shows that these areas did not represent a lack of use, but rather that they can be considered as areas with multiple and alternative uses of the land. Beekeeping and hunting are the most frequent activities. These findings have implications for the conceptualization of abandonment and for the use of the land cover type 'scrub land' as an indicator for land abandonment.

The second paper contributes to the discussion on current issues in methodologies of mapping land cover based on aerial photo interpretation. The paper discusses the consequences of the richness of vegetation gradients in the agro-silvo-pastoral landscapes of the Mediterranean for land cover mapping. These landscapes, characterized by intermixed land use and indefinite boundaries, require particular attention in applying the patch-corridor-matrix model when classifying patches and their delineation. Within this scope, a land cover mapping project in one of the case study areas, which is mainly characterized by agro-silvo pastoral systems, is compared with the mapping undertaken within a national land cover database (COS'90). Both studies were carried out on the same scale, for the year 1990 and through visual interpretation of aerial photographs. Differences in land cover classification and allocation are explored using matrix with levels of agreement. Recommendations for future land cover mapping projects are: the application of fuzzy approaches to land cover mapping in agro-silvo-pastoral landscapes should be explored and land cover classifications should be standardized in order to enhance consistency between databases. On the other hand, the fuzziness of the boundaries in this kind of landscapes is inherent to the system and should be accepted as such. The accompanying uncertainties should be taken into account when undertaking landscape analysis on the basis of land cover data.

The third paper explores the landscape dynamics of the two case study areas in the region by systematic comparisons of land cover maps of 1958, 1985 and 2000, which were for this purpose derived from aerial photographs.
The study consists of 2 separate analysis: 1) detection of land cover changes, which mainly comprehend processes of extensification, through analysis of land cover class transitions with the use of transition matrices; 2) monitoring landscape composition and configuration through the application of a set of landscape metrics.

The results show clear changes during the past forty years in landscape composition and configuration. The landscape metrics display a trend towards a more fragmented, complex, fine-grained landscape. Most widespread land cover changes were transformations from arable / grassland to other land cover categories, such as montado, forest plantations and matorral. The shift from arable/grassland to land cover classes dominated by woody species suggests an extensification of agricultural practices. The results are partly consistent with the generally assumed trends in Mediterranean landscapes: extensification of land use being a main process. However, contrary to what is often observed and assumed, this process is associated with a trend towards a more fine grained and fragmented landscape.

The fourth paper is an attempt to investigate the driving forces behind three conversions of arable land during the period 1985 - 2000 in one of the case study areas: afforestation of arable land, abandonment of arable land and regeneration of the agro-silvo-pastoral system. This was done by exploring the relations between these changes and a selection of both biophysical and socio-economic variables. For each conversion of arable land into one of the three other land use types the descriptive power of the various independent variables was evaluated using logistic regression. By comparing different statistical models (one containing only the biophysical attributes, another model containing only the socio-economic variables and finally a model containing both types of variables) the relative importance of socio-economic and biophysical variables was evaluated. The results show that both the biophysical and socio-economic variables were significantly associated with the occurrences of the land use changes. However, the models containing only the socio-economic variables were stronger related to occurrences of afforestation and regeneration of the montado, whereas the biophysical variables were more related to land abandonment. The landowner type was a significant descriptive variable across all land use change models. The results suggest that local socio-economic factors are significant in explaining the pattern of the conversion of arable land in the study area and for this reason the variety of landowners' response to the physical conditions deserves more attention in land use change modelling.

Returning to the initial key theme and the secondary objective of this thesis, the lessons learned from the present study concern contributions to the understanding of landscape and land use change in the extensively managed mixed agro-silvo-pastoral systems of the Mediterranean as well as conceptual and methodological issues.

Land use and land cover changes have been dramatic in the case study areas and are associated with a continuous trend of an increase in landscape heterogeneity; this has been observed both at farm and landscape level. Major land cover trends include afforestation of arable land, regeneration of the agro-silvo-pastoral system and invasion of shrubs on arable land (abandonment of cultivation). Local socio-economic factors are significant in explaining the pattern of the conversion of arable land in the study area and for this reason the variety of landowners' response to the physical conditions deserves more attention in land use change research and modelling.

A conceptual issue highlights the importance of the type of land use system in disentangling the relations between the concept of land abandonment, land cover and land use. In order to avoid false conclusions on the use of land, drawn from remotely sensed data, the mentioned relations should empirically be established in every research dealing with land abandonment,.

A methodological issue stresses the need for standardized rules and common criteria for land cover classification and mapping, to enhance the coherence among land cover databases. The rules to be adopted for classification need to be adapted to the special conditions and land use systems of landscapes that are rich in continuous vegetation gradients, like ones of the *montado* and *dehesas* and can not be simply imported from regions with more regular and standard landscapes. However, even when use is made of such a systematic classification, the resulting land cover databases should be treated with care, taking into account the inconsistencies and uncertainties resulting from the landscape complexity.

As the present thesis shows, simple answers do not provide an adequate understanding of landscape change. The future of the landscapes of South Portugal, is in the hands of the owners of the land, whose management is very much directed by the regulations of the European Union and the expanding world market. Recommendations for research directed to future landscape management are amongst others: an evaluation of the (future) impact of the forest plantations on landscape structure, wild fire risk and biodiversity and an assessment of landscape multifunctionality and the influence of landscape change on multifunctionality.

Resumo Alargado

A paisagem rural de Europa está a mudar. As causas são diversas, tal como os efeitos no meio ambiente, na biodiversidade, no patrimonio cultural e na paisagem. à medida que a velocidade e o impacto das mudanças estão a aumentar, também cresce a consciência de que se estão a perder valores associados à paisagem rural. Isto é reflectido pela grande quantidade de literatura académica que tem sido publicada nos últimos 20 anos dedicada às alterações da paisagem rural em Europa. Hoje em dia o estudo das causas, dos processos e das consequências das mudanças da paisagem, do uso do solo e da ocupação do solo é um dos temas principais da ecologia de paisagem.

Uma das áreas que tem sido pouco investigada, apesar do facto de lá terem ocorrido alterações enormes em termos da mudança de uso do solo, com efeitos dramáticos para a paisagem rural, é a região do Alentejo, no sul de Portugal Continental.

Durante a primeira metade do século XX, muitas áreas foram muitas áreas foram sujeitas a uma agricultura intensiva para a produção de cereais, seguido por um periodo de abandono das actividades agrícolas nos anos 70 e 80. Nos últimos 20 anos, o impacto da Política Agrícola Commun torna-se cada vez mais visível na região, por exemplo com aumento das novas florestações.

As forças motrizes da macro escala, como a mudança do clima, as negociações do Mercado Mundial e as regras da PAC são importantes para a avaliação das tendências gerais na mudança do uso do solo. No entanto, para melhorar a compreensão das mudanças no uso do solo e na paisagem, estudos ao nível local são igualmente importantes para evitar uma simplificação de processos complexos. Tais simplificações referem-se por um lado a presupostos respeitantes às causas e aos efeitos da mudança do uso do solo, mas por outro lado também têm uma origem mais profunda, que é a conceptualização e a metodologia da recolha dos dados.

O tema principal desta tese é a monitorização das mudanças na estrutura e composição do uso do solo e da paisagem, tal como a identificação das principais forças motrizes asociadas a estas mudanças em duas áreas de estudo no Sul-este de Portugal.

O objectivo secundário é salientar a importância do uso unívoco de conceitos, metodologias e ferramentas na investigação de paisagens agro-silvo-pastorís no Mediterrâneo.

A tese pretende dar resposta às seguintes questões principais:

1. Como se pode definir o conceito comum de abandono em relação à ocupação e ao uso do solo? Que tipo de uso e de ocupação do solo pode ser encontrado numa área que é considerada abandonada?
2. Como se aplica o paradigma da matriz-polígono-corredor, tal como a classificação e a cartografia da ocupação do solo, às paisagens agro-silvo pastorís? Que tipo de classificação faz sentido nestes sistemas?
3. Quais as mudanças estruturais do uso do solo e da paisagem nas áreas de estudo nos últimos 50 anos?
4. Quais os factores que explicam a mudança na localização da terra arável?

Correspondente às quatro questões principais, a tese é constituída por quatro artigos, cada um dedicado a uma das questões. O estudo tem sido realizado em duas áreas pertencentes ao concelho de Mértola, localizado na região do Baixo-Alentejo. Este concelho é uma localidade periférica, caracterizada por uma distribuição dispersa da população rural e por condições agrícolas marginais (solos pobres e condições climáticas extremas).

O primeiro artigo parte da preocupação de que para a desenvolvimento das políticas de gestão integrada dirigidas ao abandono da terra no Mediterrâneo, existe uma necessidade de avaliar o processo de mudança que se está a efectuar. Por este motivo, a ocupação do solo tanto como o uso de solo deve ser avaliado com pormenor. Um nível de investigação detalhada é necessário, porque a relação entre a ocupação de solo e o uso não é tão linear como é suposto muitas vezes, especialmente em relação áos processos de abandono da terra. O crescimento do coberto arbustivo é em geral usado como indicador para avaliar estes processos. A questão é saber qual é o significado deste indicador em termos de uso do solo. Para avaliar as práticas do uso do solo em relação à ocupação de solo que foi observada, foi realizada uma investigação detalhada. A análise foi baseada numa avaliação das mudanças de ocupação do solo recorrendo à foto-interpretação e a entrevistas com agricultores.

O estudo mostra que áreas dominadas por crescimento de mato, de facto correspondem a locais onde práticas agrícolas, como a lavoura e a pastagem, têm diminuido. No entanto, percebendo os sistemas locais de uso do solo, é óbvio que estas áreas não representam uma falta de uso, mas podem ser consideradas como áreas com usos múltiplos e alternativos. A apicultura e a caça são as actividades mais comuns. Estas conclusões têm implicações para a conceptualização do abandono da terra e para o uso de categoria de ocupação de solo 'mato' como um indicador de abandono da terra.

O segundo artigo é um contributo para a discussão sobre as metodologias de cartografia da ocupação do solo, baseadas na foto-interpretação. O artigo discute as consequências da riqueza dos gradientes de vegetação para a cartografia de paisagens agro-silvo-pastorís do Mediterrâneo. Este tipo de paisagem, caracterizada pelo uso de solo misto e limites não definidos, necessita de atenção especial quando da aplicação do modelo de polígono-corredor-matriz, especialmente quando os poligonos são classificados e delimitados. Neste âmbito, um projecto de cartografia de ocupação do solo numa das áreas de estudo, que é principalmente ocupada por sistemas agro-silvo-pastorís, foi comparada com a Carta de Ocupação de Solo (COS'90) - cartografia de ocupação de solo baseado em dados nacionais. Ambos os estudos foram executados à mesma escala, para o ano 1990 e são baseados na interpretação visual das fotografias aéreas. Diferenças na clasificação e na localização foram exploradas usando matrizes análogas.

Algumas das recomendações para futuros projectos de cartografia de ocupação de solo nas paisagens agro-silvo-pastorís são: a aplicação das abordagens tipo 'fuzzy' deve ser explorada e as clasificações da ocupação do solo devem ser estandardizadas para melhorar a consistência entre bases de dados. Por outro lado, os limites imprecisos entre classes de ocupação do solo neste tipo de paisagem é um parte integrante do sistema e deve ser aceite como tal. As incertezas associadas devem ser tomadas em conta ao executar uma análise da paisagem baseada nos dados de ocupação do solo.

O terceiro artigo explora as dinâmicas das duas áreas de estudo por comparações sistemáticas das cartas de ocupação de solo de 1958, 1985 e 2000, que, para este objectivo, foram elaboradas a partir de fotografias áereas. O estudo consiste em duas análises separadas: 1) a detecção das mudanças de ocupação do solo, incluindo principalmente processos de extensificação, por análise das transições das classes de ocupação de solo, usando matrizes de transição; 2) a

monitorização da composição e configuração da paisagem pela aplicação de *indices* da paisagem.
Os resultados mostram mudanças claras durante os 40 anos de estudo, em termos da composição e configuração da paisagem. As métricas da paisagem revelam uma tendência para uma paisagem mais fragmentada e complexa. A mudança mais comum é a transição da terra arável para outras categorias de ocupação de solo como montado, novas florestações e mato. A mudança da terra arável para classes de ocupação do solo dominadas por espécies lenhosas, sugere uma extensificação das práticas agrícolas. Os resultados são parcialmente consistentes com as tendências geralmente previstas nas paisagens mediterânicas: o processo principal é a extensificação do uso do solo. No entanto, ao contrário do que muitas vezes é presuposto, esta tendência é associada com o desenvolvimento duma paisagem com um mosaico mais fino.

O quarto artigo é uma tentativa para investigar as forças motrizes de 3 transições de terra arável durante o periodo 1985 - 2000 numa das áreas de estudo. São as transições de terra arável para: novas florestações, mato (abandono da terra arável) e a regeneração de montado. Esta investigação foi baseada numa exploração das relações entre cada uma destas mudanças e as variáveis biofísicas e sócio-económicas. Para cada transição de terra arável para um dos outros três tipos de ocupação de solo, a força descritiva das variáveis independentes foi avaliada recorrendo à regressão logística. A comparação de modelos estatísticos diferentes (um incluindo só variáveis biofísicas, um incluindo só variáveis socio-económicas e um incluindo ambos os tipos de variáveis) resulta numa avaliação da importância relativa das diferentes variáveis. Os resultados mostram que as variáveis biofísicas bem como as variáveis sócio-económicas apresentam uma correlação significativa com a ocorrência de transições da ocupação do solo. No entanto, os modelos incluindo só as variáveis sócio-económicas estão fortemente relacionados com a ocorrência de transição de terra arável para novas florestações e para montado, enquanto as variáveis biofísicas são mais relacionadas com o abandono de terra arável. O tipo de proprietário é uma variável descritiva significante para todos os modelos de mudança de ocupação do solo. Os resultados sugerem que os factores sócio-económicos locais são significativos para explicar o padrão das transições da terra arável na área de estudo. Por este motivo a variedade das respostas dos proprietários às condições físicas merece mais atenção nos modelos de mudança de ocupação do solo.

Voltando ao tema principal e ao objectivo secundário desta tese, os resultados deste estudo procuram contribuir para o entendimento das mudanças da paisagem e no uso de solo em sistemas agro-silvo-pastorís extensivos do Mediterrâneo, bem como a assuntos conceptuais e metodológicos.

As mudanças na ocupação e no uso do solo nas áreas de estudo têm sido, e são, dramáticas e são associadas a uma tendência contínua para um aumento da hetereogenidade de paisagem. As principais mudanças na ocupção do solo incluem as novas florestações em terra arável, o abandono da terra arável e a regeneração de montado.

O principal questão conceptual apoia-se na importância do tipo de sistema de uso do solo para esclarecer as relações entre o conceito de abandono, a ocupação do solo e o uso do solo. Para evitar conclusões falsas sobre o uso de solo, tiradas de dados provenientes de detecção remota, as relações mencionadas devem ser estabelecidas empiricamente em cada investigação que trata de abandono de terra.

Salienta-se a necessidade de definir regras estandardizadas e critérios gerais para a classificação e a cartografia de ocupação do solo, de forma a melhorar a coerência entre bases de dados de ocupação do solo. As regras aplicadas para a classificação devem ser adaptadas às condições específicas das sistemas de uso do solo ricos em gradientes de vegetação, como é o caso das paisagens de montado ou 'dehesa'. A classificação e a metodologia de cartografia não podem ser simplesmente importadas de regiões com paisagens mais simples. No entanto, mesmo utilizando uma classificação sistemática e específica, a base de dados de ocupação do solo deve ser tratada com prudência, tendo em consideração as inconsistências e as incertezas que resultam da complexidade da paisagem.

Como a tese actual mostra, respostas simples não conduzem a uma compreensão completa da alteração da paisagem. O futuro das paisagens do sul de Portugal está nas mãos dos proprietários, cuja gestão é muito influenciada pelas regras da União Europeia e o mercado mundial. Recomendações para a investigação dirigida à gestão de paisagem no futuro são entre outros: executar uma avaliação do impacte futuro das novas florestações na estrutura de paisagem, no risco de incêndios e na biodiversidade, bem como avaliar o impacte das mudanças na multifuncionalidade de paisagem.

recorded	code
☐ NO	
☐ YES	

Annex 1: Interview guide to apply to farmers and landowners in the area of Amendoeira da Serra and João Serra

Name of interviewer:______________________________
Place of interview:________________date:________hour:______

A

Indentification

1	Name	
2	Property	

B

Profile of farmer

				Code
6	Year of birth			
7	Place of birth			
8	Gender	☐ 1) M	☐ 2) F	
9	Education			
9	Profession			
10	Work on property	☐ 1) Full time	☐ 2) Part time	
11	When did your activity on the property start?			
12	How did you obtained the property?	☐ 1) Inheritance ☐ 2) Buying	☐ 3) Leasing ☐ 4)Other	

C

Profile of property

			# ha	code
1	Total area	1) Own		
		2) Leased		
2	Do you have workers? ☐ NO ☐ YES, how many? ☐ 1) Full time ☐ 2) Seasonal			
3	Do you have a successor for the management of the property? ☐ NO ☐ YES			
4	If somebody would buy your farm, would you sell it? ☐ NO ☐ YES, what is a good price per hectare?			

Actual use of the soil

	# Ha	Covered area with Montado (%)			Why and for what?	code
		holm oak	cork oak	mix		
Vegetable garden						
Orchard						
Arable land						
Sowed grassland						
Natural pasture						

Olive groove						
Fallow						
Plantation, pine						
'' cork oak						
'' holm oak						
'' eucalyptus						
Shrub						
Other						

Livestock on this moment at the property					code
	M	F	J	Why and for what [1]	
Cattle, milk					
Cattle, meat					
Sheep, milk					
Sheep, meat					
Goat, milk					
Goat, meat					
Pigs					
Other					

[1] 1) Home consumption; 2) For sale 3) Subsidies; 4) other

If livestock present

1	Do you buy fodder?	☐ NO ☐ YES what percentage of the annual fodder?	
2	On what market do you sell your products?	☐ local ☐ regional	☐ national ☐ international

	Products	code
1	What is the most important product for the property?	
2	On what market do you sell your products? ☐ local ☐ regional ☐ national ☐ international	
3	Are you satisfied with the production of your exploration ☐ NO ☐ YES	
4	If there was some money for investments, what would you do?	
5	Do you have other activities on the property, besides the agriculture? ☐ NO ☐ YES, which?	

D

Changes in management.				
1	**What has changed in the management of the farm ? In terms of...**			
		2004 - 1986	**1986 - 1974**	**1974 - ...**
a	**Total area of the property.**			
b	**Soil use**			
c	**Type and number of livestock**			
2	**Why did these changes happen?**			
	☐ because of subsidies ☐ another crop gained more ☐ because of a good example (neighbor, family member,..) ☐ because of technical advise ☐ because of lack of work force ☐ because of personal reasons (aging, illness,..) ☐ other reasons:			

E

Areas without agricultural production

code

1 Fallow land

a) Do you have fallow land?
☐ NO → 2
☐ Yes, what is the area? ___Ha

b) How long does a fallow period take? ____ Years

c) What is the reason for laying fallow?
☐ soil rest
☐ subsidies
☐ other:

d) What do you do after the fallow period with the land?

2 Areas without agricultural production

a) Besides the areas which laying fallow, do you have other areas without agricultural production?
☐ NO → 2d
☐ YES, what is the area? ____Ha

b) Why don't you use these lands?

c) Where they used before?
☐ NO
☐ YES, what was the last use? How long ago?

d) And formerly were there more areas without agricultural production?
☐ NO
☐ Yes, what is the area? ____Ha

e) Are you considering to leave more land without agricultural production?
☐ NO
☐ YES

3 Abandoned areas

a) Do you consider these areas without production, as being abandoned?
☐ No
☐ YES

b) What is for you an abandoned parcel? Do you know some of these parcels in this area?

c) Do these abandoned area have some interest for you?
☐ NO
☐ YES, because:

Annex 2: Publication list & participation to conferences & meetings

Publication list 9not included are the papers presented in the present thesis)

Peer reviewed

Martha Bakker, Gerard Govers, Anne van Doorn, Fabien Quetier, Dimitris Chouvardis, and Mark Rounsevell, 2007
The response of soil erosion and sediment discharge to land use change in 4 areas in Europe: the importance of the landscape pattern.
Geomorphology 2007

Jacqueline de Chazal, Fabien Quétier, Sandra Lavorel, and Anne Van Doorn
A framework for vulnerability assessment in extensive agro-pastoral landscapes of Europe
Submitted to: Ecosystems

Acosta-Michlik, L., M. Rounsevell, A. van Doorn, M. Bakker and F. Ewert Modelling Agents' Behaviour (part II): Empirical Application of an Agent-based Model to Develop Land Use Change Scenarios.
Submitted to: Journal of Environmental Management

L. Acosta-Michlik, A. van Doorn, M. Bakker, M. Rounsevell and M. Delgado,
Modelling Agents' Behaviour (part I): Framing an Agent-based Land Use Change Model in Traditional Agricultural Landscapes in Europe
Submitted to: Journal of Environmental management.

Non peer reviewed papers, proceedings and reports

Teresa Pinto-Correia, Bas Breman, Van Doorn A. 2006
Que Marginalização em Território Rural ?
Diferenciação dos processos em curso em Portugal Continental
Submitted to: Agronomia Lusitana, "Impacte do abandono agrícola na paisagem"

Van Doorn, A.M. & T. Pinto Correia 2005. Complex interactions between land cover and land use in a changing peripheral landscape in southeast Portugal, proceedings X Colóquio Ibérico de Geografia, Évora, Portugal

Van Doorn, A.M, 2005 Understanding land cover changes in a case study in Mértola, Portugal: An example of using land cover trajectories as a tool. Documentation International Congress LPN

Van Doorn, A.M 2002. *Managing the Montado in the region of the Alentejo: how are the agro-environmental measures being used?* Msc-thesis, University of Évora.

Van Doorn, A.M 2001.*A landscape ecological analysis of a Mediterranean regional park Portofino (Italy)*. Internal report, Alterra Wageningen, the Netherlands

Participation to conferences and meetings

May 2006 Oral presentation: Linking landowners' types and landscape functions: a proposal for an integrated approach from southern Portugal. IFSA-conference, Wageningen, the Netherlands.

Oct. 2005 Oral presentation: Dinâmicas e factores na ocupação do solo: Casos de estudo em Mértola e Castro Verde. Van Doorn, A.M. Stakeholder workshop VISTA project, Castro Verde, Portugal.

Sept. 2005 Oral presentation: Ocupação vs uso do sulo nama paisagem em mudança no sudeste de Portugal. Van Doorn, A.M. X Colóquio Ibérico de Geografia, Évora, Portugal

Feb. 2005 Oral presentation: Refining the concept of land abandonment. Experiences from Southern Portugal. Van Doorn, A.M. International IALE conference, Faro, Portugal.
Poster presentation: Searching for drivers of spatial heterogeneity of landscape change, an interdisciplinary approach in a case study area in Southern Portugal, Van Doorn, A.M. International IALE conference, Faro, Portugal.

Nov. 2004 Oral presentation: Understanding land cover changes in a case study in Mértola, Portugal: An example of using land cover trajectories as a tool. Van Doorn, A.M. International Congress LPN, Castro Verde, Portugal.

June 2004 Poster presentation: Mapping landscape history in the Mediterranean; methodologies applied to a small case study area in Southeast Portugal, Van Doorn, A.M. Fifth International Workshop on Sustainable Land Use Planning: Multiple landscape: Merging past and present in Landscape Planning, June 7-9, Wageningen, the Netherlands

Sept. 2003 Oral presentation: A different View on the Montado, The role of Montado for landscape multifuncionality: examples from Southern Alentejo, Van Doorn, A.M., Oliveira, R., Pinto-Correia, M.T. International Conference 'Sustainability of dehesas, montados and other agro-silvo-pastoral systems' Cáceres, Spain.

Nov. 2002 Oral presentation: Managing the Montado in the region of the Alentejo: How are the agri-environmental measures being used? Van Doorn, A.M., Pinto-Correia, M.T.III Colóquio de Valorização do Montado, Portel, Portugal.

Sept. 2002 Poster presentation: Managing the Montado in the region of the Alentejo: How are the agri-environmental measures being used? Van Doorn, A.M., Pinto-Correia, M.T. at the Permanent European Conference of the Study of the Rural Landscape-conference, Tartu, Estonia.