Learning from the Past: What Cultural Heritage Can Teach Us About Water Storage and Management

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Abstract

This chapter is aimed at contributing to the debate on water security in a more sustainable world, especially in drylands or in regions with irregular rainfall. In this context, ancient practices and technologies are analyzed, some of them no longer used, but could contribute to facing contemporary environmental challenges regarding management perspectives in present situations of water scarcity. Several examples of water supply infrastructure around the world are presented, such as reservoirs and aqueducts, analyzing the current viability of each one, considering the magnitude of the infrastructure, the distance to the source, and the type of water source. For that reason a concept map to classify ancient water systems into urban systems was utilized. Additionally, with a view to ensuring

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C. Constance (ed.), *The Palgrave Handbook of Global Sustainability*,
https://doi.org/10.1007/978-3-030-38948-2_170-1

water security in present urban systems, especially in small villages, alternatives adopted in the past that combine water harvesting and storage were analyzed, with special emphasis on cistern technology, capable of promoting a sustainable water supply in small areas, on a small scale, with local empowerment. Understanding the past, analyzing the present to design a fairer and more sustainable future is also a matter of environmental education, which is essential for questioning the contemporary way of life, which could lead to the structural changes needed. This pedagogical attitude, integrating the cultural and historical assets and heritage, promotes people knowledge and skills, contributing to both natural and cultural heritage protection and to the development of nature conservation attitudes and environmental stewardship.

Keywords

Water scarcity · Environmental education · Science across cultures · Sustainability · Cistern · Dryland

1 Summary

Due to increasing water crisis, water security is becoming more and more mainstream and associated with the Sustainable Development Goals and the human right to water. Water supply, especially for households, becomes more and more challenging. Looking to the past, several water-harvesting techniques implemented around the world since ancient times can be found and they were succeeded to deal with water scarcity and to promote food and water security. Their replacement by modern techniques not always represents a sustainable solution. The future challenge is to go further, through an integrative vision that minimizes the environmental impacts of water use techniques, and the possibility of learning from the past. In this context, the solutions can be a combination between culture and traditional knowledge, with modern water technology and its management. We propose looking at this issue considering ancient techniques for harvesting and storing water for human supply in small villages, under a pedagogical attitude of learning how to emphasize the relationship between nature processes and society, from the perspective of Ecosystem services. Different techniques were analyzed, considering the magnitude of the infrastructure, the distance to the source, and the type of water source. A classification framework of ancient water systems was designed. Then, careful attention was paid to the existing hydraulic heritage of the living Monsaraz medieval village, located in the south of Portugal, as an example. The resultant analysis considers both ancient water-harvesting and water-storage techniques in an urban context so that they could positively answer the contemporary challenge of transforming water-scarce into water-secure villages, with a focus on rainwater harvesting.

2 Introduction

In the last two centuries there has been a rapid degradation of natural ecosystems, incomparable with any other period in history. Crutzen and Stoermer (2000) propose the term "Anthropocene" to characterize a new geological era, centered on the effects that the human being had on the global Earth system (Steffen et al. 2007).

The freshwater ecosystems are particularly threatened, some of them with irreversible levels of degradation, owing to the continuous pressures to which they are subjected, resulting from human settlements, which over time have developed and grown close to rivers and lakes (e.g., Malmqvist and Rundle 2002; Dudgeon et al. 2006; Vörösmarty et al. 2010; Tonkin et al. 2019). Among the pressures that have most contributed to the degradation of these ecosystems, especially in drylands or in regions with irregular rainfalls, the following stand out, among others: 1) uncontrolled urbanization; 2) inappropriate land use policies, such as intensive agriculture; 3) the excessive and uncontrolled use of fertilizers and pesticides (it should be noted that the highest percentage of conversion of atmospheric nitrogen into reactive forms results from the production of fertilizers and the combustion of fossil fuels (Braga et al. 2014, p. 4) the invasive species that alter the trophic chains and therefore the ecological and functioning processes of the system; 5) climate change. Owing to CO_2 emissions, the climate has deviated significantly from natural behavior. The land is heating up rapidly (IPCC 2007, 2014) with unpredictable consequences for the availability of water in several regions of the globe, namely in the Mediterranean Basin – an important hotspot in terms of biodiversity, supporting a high number of endemic species and providing numerous Ecosystem Services (Bonada 2007; Cuttelod et al. 2008; Tierno de Figueiredo 2013). Accordingly, these pressures threaten the sustainability of ecosystems, the provision of Ecosystem Services (concerning the water supply), and, ultimately, human well-being.

In Europe, the current policy related to the conservation and integrated management of the landscape, such as the Water Framework Directive (2000/60 / EC), the Habitats Directive (2009/ EC & 92/43/ EEC), the Floods (2007/60/EC) and the European Biodiversity Strategy 2020, among others, demonstrate the need for coordination and cooperation between different areas, from the perspective of knowledge integration. From the same perspective, in 2015, the United Nations proposed the Sustainable Development Goals to achieve the following goals, among others: environmental stability, safe drinking water, and sustainable resource management.

The need to look for innovative solutions for environmental recovery and restoration that consider the resilience of systems from the perspective, double and complex, of the conservation and protection of biodiversity and the provision of Ecosystem Services (namely those related to the access to a secure water supply) is globally recognized.

To this end, it is necessary to assume an integrative posture, considering the relationship between nature and society through a complex socio-ecological system (e.g., Langhans et al. 2019). From this conceptual perspective, human society comes to be considered as an element belonging to the ecosystem; therefore, it is essential to adopt an integrated management that includes the assessment and adoption of complex adaptive recovery and restoration solutions. From this perspective, and because the human being will have to recover and restore what has degraded, it is necessary to rescue the society–nature relationship in all its complexity. It is necessary to discuss the perception of the insertion of humans into Nature, with a similar destiny for all the other species that inhabit the planet. This concept, as opposed to an anthropocentric ontology, places the human in a network of symmetrical relationships with other species and with Nature, reciprocally determined, with no hierarchy (Capra 1996). However, the current economic, financial, and environmental crisis (which began in 2008 and has recently expanded), as a result of a self-destructive style of thought and social imagery, has led us to enormous social injustices, namely with regard to access to basic natural resources.

The United Nations General Assembly explicitly recognized the human right to water and sanitation on 28 July 2010, and acknowledged that clean drinking water and sanitation are essential to the realization of all human rights. Nevertheless, it is expected that only one in five countries below 95% coverage is on track to achieve universal basic water services by 2030. In this context, the target 6.1 of the Sustainable Development Goals seeks to extend services to 844 million people who still lack a basic water service (UN-Water 2018). However, the anthropogenic pressures mentioned (e.g., climate change, increasing urbanization, and ecosystem degradation) create obstacles to accomplishing the target, placing water shortage as one of the most relevant challenges in the present day. Eliasson (2015) wrote that the world was experiencing increasing water-related crises, and that the demand for water would be grow by more than 40% by 2050. Additionally, he projected that about 1.8 billion people would be living in countries or regions in which water is scarce by 2025. These projections may confirm the idea that the magnitude of the global water crisis has been greatly underestimated (Axworthy and Sandford 2012). Water security is becoming more and more mainstream (Cook and Bakker 2012) and is centrally associated with the Sustainable Development Goals and the human right to water (UNESCO and UNESCO i-WSSM 2019).

Understanding the past, analyzing the present, and having the ability to envision the future determine an essential philosophical position for the human being to question who he is, where he is on planet Earth, where society is heading, and why. This attitude requires an openness to inter- and transdisciplinarity that integrates the different factors related to global changes, which are also interrelated. In this context, is it legitimate to ask what kind of knowledge and techniques can improve water supplies, without damaging the already degraded ecosystems, or those under strong inter-annual variability of precipitation?

Looking to the past, water-harvesting techniques have been implemented around the world since ancient times to deal with water scarcity, and to promote food and water security (Bitterman et al. 2016). However, many of these strategies and techniques are completely ignored or replaced by modern ones, often bringing problems where the modern techniques implemented are not adapted to the local environmental conditions and where the knowledge of how to operate and maintain these techniques is lacking or weak. Additionally, the traditional knowledge is lost or about to be lost, as knowledge is transmitted down through the generations, based on practice without written records (Berking and Schütt 2018).

The future challenge is to go further, through an integrative vision that minimizes the environmental impacts of water use techniques, and the possibility of learning from the past. In this context, the solutions can be a combination between culture and traditional knowledge, with modern water technology and its management (World Water Council 2003).

In this manuscript, we propose looking at this issue considering ancient techniques for harvesting and storing water for human supply in small villages, under a pedagogical attitude of learning how to emphasize the relationship between nature processes and society, from the perspective of Ecosystem services. Different techniques were analyzed, considering the magnitude of the infrastructure, the distance to the source and the type of water source. A classification framework of ancient water systems was designed. Then, careful attention was paid to the existing hydraulic heritage of the living Monsaraz medieval village, located in the south of Portugal, as an example.

The next reflection considers both ancient water-harvesting and water-storage techniques in an urban context so that they could positively answer the contemporary challenge of transforming water-scarce into water-secure villages, with a focus on rainwater harvesting.

3 Examples of Ancient Water Harvesting Techniques

Local and historical studies of water use and techniques have a key role in supporting future strategies to cope with water crisis and challenges. Berking and Schütt (2018, based on Lofchie 1975) comment that only in the second half of the twentieth century did interest in local, low-cost alternatives for water management start to develop. As part of this new approach, the interrelationship between culture and heritage began to be considered as a viable component for the management of water resources, as throughout human history, culture has been dialectically shaped by the availability of water and vice versa (Klaver 2012).

In fact, the enormous cultural diversity all over the world represents a great potential for the implementation of adaptation strategies for the water supply, capable of promoting the sustainable use of natural resources with regard to the ecological integrity of the natural ecosystems. The past assets and the studies about ancient practices of water harvesting, storage and supply can enlighten present practices toward the paths of sustainability.

For example, in India it is possible to find examples of ancient practices for rainfall harvesting in micro or macro catchments still being used, in addition to their decline. For instance, the so-called "*chaals*" from the Garhwal region (state of Uttarakhand, in western India) located in the Himalayas; and the "*johads*" from North India. "*Chaals*" correspond to ancient structures for harvesting water found along the top of the mountains, in the saddle between two adjacent ridges: capable small lakes or ponds are formed with a relatively thick soil bed. According to

Acharya (2012), these structures represent an example of the culture–water relationship in this inhospitable region. Currently, the use and maintenance of these structures is in decline, owing to the modern policy of forest management, which implemented measures to restrict grazing practiced by local populations. "*Johads*", were traditional mud barriers that were built across the hill slope to harvest water from the brief and intense precipitations during summer monsoons (Santos et al. 2005; Hussain et al. 2014).

Concerning ancient practices of groundwater harvesting, it is indispensable to mention the "*qanāt*", found among Persians more than 5000 years ago. "*Qanāt*" were composed by a system of artificial underground water channels up to 305 m deep, to bring a continual flux of water to the earth's surface for human agricultural and domestic use (Taghavi-Jeloudar et al. 2013). The ancient "*qanāt system*" was always controlled by the level of the underground water table, utilizing groundwater as a renewable resource. Consequently, significant drawdown in an aquifer is avoided because the water flow is dependent on the subsurface water supply, bringing advantages over traditional wells (Taghavi-Jeloudar et al. 2013). UNESCO recognized the "*qanāt system*" as a testimony to the ancestral tradition, providing water to support human settlements in arid zones. Thus, UNESCO included the "*qanāt system*" in the World Heritage List by the United Nations Educational, Scientific and Cultural Organization. Based on "*qanāt*" operating characteristics, which are very well adapted to local conditions, Rahnemaei et al. (2013) proposed restoring the dried up ones, by raising the unconfined water table through the artificial recharge of groundwater, supplying water by a permanent flow to the desert-dwellers. However, Ahmadi et al. (2010) considered that the "*qanāt system*" could not be the only solution for the present-day challenges of water scarcity in arid and semiarid regions.

Looking to another part of the Planet, in Rapa Nui (Easter Island), the native civilization has transformed natural ravines, through the building of stone and earth terraces, across gullies to function as a dam (Vogt and Moser 2010). Saito (2017) described the "*rapanui strategy*" to settle their houses close to water sources, namely: i) in cellars containing water, in the interior areas; ii) in places near the seashore where water emergence from the ground would be found during low-tide periods.

As was reported, ancient rainwater harvesting techniques have been largely investigated, but the examples presented are mainly related to rural areas, namely: terraces; ponds; sand dams; small reservoirs; hillside conduits; qanats, etc. (Oweis et al. 2001; Beckers et al. 2013; Bitterman et al. 2016; Berking 2018). Our focus reinforces a classification of water-harvesting techniques in dichotomous groups of micro and macro catchments or allogenic and autogenic sources.

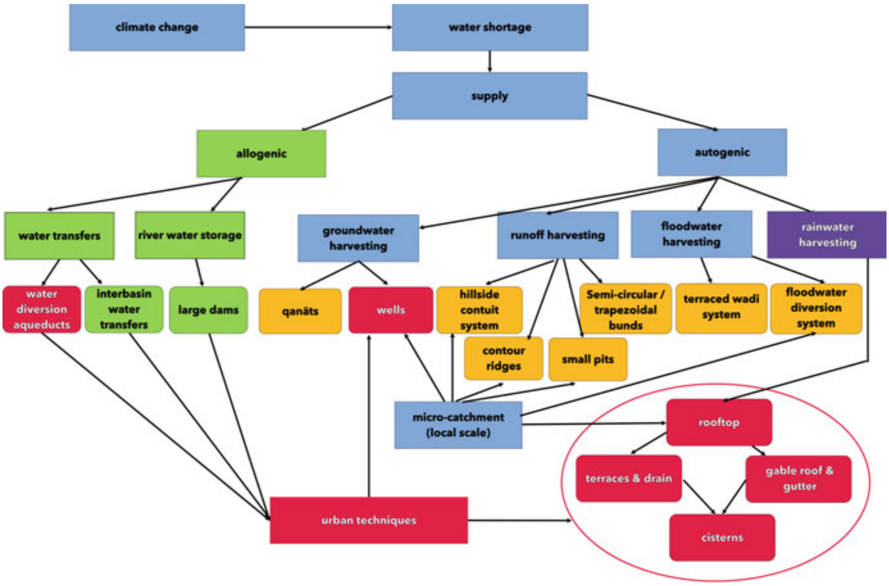

Fig. 1 Different ancient water harvesting systems. Blue boxes refer to the general context of the climate–water–local scale water harvesting relationship; red boxes refer to urban water harvesting; yellow boxes refer to rural water-harvesting contexts; and green boxes present the large infrastructure applicable to both urban and rural contexts. (Modified from Oweis et al. 2001; Beckers et al. 2013; Bitterman et al. 2016)

4 Past Water Harvesting in an Urban Context

In global terms, there are many harvesting techniques, which makes comprehension and comparability among different regions difficult. In order to solve this difficulty (Berking 2018) categorized these techniques into four major attributes: 1) the origin of the water that is used; 2) the type of the water that is harvested; 3) the scale of the water harvesting system that is applied; 4) the technique that is applied. The first attribute defines whether the system is autogenic (internal or local) or allogenic (external or floodwater). The second attribute is to state the type of water harvested and whether it originates from the surface (rainfall-runoff or flood-water) or is of subsurface origin (groundwater). The third attribute is the size of the water harvesting system. The fourth and final attribute describes the respective technique.

As the focus is on the harvesting systems in an urban context, in Fig. 1 we present its position within the categorization based on the four attributes.

In urban areas, the higher demands of waters associated with the social dynamics, established some particular configuration of city water systems (Winiwarter et al. 2016). However, as mentioned by Winiwarter et al. 2016, a long-term co-evolution of the urbanites, focusing on how the water was made available, has led to urban society transformation. In this context, a core question can be posed: *what has been the main role of water throughout human history?*

In western civilizations, aqueducts represent a remarkable water distribution technique that has enabled human settlements. They were found among Roman empire heritage assets, built for transferring water from pristine mountain sources to a destination inside the same basin, just based on gravitational force. The same technique has been applied in modern water pipelines with a similar objective, which is to bring water from far away springs into cities and villages. Vestiges of aqueducts are present in the landscapes of several countries worldwide, in France (Saint Clément aqueduct in Montpellier and the Pont du Gard aqueduct near Nîmes, Uzés, and Avignon), Spain (the most famous one is in Segovia), Turkey (the Valens aqueduct in Istanbul), Italy (Rome itself has 11 aqueducts), Portugal (the Água de Prata aqueduct in Évora entered into operation in the sixteenth century). In eighteenth century, in Portugal and also in Brazil (where the Portuguese built these infrastructures), aqueducts were planned to bring water from distant sources to their capital (Águas Livres aqueduct in Lisbon and Lapa aqueduct in Rio de Janeiro). These megaprojects had a macro catchment profile designed with the objective of supporting urban settlements in a phase of increasing expansion. Although they do not work anymore, they represent a historic milestone in the development of the cities where they were built, with the majority classified as part of the architectural heritage of humanity.

Harvesting systems used to make water available in urban settlements must be combined in an interdependent way with water storage, thus highlighting a technology from the past capable of storing a large amount of water: the cistern. These early large cisterns were usually connected to aqueducts (Wilson 2001). Some remarkable examples all over the world can be cited: the Basilica Cistern in Istanbul, Turkey; the Piscina Mirabilis cistern supplied by water from the Augustan aqueduct in Southern Italy; the Upper São Francisco cistern in Curitiba, Brazil; the cistern of the Water Tower in Montpellier, France; the Patriarchal cistern in Lisbon, Portugal, among others. In Turkey, more than 30 cisterns were constructed in Istanbul during Byzantine times.

The largest covered cistern is the Yerebatan Palace, also known as the Basilica Cistern, which was probably built in the early sixth century by the emperor Justinian (Yilmaz-Emre 2014). The cistern measures about 140 m long and 70 m wide, with 336 columns supporting its roof (Lerner 1989). This cistern was supplied by 20 km of aqueducts from a reservoir near the Black Sea. The cistern, however, is no longer entirely filled with water. Today there are some walkways that allow visitors to walk along the inner reservoir and see the marble columns that sustain the structure which has housed more than 100 million litres of water.

In Brazil, the construction of the first subterranean cistern of Curitiba city, in the southern region of this country, was agreed in 1904 followed by the implementation of an adductor with a length of 40 km, from the catchment point in the springs of the Serra do Mar to the city. Four years later, on 24 August 1908, the subterranean Upper São Francisco cistern, with a capacity of 6881 m^3 (more than 6 million l of water) finally began to be filled with the water brought from Serra do Mar through its own gravity. In 1908, Curitiba had a population of close to 50,000 people. The complex system included a fountain at the public square, the operating house, and the subterranean reservoir underneath the square. The cistern itself, with pillars of foundation and ceiling of vaults and arches, was inspired from ancient civilizations. Nowadays, more than 200,000 people of Curitiba city continue to receive water from this cistern (https://ricmais.com.br/noticias/reservatorio-sao-francisco-guarda-muita-agua-embaixo-do-centro-historico-de-curitiba/ and https://gshow.globo.com/RPC/Estudio-C/noticia/mergulhe-nessa-historia-o-abastecimento-de-agua-no-parana-o-reservatorio-de-sao-francisco-o-mais-antigo-fica-em-curitiba.ghtml).

In Montpellier, France, the water tower with a cistern on the promenade of rue du Peyrou was designed in 1768 and supplied by the Saint Clément de Pitot aqueduct. Initially, the aqueduct brought water from the springs of Saint Clément, and later, from the spring of Lez, near Prades-le-Lez, the main regional karst spring (source of the river Lez). The construction of the aqueduct started in 1743 and ended in 1765 (https://www.trekearth.com/gallery/Europe/France/South/Languedoc-Roussillon/Montpellier/photo1063675.htm). Initially, there was only a tank of about 105 m^3 at 2 ft and 3 in. (= 0.73 m) below the Saint Clément spring; subsequently, a reservoir of the same size for water distribution was built, under the Peyrou promenade (http://aqueducsaintclement.blogspot.com.br/2011/02/petite-histoire-dadduction-deau.html) (Bakalowicz 2012). At the beginning of the 1980s, the underground collection station of the Lez spring was inaugurated, and the aqueduct ceased its original function, remaining only as a tourist attraction.

In Portugal, the Patriarchal Cistern, also known as the Praça de D. Pedro V Cistern, is an underground octagonally shaped cistern built between 1860 and 1864 to regulate the pressure between the "*Mãe d'Água das Amoreiras*" reservoir and supply the downtown area of Lisbon. The cistern, with a capacity of 884 m^3, was initially supplied by the Águas Livres Aqueduct, which was inaugurated in 1748 to transport water from sources some 18 km northwest of the city. The Patriarchal Cistern has 31 pillars measuring 9.25 m high, supporting the stonework arches, which in turn support the cupolas. Over the cupolas lies a lake with a waterspout, which was part of a water-airing system. In this system, water should be aired before entering the cistern. The Patriarchal cistern served palaces and convents, and a network of public fountains (Saraiva et al. 2014).

From now on, one can wonder, what lessons can we draw from these technologies used in the past for current sustainable water management?

5 Lessons from the Past: The Return to Small

Mithen (2013) suggested that although it is necessary to be cautious about drawing lessons from the past, it is important to identify reminders for an appropriate water–human relationship that humankind should have learned, specifically, the necessity of controlling the water supply system and the importance of considering local knowledge and stakeholders' opinion to avoid trade-offs between water supply and the need to preserve the integrity of natural aquatic ecosystems. These key reminders are connected to the contemporary concept of water security proposed by UN-Water (2013).

Rosado and Morais (2010) addressed several strategies for water management in the Mediterranean and semi-arid regions, through a literature review, namely: rainfall water storage in cisterns; infiltration and recharge of ephemeral streams underlain by alluvial aquifers (Middle-East “wadis”); reservoirs created by dams; subsurface dams for water storage; wastewater treatment for reuse; desalination of sea water; and inter-basin water transfers. Some of these infrastructures are small-scaled, others are large-scaled. Taking into account these different strategies, and if we want to consider examples from the past, we can infer that there are different scaled alternatives to be considered.

Additionally, it is important to look to strategies in the past that combine both water harvesting and water storage, but avoiding large infrastructures, such as the aqueducts. Presently, aqueducts (large-scaled infrastructures) are nonfunctional structures, remaining as testimonies of the effort spent in the past to bring water from distant sources to cities. Large dams of our recent history (large-scaled infrastructures) are not the solutions either, they require large investment with enormous impacts on the environment and biodiversity. Territorial independence and concerns for the preservation of natural ecosystems and biodiversity suggest the necessity of solution at on a local scale (small-scaled).

It is important to link the increasing urbanization with the deterioration of water quality. In the past (but still in some regions of the world), cities used to dump untreated domestic waste into any aquatic system (e.g., rivers, streams, lakes), from where they later took water for different uses. In fact, even in the present, a large proportion of both urban and rural populations still depend on natural flows for water supply. Currently, it is absolutely necessary to find alternative solutions, as pollution not only contributes to the degradation of ecosystems and their biodiversity, but also jeopardizes the ability of people, mainly the poor ones, to access a secure water supply (Kumar 2004).

In this context, it is proposed to re-examine the cisterns, mainly because this technology can be adopted in a small urban context, in both households and in a set of houses closer to each other. Note that the other ancient practices of water supply, previously mentioned, such as qanats, johads, and chaals, are more adjustable to rural areas. This proposal considers that instead of feeding cisterns with water brought from distant places (a combined process of aqueducts and cisterns that was used in the past), these ones should be filled locally via rainwater harvesting. This idea was also present in the past. Mays et al. (2013) mentioned several examples of ancient cisterns harvesting rainwater, such as in the smaller Aegean islands of Classical and Hellenistic Crete, or in the island of Thera (known as Santorini). According to these authors, rainwater-harvesting cisterns were built not only as public facilities but also as private ones, in several past civilizations, with many of testimonial ruins.

Klingborg and Finné (2018) consider that the Mediterranean region is a good source of information for studying issues of water supply from this time scale perspective, owing to its long history of human activity with a relatively well-investigated archaeological record. In this context, we propose to looking at a past

Fig. 2 Cistern of Monsaraz village for public supply (fourteenth and fifteenth centuries), Alentejo region, Southern Portugal

Fig. 3 Terrace for rainwater harvesting above the cistern of Monsaraz village, Alentejo region, Southern Portugal

still living, searching for examples of cisterns still working in the present days to function as vivid lessons.

5.1 Cistern of Monsaraz Village, Alentejo Region, Southern Portugal

According to José Pires Gonçalves, the etymology of the word Monsaraz is Arabic, proposing Mons, Monstis, meaning hill, and an Arabic suffix – Saris or Snarish/ Xarez-Xaraz (land used by “scrubs” and “esteva” or Xara) (Gião Passinhas 2017). However, Monsaraz is currently a very well preserved medieval village, conquered from the Moors in 1167 with the aid of the Templars (Gião Passinhas 2017). It is a

Fig. 4 Rainwater-harvesting system of gutters, placed in the eaves of the house roof in Monsaraz village, Alentejo region, Southern Portugal

walled village with a castle, which allowed the fixation of the population in an area continuously threatened by Arab and Castile offensives. It is situated in a landscape of a wide wavy plain with elevations that stand out in contrast to the dominant horizontality. One of these elevations is the hill where the village was settled, with an amazing view of the river Guadiana, which was navigable at that time. Consequently, Monsaraz was significant in the control of the Guadiana passage, with several ports near the village.

Despite the geographical proximity to the river Guadiana, the supply of water was mainly made through rainwater harvesting conducted into an underground cistern. The ancient's hydraulic elements in Monsaraz were identified in the "military court" castle (a cistern and a well, not preserved and destroyed over time), which was the starting point of the village and the last refuge in the case of siege by the enemy (Gião Passinhas 2017). Encompassing the growth of the village and the construction of the walls, new hydraulic elements appeared to maintain the population's water supply. The most important, owing to its size, still preserved today, is the village cistern, which stored water for a long time (Fig. 2).

Built between the fourteenth and fifteenth centuries, the cistern has always been a precious element in village planning. It is composed of a longitudinal, simple, and regular plant with a vault cover supported by eight arches in granite, stone, and towed brick. It was the main water reservoir within the walls, collecting and storing the rainwater to supply the resident population (Gião Passinhas 2017). The cistern is paired on the eastern side with the Dionysian wall, nearby to the "Buraco" gate, demarcated to the west in the public lane by a gothic stone arch, which gave passage to the general collector of the waters (https://www.cm-reguengos-monsaraz.pt/locais/cisterna/). Outside, above the cistern, there is a terrace, with shale slabs placed on a slope, which allowed the rainwater to drain to the holes excavated in the corners of the terrace floor. In the center of the terrace there is a well where the residents could collect water (Fig. 3).

Fig. 5 Terrace for rainwater harvesting in a Brazilian house (Brasilia, central Brazil), inspired by the cistern of Monsaraz village (Alentejo region, Southern Portugal)

Complementarily, there is a complex system of gutters, placed in the eaves of the house roofs, and a pipe embedded in the pavement that passed in the main street, guiding the water by gravity to the cistern (Fig. 4). In addition, there was the village well, despite its lack of importance in terms of water quantity and quality. The well, located in the center of the village in front of the church, presents medieval characteristics of the water infrastructures, placed in a central position of easy access for inhabitants and visitors. However, according to recent research, the well was constructed later, probably, at the beginning of the nineteenth century. Allied to these elements, outside the walls, there were watermen looking for springs, wells, or other sources of drinking water, to market in the village, transporting the water in jugs on the top of donkeys (Gião Passinhas 2017). In 1950, Monsaraz benefited from the public water system supply, being one of the first villages in Alentejo region where the system was implemented. From this moment, the historical systems have lost their importance. Nevertheless, the utilization of cisterns remained as a habit for domestic and irrigation activities.

What is interesting in this cistern structure in Monsaraz is the simplicity and the possibility of applying the idea of rainwater harvesting on the terrace in other urban

Fig. 6 A cistern built within the One Million Cisterns Program, Brazilian semi-arid region, Brazil

areas. The strategy for the collection of rainwater preparing the terrace adequately for this purpose inspired a house owner in Brazil just after seeing Monsaraz cistern, demonstrating the power of ancient lessons in the present (Fig. 5).

5.2 Cistern of University of Évora, Portugal

It is also interesting to refer to another rainwater harvesting and cistern system: the cistern and the lavatory from the sixteenth century, placed on the emblematic building of the University of Évora "*Colégio do Espirito Santo*" founded in 1559. Underneath the secondary cloisters of the "*Colégio do Espirito Santo*," a cistern supplied with rainwater existed, harvesting through a terrace with a slight curvature placed above and connected to the cistern by holes in the corners, and from the eaves of the roof. According to the architect who restored this cistern in the 1990s (Fernando Pinto, personal communication), the gutters that carried the water into the cistern were painted with lime, to treat the water for possible contamination. In the terrace there was a well from which the stored water was utilized.

6 Current Rainwater Harvesting in Rural Communities (A Brazilian Case)

One Million Cisterns Program (Programa de Formação e Mobilização Social para Convivência com o Semiárido – Um Milhão de Cisternas Rurais – P1MC) is a training and social mobilization program for coexistence with the Brazilian semi-arid region. This program was conceived in 2001 by the network of social organizations called Brazilian Semi-Arid Articulation (Articulação Semiárido Brasileiro – ASA), which was included in the federal government program. The P1MC mainstreamed

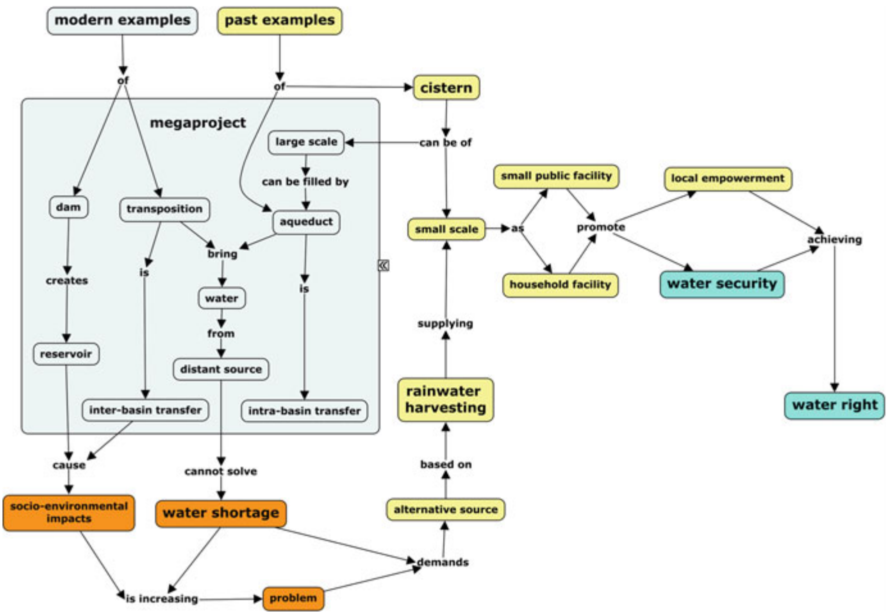

Fig. 7 Concept map of the main proposal of our research: strategies of water supply systems, emphasizing the small-scale cisterns and their relation to water security. Modern and past examples (gray and light yellow boxes respectively) are placed side by side, showing how the first is related to potential problems (orange boxes) and how the second can be part of solution aiming for water security and the right to water (blue boxes)

the "*Coexistence with the semi-arid*," through the guarantee of access to water supply autonomously, aiming to ensure the permanence of the rural population in the region (Moraes and Rocha 2013; Nogueira 2017). These cisterns were originally conceived as a rainwater harvesting system composed of gutters and pipes that deliver rainwater falling on the rooftop to cisterns. However, presently, many of them do not store water from the rooftop, being supplied by water delivery trucks (Fig. 6).

In rural areas of the Brazilian semi-arid region, poor people have very small houses with reduced rooftop areas that collect very few waters. This constraint often prevents or decreases the effectiveness of these cisterns, failing to fulfill the water storage function. Thus, an idea to minimize this difficulty is to increase the harvesting area, which can be achieved through the construction of large terraces connected to water storage cisterns, an idea inspired by the old Portuguese model.

7 Rainwater Harvesting a Concept of Sustainability

The complex rainwater-harvesting and storage system can be individually adopted by households, becoming a complementary solution to reduce demands for the public water supply system in modern villages. These structures can also be adopted by local authorities, through the implementation of small public facilities in strategic sites. These solutions also empower the local community, increasing their autonomy and skills regarding a more water-secure daily life, preventing water shortage and guaranteeing the right to water. Additionally, this rainwater-harvesting system is environmentally friendly. Vialle et al. (2015), based on a French case study of water footprint analysis, concluded that rainwater harvesting systems relieve the stress on local water resources, whereas the modern drinking water production systems do not.

In Fig. 7 a concept map is presented that summarizes different strategies of water supply systems, emphasizing the small-scale cisterns and their relation to water security.

The concept map (Fig. 7) presents different mega-projects proposed to solve problems of water scarcity for large-scale human populations. As a modern example dams and their respective reservoirs, and water transpositions between basins, are presented. As past examples aqueducts are mentioned. Aqueducts and transpositions face the difficulties of bringing water from distant sources; the former as an intra-basin transfer, and the last one as an inter-basin transfer technique. Both options present great socio-environmental impacts, as large distances in the water path between the source and the destination do not normally meet the demand for water. On the other hand, it is possible to say that "*the greater distance the water travels in a forced way, the greater the impact*". In the past, a large-scale solution to supply water in an urban context was based on cistern techniques filled through aqueducts.

Besides this large-scale technology, there was also the small-scale option supported by rainfall harvesting (yellow boxes in Fig. 7). These small-scale cisterns, both in the past and in the present, can serve household and public facilities. They also have the advantage of promoting local empowerment to face water shortage, contributing to increasing safe access to water, which is a universal right.

Looking at the past, it might be possible to conclude that rainwater harvesting has been a very common social practice in the entire region around the Mediterranean and the Near East since the third millennium BCE (Mays et al. 2013). A proof of this is the countless vestiges of ancient cisterns. These examples, contribute to the development of a more respectful view of our present diversity of cultural practices, supported by scientific knowledge that rescues ancient and traditional practices – as recognition of their wisdom (Saito 2014, 2017).

Nowadays, there is increasing concern about the value of past assets, as vivid examples of sustainable environmental management, livelihoods, and wisdom, leading to global attention to the conservation, protection, and management of indigenous, ecological, and sacred sites (Sarfo-Mensah et al. 2014). An Environmental Education integrative model that also integrates the cultural and historical assets and heritage has been promoted to improve people knowledge and skills. This pedagogical scope has contributed to both natural and cultural heritage protection and to the development of nature conservation attitudes and environmental stewardship (Kohl 2008; Ardoin and Ryan 2011; Kudryavtsev et al. 2012). The sense of place can facilitate public involvement on natural resources management. Additionally, the acquired knowledge empowers local communities to have greater control of decisions relating to the use of natural resources that directly affect them (Diduck 1999).

These environmental education strategies respect cultural diversity and are willing to learn from the past. Saito (2014) commented about how the Basarwa (Bushman) people collected water from the sand holes covered with an animal membrane in the Kalahari Desert, and how this ancient practice, based on a solid knowledge of natural processes, understood by western modern science, could help to avoid water losses by evaporation on the irrigation canals in the Brazilian semiarid region. That is why management strategies should consider cultural aspects and must be implemented at the regional/local level, taking into account the present cultural diversity, which should be regarded as a source of sustainable practices and innovative approaches. It is also important to look to the past from the perspective of understanding the mechanisms inherent to the restoration of ancient structures that allowed the water supply to be provided to populations. To face the future, there must be an understanding of the common past and shared heritage. This is particularly relevant within Brazil and Portugal, where after 70 years, water supply is inextricably bound to the availability and development of a huge water infrastructure (i.e., large dams). Without understanding the functional basis and context of the existing infrastructure and management, ignoring alternative systems that operated successfully in the past, it is impossible to globally analyze different options.

8 Final Words

The valorization of the water culture and the hydraulic artifacts and infrastructure heritage help us to preserve the architectural and cultural memory, also contributing to a conscious understanding of how the population has survived and lived over time. On the other hand, this valorization of the ancient water culture also contributes to disclosing the importance of the sustainable management of water resources, linking water harvesting to its storage on a human dimension scale.

Past experiences can teach us about infrastructures for water supply, identify those that have been abandoned and those that are still in use, and understand the model behind these solutions.

Water intra-basin transfers such as aqueducts are past megaprojects, substituted by modern water pipelines. However, in some cases, their linked cisterns are still working. It can be concluded that the model of water storage based on cisterns is still valid. Some alternative to water transfer by aqueducts indicates that rainwater harvesting has been an efficient solution in some Portuguese ancient villages facing water shortages. Although cisterns can be used on a small scale (cisterns for water harvesting) and on a large scale (water supply projects supported by aqueduct flows), the former seems to fit better in the present day.

Thus, mainstreaming water security seems to be not only a matter of modern management techniques. It is necessary to look back to the past and try to learn from the ancient practices to better sustain and integrate water management and provide models of sustainability, promoting recognition and support of cultural diversity and heritage.

It will be through a plural and integrative knowledge, which increases acceptance by the local actors, that the world will be capable of leading itself to the development of daily practices of environmental preservation that impose differentiating attitudes (i.e., by changing perceptions and values). In this context of a complex rapprochement among human needs, local knowledge, and natural water availability the necessary paradigm shift can be made in order to face the threats of global change.

9 Cross-References

- ► Climate Change
- ► Consumerism
- ► Culture, Travel, Tourism, and Recreation and Sustainability
- ► Education and Sustainability
- ► Environmental Sustainability
- ► Human History and Sustainability
- ► International Benchmarking and National Sustainability Planning
- ► National, Regional, or Local Organizations
- ► Natural Resource Management
- ► Sustainability and Equity
- ► Sustainability in the Developing World
- ► Urban and Regional Planning and Sustainability
- ► Water Global Water Use, Water Resources: Aquifers, Reservoirs, Lakes, and Rivers, Water Management

Acknowledgments Acknowledgments should also be made to the Brazilian National Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (Capes), and the Federal District Research Support Foundation (FAPDF), Brazil, for their research support. The manuscript is also part of the INCT/Odisseia project – Observatory of socio-environmental dynamics: sustainability and adaptation to climate, environmental and demographic changes, under the Brazilian National Institutes of Science and Technology Program (Call INCT – MCTI/CNPq/CAPES/FAPs n.16/2014). The study in Portugal was funded by the ALEX 2014 (EXPL/GEOMET/1422/2013) and ALOP (ALT20-03-0145-FEDER-000004) projects and also by the European Union through the European Regional Development Fund, included in the COMPETE 2020 (Operational Program Competitiveness and Internationalization) through the ICT project (UID/GEO/04683/2013) with the reference POCI-01-0145-FEDER 007690.

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