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Policy and management of water as a common-pool resource in Spain

The case of the aquifer 'Carbonatado de la Loma de Úbeda'

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Abstract

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The issue of water is constantly attracting attention on a global scale. Achieving a reduction of water use is difficult, due to population growth and pressure from agriculture inter alia. Therefore a more efficient management of the resource is of importance. The Master thesis investigates the policy and management of water as a common pool resource with the main focus on the aquifer 'Carbonatado de la Loma de Úbeda', located in the province of Jaen in southern Spain. The study examines the policy applied in managing the issues from extensive irrigation practices, the role of EU and solutions discussed for water improvements in the area. The study also covers the major issues of water management in the aquifer and the main actors participating in the process of managing the water resource. The alternatives towards a sustainable water use in the aquifer are also discussed.

Besides a literature study interviews were conducted consisting of farmers, the main Association and authorities in the area of the aquifer. The result from the interviews indicates major issues regarding control of water use in the area, a large expansion of wells, over extraction of water and an overexploited aquifer. The study also revealed conflicts between major actors, lack of management, and a gap between policy and implementation. Cooperation and improvement of the water situation is highly necessary. There needs to be a change in policy and management to reach an improvement of the water resource.

Keywords: Water management, policy, EU, common-pool resource, adaptation, 'Carbonatado de la Loma de Úbeda’, irrigation, sustainable water use

Acronyms

AWC – Andalucía Water Council
CA – Regional Government (Junta de Andalucía)
CAP – Common Agricultural Policy
CEDEX - The Centre of Studies and Experimentation
CH – Basin Authority (Confederación Hidrografica)
CPR – Common Pool Resource
CR – Irrigation Communities (Comunidades de Regantes)
GRB – Guadalquivir River Basin
HBP – Hydrological Basin Plan
GESTAGUA - Management Program of Irrigation Communities (Programa de Gestión de Comunidades de Regantes)
IGME – Geological and Mining Institute of Spain (Instituto Geológico y Minero de España)
IWRM- Integrated Water Resource Management
MIMAM – Ministry of Environment
MOPTMA – Ministry of Public Works, Transport and Environment
NIP – National Irrigation Plan
PoM – Program of Measures
PPP – Pollution Pays Principle
RBMP – River Basin Management Plan
WDF – Water Framework Directive

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1 Introduction

Water is a common resource and seen as a component for good quality of life (Biswas 2009), but water scarcity has become a major concern in the 21th century. Many regions are facing lack of water and severe water pollution, resulting in environmental, economic, social and political consequences. Immediate actions are strongly needed, though the required solutions are not easy to accomplish (Development Alternatives Information networks N/D). 97 percent of the world's water is undrinkable saltwater, which leaves the remaining 3 percent being freshwater. Today about 900 million people do not have access to clean water. More than 2,7 million do not have access to sanitation with negative consequences for socioeconomic development in several countries. Human activities are impacting the oceans around the world and 40 percent are marked as heavily affected (United Nations Development Program, 2012). Droughts in Europe have during the past 15 years been more long-lasting, resulting in more severe environmental, economic and social effects than earlier (Strosser et al, 2007). An additional important impact is the population growth, since it is putting more pressure on the demand for water and increasing the amount of wastewater and pollution. Estimates indicate that by 2050 the world's population will increase by about 3 billion people (Hassing et al, 2009).

The extraction of freshwater around the world for irrigation use is about 70 percent. In semiarid countries irrigation use accounts for about 80-90 percent and the groundwater use has in past half-century faced a major increase (Ross and Martinez-Santos N/D). At first, groundwater was defined as a renewable resource, as wind and solar radiation, due to free availability of the resource. Water is therefore seen as a non-economical good and in several countries the use of water is free (Mesa Jurado et al, 2010). Groundwater as a source of supply has several benefits. In comparison to surface water it does not have an equal evaporative process. Groundwater moves more slowly and it can be extracted close to the place of use. The supply of groundwater is available throughout the year, also during periods of drought. This is one of the reasons why farmers increase the use of groundwater for irrigation. The infrastructure for groundwater has a relative low cost, facilitating the supply for individual farmers. The disadvantage is the major difficulties in governing the groundwater in comparison to surface water. Groundwater movements are not visual and therefore cannot be easily mapped. Hydro geological boundaries are often unclear, as well the boundaries between individual aquifers in relation to other aquifers and surface waters. In the past, land owners were allowed to extract water below their land and control barely existed. Irrigation has resulted in important economic and social benefits, particularly in regions with arid and semiarid climate. Major extractions of groundwater can result in land subsidence and severe ecological impacts within the aquatic systems (Ross and Martinez-Santos N/D).

The overexploitation and inefficient use of the resource is seen as a result of lack of economic value, necessary for a rational management (Mesa Jurado et al, 2010). Rational planning and management of water is very complex mainly because it is a common resource. Water is constantly passing through regions, states and countries, and a single institution is not able to manage it, in spite of technical support, access to resources and management capacity. The quantity, quality and availability of water are limited. Water is neither consistent nor homogenous over time. Different regions have different conditions, even within countries, between seasons and years. Many factors are involved in relation to water use including how it is managed, and the capacities of the institutions who manage it. The issue today is how to manage it in a world that is both time constrained and with the need to be cost-effective (Biswas, 2009).

Spain is a country with dry and hot climate, in particular the Mediterranean climate in the south, causing water scarcity and common occurrence of droughts. Further climate changes will result in additional severe impacts such as increased frequency of drought and floods (Lloyd-Roberts, 2008). Andalucía, the southern region of Spain, has always been extremely dry and with little precipitation during the summer seasons, making it more vulnerable to global warming. In the 1990's the southern region had a severe drought and at present time the reservoirs are low and statistics show that the rainfall has been reduced by half (Global Water Intelligence, 2012). The use of groundwater in south of Spain has during the past two decades increased tremendously, being defined as "the silent revolution of groundwater" (Gonzalez-Ramon et al, 2013). Agriculture requires a large amount of water and is one of the main factors increasing the water demand, accounting for 80 percent of the water consumption in Spain. Despite this only 3 percent of Spain's GDP comes from agriculture. Around the Mediterranean coast irrigated agriculture and associated industries represent 40 percent of employment (Global Water Intelligence, 2012). The Guadalquivir River Basin consists of large amount of olive crops, dating back to Roman times. It was until the mid 1970s a rain fed crop until implementation of irrigation and drip technology, resulting in a major intensification process (Berbel et al, 2013). Despite the enormous limitations of water, Spain is one of the countries with the lowest tariff on water. A sustainable water management is highly necessary, but it would require large investments. A limiting factor is the current economic crisis in Spain. Higher prices on water could result in severe consequences, especially for smaller farmers (Global Water Intelligence, 2012).

1.1 Aim of the research

The aim of the research is to investigate policy and management of water as a common pool resource in the area of the aquifer 'Carbonatado de la Loma de Úbeda'. The study will look at the policy applied in managing the issues from extensive irrigation practices, the role of European Union (EU) and solutions discussed for water improvements in the area. The area was chosen due to major challenges in water use and management and with large amount of irrigated agriculture, in particular olive groves.

1.2 Research questions

- What are the main issues of water management in the aquifer of 'la Loma' and what are the main actors involved in the management process?
- What are the policies implemented to regulate irrigation?
- What future alternatives are discussed with the intention to create a more sustainable use of water and to secure a continuous water supply?

1.3 Delimitations

A geographical delimitation was made since water management is an extensive topic and a global issue. Water management includes a range of different factors, such as environmental, social, economic and political. Different regions consist of different conditions. The paper will focus mainly on the political aspects. The research area was first narrowed down to investigate the water management in the Guadalquivir River Basin (GRB). An additional delimitation was made, due to considerations of the time limitation of the thesis and the large extent of the River Basin. In order to make the thesis feasible the thesis focus on the aquifer 'Carbonatado de la Loma de Úbeda', located in the province of Jaen. To contextualize the topic of water management it is essential to include a broader perspective that involves regional, national and global contexts. Jaen as a province within the region of Andalucía, involves restrictions and regulations on a regional and national level. Impacts of the EU are included, since it requires some regulations and restrictions for all member states. Interesting issues raised in this paper are the conflicts of interest affecting the water use, the management regimes, and the responsible authorities. Irrigation initiated in the area of 'la Loma' in the early 90's and therefore focus will mainly be put from this period forward.

1.4 Relation to previous research

The topic of water management is already presented in a large amount of studies. Issues such as water scarcity, common-pool resources, integration and adaptation are highly debated around the world, particularly in the areas with dry and hot climate. Studies and reports regarding the GRB and the aquifer of 'la Loma' have been produced. There is lot of information available covering the issues of water management, the responsible authorities managing the water resource, and about the conflicts of interest affecting the water management. The conflicts of interest and the lack of monitoring and control of the water resource are some of the main political issues in the area. The political issues in 'la Loma' is one of the reasons making the area interesting to study. More attention and investigation are required, being one of the reasons why the area was chosen as a topic of this thesis.

1.5 Definition of water scarcity

Water insecurity refers to individuals lacking access to safe water in the daily life, such as water for drinking, food and washing (Rijsberman, 2005). Water scarcity refers to an area consisting of a larger amount of people suffering from water insecurity during a longer time period. A definition of water scarcity that is commonly accepted does not exist. The qualification for an area being water scarce depends on different factors. These include, 1) definition of the actual needs of the population and considerations regarding the environmental needs, 2) the actual, or possibly, available resource, for the needs to be satisfied, and 3) definition of scarcity through temporal and spatial scales (Rijsberman, 2005). Water scarcity needs to be understood, since it influences the decisions of policy makers and users in how to address the water crisis and the implementation of policies most suitable. Water scarcity is often referred to as a correlation of the available resource and human population, as for example water availability per capita per year. This is used as a measurement of scarcity by looking at the availability of water per person in comparison to the amount of water needed to fulfill each person's need (Rijsberman, 2005).

One of the more commonly measures of water scarcity is the Falkenmark index, also referred to as the “water stress index”. Falkenmark et al (1989) suggests that the threshold for renewable water resources/capita/year is 1700 m^3. The estimation covers the requirements of water use for the household, the environmental needs, and the agricultural, energy, and industrial sectors. Areas below these estimations are defined as being water stressed. Water scarcity is reached in the areas with less than 1000 m^3, and absolute scarcity in areas with less than 500 m^3. This indicator has two main advantages, 1) the easy availability of the data, and 2) its significance is intuitive and easily comprehensive. The indicator also involves limitations, 1) on smaller scales significant scarcity can be hidden by the national annual averages, 2) the available infrastructure modifying the access of water to the users are not considered, and 3) significant variations in demand, as a result of climate, lifestyle, etc, between countries are not taken into account. Raskin et al. (1997) used water withdrawals instead of water demand, resulting in a “Water Resources Vulnerability Index”. The index defines scarcity as the total withdrawal per year, including the water extracted for human needs from groundwater aquifers, rivers, and streams. Water scarcity is defined as the withdrawal on an annual basis reaching 20-40 percent of the total supply and more than 40 percent defines severe water scarcity (Rijsberman, 2005). Seckler et al (1998) performed an analyze regarding the future adaptive capacity. It involved mainly the development of infrastructure and an increase of more efficient irrigation practices by improvement of policies within water management during 2000-2025. The nations not reaching the estimated water demands until 2025, despite after applying the future adaptive capacity are referred to be “physically water scarce”. The nations not lacking the water resource, but with the need of major investments to implement water infrastructure to make the resource accessible for the population, are referred to be “economically water scarce”. Analyses demonstrate that about two-thirds of the world's population will during the coming decades suffer from water scarcity, in particular with a continuous growing population. This will result in a reduction of accessible water per capita. Yang et al. (2003), emphasize that the domestic use of water will not be affected by scarcity, rather the water for food production will become scarce.

Water scarcity at the river basin scale

Whether regions or individuals are water scarce or not is difficult to secure through global analysis. The river basins are continuously being adopted and seen as the appropriate scale to understand the key elements for expanded water scarcity. This since human impacts results in “basin closure” (see chapter 4.4 for more information of basin closure) (Rijsberman, 2005). Keller et al (1998) explain the development of water scarcity within a river basin and use a linear three-stage evolution: 1) infrastructure is used to increase the supply, 2) the strive for more efficient use and conservation of water, and 3) a shift to re-distribution of the resource between users. The renewable water resource is defined as the runoff in rivers and streams, and recharge of the aquifers annually; this can be defined as “blue water”. About 60 percent of the annual precipitation is left out within this definition, which is being infiltrated in the soil, it turns into soil moisture and later evapotranspiration before entering the groundwater and rivers. The soil water can be defined as “green water”, which together with the “blue water” complete the hydrological cycle. This water is for the most part insignificant for human use, since it cannot be used for additional purposes. Though, for agriculture and the environment it has a significant importance, providing a high value resource to the rain fed agriculture and ecosystems. An analysis focusing on agriculture and water scarcity cannot solely focus on the renewable water. It has to involve all sectors using water and the interactions between these. Another important aspect is the reservoirs of soil moisture, the role of the soil, and the interaction of soil-water (Rijsberman, 2005).

Construction of dams has been the engineering response to address water scarcity, to control the resource by humans and augment the total renewable resource for human purposes. The benefits are the provision of water supply, sanitation, and a valuable resource in the production of cheap food. The disadvantages are that sanitation is not available to about half of the world's population, water for production use does not exists in several of the poor rural areas, the level of groundwater is being reduced with a rapid pace in some of the main aquifers, and several rivers does not reach the sea. These issues have resulted in request in a change from supply management to demand management. The shift is aiming at an “integrated water resources management”. Some of the proposals are 1) an increased involvement of users in the water management, as for example water user associations, 2) pricing of water and/or water as a tradable good, and 3) establishment of river basin authorities, as the single responsible authority for the river basin (Rijsberman, 2005).

1.6 Thesis outline

Chapter 1 introduces the topic of water management and the water situation in Spain. Further on the aim of the research and research questions are provided, as well as delimitations, relation to previous research and finally a definition of water scarcity.

Chapter 2 presents the methodology. It contains the literature study, the semi-structured interviews and the limitations of the methodology.

Chapter 3 provides the theoretical framework of the thesis. Chapter 3 is divided into four different parts. First, the concept of a common-pool resource. Second, Integrated Water Resource Management. Third, the concept of political ecology. Fourth, the concept of adaptation.

Chapter 4 includes a description of the Guadalquivir River Basin in general and reflects upon the expanded irrigation within the basin.

Chapter 5 describes the political situation in Spain in terms of water management at different political levels.

Chapter 6 provides a general background section of the aquifer of 'la Loma'.

Chapter 7 involves the primary data gathered from the semi-structured interviews.

Chapter 8 includes the analysis and discussion from the data obtained in chapter 7 and connections with the literature study mainly in chapter 3, but also reflections from chapter 4, 5, and 6.

Chapter 9 provides the conclusions of the thesis based on the gathered information from the primary and secondary data, and the analysis.

2 Methodology

This section involves the research methodology. The research which is a case study used different data collection methods to gather the information, being a combination of interviews, book publications and academic journals.

Research design

The thesis is partly based upon a case study of the aquifer ‘Carbonatado de la Loma de Úbeda’, located in the Guadalquivir River Basin (GRB) in southern Spain, investigating the management of water in the area. Silverman (2010) refers to a case study as being a more detailed investigation conducted within a specific area. The main aim of conducting a case study is to create an understanding of the investigated area. A case study is based on being descriptive, though clear boundaries within the particular study are essential in order for the thesis to be feasible (Silverman, 2010). The boundaries within the thesis focus on the aquifer in the specific area. An additional boundary is the focus of the political aspects of water management. The case study will be contextualized with support from previous literature to create a broader understanding of the water situation and the issues of management in Spain and the area of ´la Loma´.

The study involves a qualitative method to obtain information regarding the water management in the selected area. According to Silverman (2001) the use of qualitative methods contributes to a deeper understanding of social phenomenon. This is of particular interest, since the thesis aim to be interpretative and understandable. Performing research based on qualitative methods intends to involve experiences, both personal and subjective. Whereas quantitative methods are defined as being deficient in the essential dimension of social reality, reality is unexpected and with continuous variations, generated by the changes of social interaction (Sullivan, 2001).

Primary data

The primary data was obtained through semi-structured interviews (see Appendix I and II for a list of interview questions). Depending on the respondent's answers questions were added. The interviews appeared more as a conversation rather than interrogation. The interviewees feel more free to respond with their opinions and what they believe is important to mention (Valentine, 2005). Interviews were preferable for this research. This since an interview according to Valentine (2005) can provide a deeper understanding than a questionnaire, since it is more unstructured. An interview can be customized, depending on experiences and interests. The conversation can be turned in different directions and the content is more detailed and multi-layered. This because it is possible to ask questions that encourages interviewees to speak freely. Different actors can have different views and opinions regarding the water situation and its management. Therefore it was of interest to have interviewees from different units. Valentine (2005) emphasizes snowballing as an important interview method, since one contact can introduce the interviewer to another contact that can hold essential knowledge regarding the subject matter. Through snowballing the respondent obtain certain information about the researcher by the previous contact, which could facilitate the creation of trust. The method is also beneficial since it can create a larger network of providers of information, interviewees and a larger quantity and diversity of results. As a researcher it is necessary to be cautious for misunderstanding that could interfere with the research and cause obstacles for the feasibility of the research (Valentine, 2005). Interviews provide a genuine comprehension of people's experiences and are both people-oriented and sensitive. Within these terms the interviewees are allowed to explain and describe their personal experiences with own words. The technique of using semi-structured interviews to gain primary data for the thesis has been the right choice, since it provided information through more open conversations where opinions and personal experiences could be included. Despite existence of previous research both on water management in Spain and the situation in ´la Loma´; the water situation in the area of ’la Loma’ is not sufficiently highlighted. Thus while information and reports regarding ‘la Loma’ can be found, the interviewees and the reports provided by each of them has been essential for this thesis.

The interviews were used to broaden the knowledge of the management and current situation in the aquifer, the impacts of irrigation and future aspects towards a more sustainable use. The governmental authorities, such as the Basin Authority and the regional government - Junta de Andalucía, were contacted by e-mail while in Sweden for the respondents to have time to answer and confirm a day for the interview. Once in Spain the e-mails were followed by phone calls. An additional e-mail was requested by the authority to delegate to the person most suited. Due to extreme flooding in the Guadalquivir River the interviews were delayed. During this period an additional delimitation of the research area was made to be able to make the study more focused, since the entire GRB would be too broad. The aquifer 'Carbonatado de la Loma de Úbeda' (further on referred to as 'la Loma') was chosen, with recommendations from researchers at the University of Córdoba. The responsible Association for the users in 'la Loma' was contacted by e-mail. This was followed by two trips to the province of Jaen. The first destination was to the village Villacarrillo, where the Association is located. An interview was conducted with the Executive Secretary, whom introduced to the second interviewee, a farmer and agricultural engineer. The second trip was made to the capital of Jaen, where a meeting was scheduled with two interviewees. The first interview was with the lawyer representing the Association. The second one was with the secretary of the Association and employee in Asaja, an agrarian organization in Jaen. While in Jaen additional persons were introduced to gain more knowledge. One being an employee of the Basin Authority of Jaen and were contacted while in Jaen. Three other persons were recommended. One was the president of the Association, who was contacted and interviewed by telephone at a later stage. The other two are part of the Governing Board of the Association and also engineers and farmers, and were contacted and interviewed by e-mail. The respondents were informed about the reason for the interview, the aim of the research and how it will be used later on. The interviewees were guaranteed anonymity. Despite the amount of interviewees being quite few, a major amount of information was received from the conducted interviews. The obtained information helped a lot to understand the situation in ‘la Loma’ and the issues of water management. The structure of the interview questions were divided into different sections. The aim was to gain knowledge of the past situation in the area, the implemented constitution as well as changes made during the years, the present situation, future aspects and solutions discussed to improve the current situation. To ensure that all necessary fields and important aspects were covered during the interviews main questions were prepared. Depending on the interviewee's position related sub-questions were prepared for each interviewee. More concrete questions were asked for the interviews performed by e-mail, but with room to answer freely and with the possibility to involve different aspects. The Association was of particular interest, since being the active unit dealing with the management issues and the political conflicts in the aquifer.

All interviews were made in Spanish. Even with knowledge of the language, a different interpretation or misunderstanding of the answers cannot be excluded. All interviewees were very understandable of the potential lack of language and attempted to speak more slowly and clarified certain information additionally that was not well understood. The literature review on both policies and background of the area facilitated the understanding of the information provided by the interviewees and helped to ask further questions. My own background and experiences did not have a large influence on the data collection per se. Despite opinions on certain things an objective view was conducted when analyzing the collected data, in order not to angle the information in a subjective way. The respondents were kept anonymous based on ethical reasons.

Secondary data

The secondary data consists of a literature review to contextualize and create a broader knowledge of the field of study. The importance of the literature study is, together with the semi-structures interviews, to contribute towards an interpretative departure point. The study aims to have a more explanatory approach to render the impacts of the quantity and quality of the water caused by the agricultural sector and the extensive use of water for irrigation. The literature used consisted mainly of book publications, academic journals and government reports. They were used to gain a more profound knowledge of policy and management on EU, national, regional and local level. The information gained was used to prepare interview questions. This helped to understand what has been done on different governmental levels, the actual situation at present and the existing issues within water use and management in the river basin as a whole as well as the particular case of 'la Loma'.

Methodological limits

As mentioned above, one of the interviews was conducted by telephone and two of the interviews by e-mail. The reason was that the interviewees were not accessible during the two trips to Jaen. It could have been preferable with a personal interview, since it could be more difficult to communicate on the telephone and e-mail with a lot of detailed information. Though, since the interview was performed after both of the trips to Jaen, it facilitated the interview on the telephone and was an opportunity to follow up information lacking or needed to be clarified from the other interviews. Interviews by e-mail could result in excluded information, since written answers could result in shorter answers or difficulty to describe opinions and experiences in the same matter as during a personal interview. However, both the interviewees provided long answers and included personal thoughts and experiences. There is a possibility of slightly skewed answers, due to translation of the interviews. The interviews were made in Spanish and later translated to English, which could result in that the English translation becomes less precise or that certain expressions do not have the same meaning between the two languages. Major effort has been made for the translation to be as correct and clear as possible.

3 Theoretical framework

This section covers the theoretical concepts that later on will be used in the analyze. The major part of this section consists of the concept of a common pool resource. Further, three additional concepts are described, Integrated Water Resources Management, Political Ecology and Adaptation.

3.1 The concept of a common pool resource

In 1968 the ecologist Garrett Hardin introduced the term 'the tragedy of the commons', which has become a well known concept among scholars and policy-makers aiming to create a more effective control of the common-pool resources (CPR). Researches based on Hardin's article has demonstrated the existence of tragedies of the commons and observed that effective solutions are not easy to accomplish nor error-free (Ostrom et al, 1999). Hardin wanted to illustrate the overexploitation of natural resources that take place due to lack of ownership and that competition of resources creates conflicts. The solution he provided was privatization, since the resources could become more controlled (Söderqvist et al, 2004). Elinor Ostrom developed eight principles of governing the commons and disagrees of privatization as the only solution. Ostrom believes in effective governance of the commons as a solution (Earl and Potts, 2011). Below are the principles presented by Ostrom (1990).

1. *Clearly defined boundaries*: The boundaries of the resource system, and the individuals or households with rights to harvest resource units are clearly defined.
2. *Proportional equivalence between benefits and costs*: Rules specifying the amount of resource product that a user is allocated are related to local conditions and to rules requiring labor, materials and/or money input (most participants receive sufficiently large payoffs that they are willing to learn about better options). Participants with larger stakes have interests broadly congruent with increased productivity for the system.
3. Collective *choice arrangements*: Many of the individuals affected by harvesting and protection rules are included in the group who can modify these rules.
4. *Monitoring*: Monitors who actively audit biophysical conditions and user behavior, are at least partially accountable to the users and/or the users themselves.
5. *Graduated sanctions*: Users who violate rules are likely to receive graduated sanctions (depending on the seriousness and context of the events) from other users, officials accountable to these users, or from both.
6. *Conflict resolution mechanisms*: Users and their officials have rapid access to low-cost local arenas to resolve conflicts among users or between users and officials.
7. *Minimal recognition of rights*
    a. Resource users have long-term tenure rights to the resource.
    b. The rights of users to devise their own institutions are not challenged by external government authorities. (The political environment encourages autonomy but also provides oversight regarding corruption, accountability, and conflict resolution).
8. *Nested enterprises*: Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organized in multiple layers of nested enterprises.

Water is a CPR, in which humans strongly rely on. Accuracy of flows and stocks of CPRs are difficult to define. This creates one of the major challenges to govern CPRs, one of the reasons being the difference of geographic scales. Another issue is that negative externalities often arise in the use of CPRs and more often involves those not gaining benefits from the use. Several regimes have already been a part of governing the majority of the traditional CPRs, some more successful than others. Several policymakers have chosen between two alternative solutions to manage the "tragedy of the commons", either privatization of the resources or to be governed by national government. In order to manage CPR and avoid over-use, either external authorities or the users has to regulate it by rules. This requires large collective action from the users. Scholars from multiple disciplines need to collaborate to create less confusion regarding the term CPR. An analytical approach to the topic and a technical vocabulary would be a first step. Two characteristics can describe a CPR. The first one is sub-tractability or rivalness, meaning that one individual's consumption can decrease the consumption of another individual. The second regards exclusion of accessing the resource for potential beneficiaries. In this sense, CPRs have similar issues as public goods, the temptation of free riding. This means not paying the cost of the resource while receiving the benefits from it (Dolsak & Ostrom, 2003).

A CPR can be governed by three broad forms of ownership; private, government or common-property. A broad variety of these exists, but there is no evidence which suits best for each resource. Privatization is one of the more recommended solutions. Common property regime could also be a kind of privatization. One of the challenges is to create an institutional design that reaches for both sustainability and efficiency. Institutional designs for managing resources needs to be customized depending on the location of the region, but management of resources includes complexities (Dolsak & Ostrom, 2003). Ostrom argues that institutions on a small-scale community level could be more efficient in achieving sustainable development in comparison to a centralized government. This does not mean exclusion of large-scale institutions, since they have high importance in certain aspects, such as facilities of education and extension, provider of reliable information, low-cost conflict resolution mechanisms, protection of the rights of citizens, assistance after natural disasters, etc. Arrangement on a higher level are necessary to manage complex systems with multiple actors involved, policies, organizations and statutory framework (Ross and Martinez-Santos, N/D). Simple theoretical models have been formed by scholars to analyze the resource issues and create solutions that are universal. Theoretical predictions propose that lack of property systems has resulted in destruction of natural resources and that policies has reached a one-size-fits-all. Users could tend to overlook the need for management of a resource in the future if it already is at an exhausted stage. Investments from users in self-organization are usually applied when scarcity already can be observed. Easter Island is one example of destruction of resources and lack of understanding of the carrying capacity (Ostrom, 2009).

Ostrom et al (1999) discusses some of the more difficult challenges regarding resource management on a large-scale and the importance of international cooperation, as for example fresh water on an international basin scale. Biological diversity is agreed to be highly important for the human long-term survival. Though, institutional diversity could be of the same importance. It is argued that external authorities have to enforce solutions for the users. Despite tragedies, the management of CPRs has been self-organized for thousands of years. Sustainable, long-term institutions have been designed by users to improve governance of the resources. Ostrom et al (1999) argues for the existence of solutions beyond the solution proposed by Hardin. The authors discuss that failure can occur within both privatization and government ownership. The authors give an example from northern China, Mongolia and southern Siberia regarding grassland degradation and the difference between central government management and the traditional, self-organized group-property regime. The degradation in Mongolia was a lot less in comparison to the Russian part. The differences was that Mongolia included institutions of traditional group-property, involving large-scale movements among seasonal pastures, while Russia and China both were under the central government, involving permanent settlements (Ostrom et al, 1999). A successful management, both within theory and practice, includes management of resources by groups on a small to a relatively large level situated in a single country, involving nested institutions at different scales. Management of resources, as for example fresh water in an international basin or large marine ecosystems, are depending on that international, national, regional and local institutions are cooperating, since these resources become effectively depleted in an international context. Certain resources can be difficult to measure or require advanced technology to be measured, as for example petroleum reserves and stocks of ocean fishes. Other issues can with human impacts be more self healing, as for example the global climate, though the resilience of the system has its limitations. The amount of issues of the commons will increase at both regional and local scales, requiring an increase of effective approaches on a global scale. Global commons can result in additional new issues, as a result of high complexity and extreme size. To increase the understanding of the complexities of CPRs, a separation of concepts has to be made between those concerning resource systems and those involving property rights (Ostrom et al, 1999). Ostrom et al (1999) refer to resource systems by using the term CPR, independent of the property right.

The two characteristics of CPRs mentioned above, the difficulty of exclusion and sub-tractability, create certain dilemmas. Users striving for the individual short-term interest create outcomes not included in the long-term interest for anyone. Free-riding can occur in two forms: 1) overuse of the resource and absence of consequences for others, and 2) absence of resources contributing the CPR to be preserved and improved. CPRs are seen as both renewable and non-renewable resources. These resources can involve components of the earth system, as for example groundwater basins, and products created by humans, as for example irrigation systems. The development of an effective governance regime is affected by the characteristics of CPRs. These characteristics involves the resource systems' size and carrying capacity; the quantifiability of the resource; the availability of the resource flows both in temporal and spatial terms; the storage quantity in the system; if resources are moving (as for example water) or are stationary (as for example trees); the ability of regeneration; and how structure of regeneration is affected by different harvesting technologies. The available irrigation water with lack of storage capacity is a lot more difficult to assess than estimation of the amount and size of trees in the forest. Monitoring and identification of resources can be improved by technology and help in making decisions, but it cannot be seen as a substitute for the decision making (Ostrom et al, 1999).

Two elements need to be included to solve the issues of CPRs, 1) a restricted access, and 2) to create incentives in order for the users to make investments in the resource and not overexploiting it. Solely a restricted access does not solve the issues in the case where users are competing for the access. The lack of regulations or incentives results in overexploitation. The CPRs are divided into four major types of property rights (see table 1 below).

Property rights	**Characteristics**
Open access	Absence of enforced property rights
Group property	Resource rights held by a group of users who can exclude others
Individual property	Resource rights held by individuals (or firms) who can exclude others
Government property	Resource rights held by a government that can regulate or subsidize use

Table 1. Types of property rights systems used to regulate common-pool resources. Source: Ostrom et al, 1999

An open-access regime generally results in overexploitation and possibly destruction of the resource. Regimes involving group-property or individual-property include individuals with rights to access and use the resource. The government property is controlled on a national and regional level or by local public agency, and can either allow or forbid individuals to use the resource. It has been demonstrated by empirical studies that efficiency, fairness and sustainability is not reached by one single property regime for all CPRs. CPRs can be governed successfully with designed principles and strong institutions (Ostrom et al 1999).

Users of a CPR can be divided into four groups, 1) individuals always acting in a selfish manner and never participate in solving the situation, referred to as free-riders, 2) individuals not cooperating if unsure to pay the cost of the free-riders, 3) individuals taking initiatives to cooperate with hope that others will return something back, and 4) individuals always giving more to achieve a better situation. Groups being able to identify one and another have higher possibilities to create trust and implement norms reducing the use of the resources in comparison to a group of strangers. Though, the prevention of over-use is not always assured by development of norms. Rules developed by external authorities or participants are highly necessary to create limitations of who can access the resource, defining the amount allowed and when it is allowed to use the resource, develop and finance monitoring arrangements, and implement sanctions. Resources providing the users with valuable products generate a larger amount of benefits. Independence of the users is necessary in order for their own rules to be developed and enforced. The long-term sustainability of the resource also needs to be highly valued by the users. Development of effective rules dealing with the resources' complex interactions and dynamics and at the same time being effective, legitimate and fair to users can be highly difficult. Despite the high difficulty of designing optimal rules within systems of high complexity, users have during a long time developed their own rules to sustain resources. In order for users to see the actual benefits, the stage of the resource cannot have reached the level where it is useless. When users possess more precise knowledge regarding the external boundaries, the internal microenvironments, and when the resource conditions constitute of dependable and legitimate indicators the achievements of benefits are facilitated (Ostrom et al, 1999).

The affects of different management regimes, regarding costs and benefits in the long-term perspective are easier to evaluate with a more predictable resource flow. Trust between users can result in monitoring and sanctioning at low cost. Local self-organization can both be hindered and helped by national governments. National governments can help in terms of organizing meetings, identification of potential solutions and issues at stake by providing information, and legitimize agreements provided by the local users as well as enforce them. National governments could hinder local self organization through a defense of rights resulting in overexploitation of the resource or retain the state as the unit of control of the resource without monitoring and enforcing substantial regulations. The adoption of effective rules by the users is more probable in marco-regimes, since the efforts of the users are eased and the central authorities are not seen as the only decision maker. Local authorities not recognized by higher level authorities create more difficulties for enforceable rules to be established by users. A better management could be encouraged with increasing prices of the resource. Lower prices create a reduction of organization and the guarantee of available resources in the future. Lessons can be learned from the past, though new challenges are occurring and require global institutions to manage the issues of CPRs (Ostrom et al, 1999).

3.2 Integrated Water Resource Management

Integrated Water Resources Management (IWRM) was defined in 1977 during the first global water conference in Mar del Plata. Though, the concept was not implemented until after the conference in Rio 1992, the World Summit on Sustainable Development. The definition of IWRM by the Global Water Partnerships is as follows: "*IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*" (United Nations Department for Economic and Social Affairs, N/D). The World Bank introduced the term good governance in 1989 and the term has since then grown on the development agenda. There are disagreements regarding the effects of the term, the meaning of it and the causes. Multiple definitions are causing conflicting criteria for the countries involved, which could affect the economic and social development. The World Bank created four criteria for good governance; '*an efficient public service, an accountable administration, a reliable judicial system, and a balance between the government and the governed*' (Van DoeVeren, 2011:304). There were fundamental disagreement with these criteria's, resulting in six new definitions; participation, decency, fairness, accountability, transparency, and efficiency. The criteria of good governance have continued to change, both over time and between countries. The issues that arise are uncertainty of what requirement to fulfill. The EU is able to implement new criteria's and vary it between the member states (Van DoeVeren, 2011). Tools to implement the central criteria are legal framework, public sector management and strategic vision (Allan and Alistair, 2010).

Freshwater and marine systems provide socio-economic benefits, which require integrated, adaptive and ecosystem-based approaches through effective governance to be able to manage the resources. The components within IWRM are equity, efficiency and environment, all of which needs be integrated (United Nations Development Program, 2012). The development objectives for implementation of IWRM are demonstrated in figure 2.

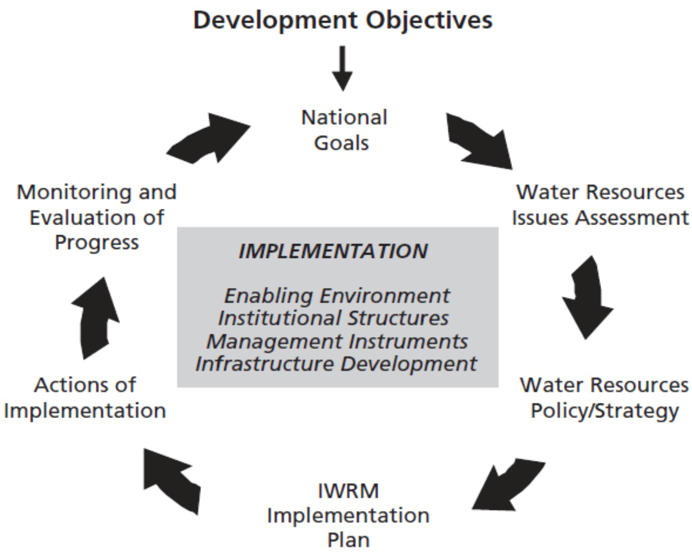

Figure 1. Development objectives of IWRM. Source: United Nations Department for Economic and Social Affairs, N/D

Measurements of governance in general has been developed, hence development of methodologies for governance with focus on water management, especially IWRM, has not been designed to the same degree. An understanding of good governance is required. The water crisis is often connected to the issue of lack of governance. If the global water crisis is applied to how the water is governed, locally, nationally and internationally, there are possibilities to address the water issue. The concept of governance has been defined as a lack of a functioning government (Allan and Alistair, 2010). In the 1980's new institutions and network scholars introduced a new definition of governance as "bringing the state back in". In the 1990's the definition of the term governance changed to include all the dynamic processes of political decision-making. A more strict definition is absent, giving scholar the freedom to choose to adopt as preferred (Van DoeVeren, 2011).

The strive towards a new paradigm of water management is one of the reasons behind the development of the concept of IWRM. The requirements as well as the options for water management are affected by pressure on the water resource by mainly socio-economic factors but also climate change, which is a factor being less controllable. The principles of IWRM are followed within the water management and major cross-section of sectors has adopted these principles, including decision-makers, water managers and politicians on a global level. The wide recognition of IWRM has among other been due to that irrigated agriculture has resulted in a production with high efficiency of food crops. The concept has helped decreasing health risks being water-related and preventing the risks of droughts and floods. Principles towards a more efficient and sustainable water management have been linked within a societal framework in association with sustainability of ecosystems, social equity and economic efficiency (Hassing et al, 2009).

Hassing et al (2009) present the main principles in IWRM (The Dublin principles):

- Freshwater is a resource both limited and vulnerable, vital for the maintenance of life, the environment and development.
- A participatory approach that includes all levels of policy makers, users and planners should create the base for the water development and its management.
- Women have a central role within the regulation, management and preservation of water.
- Water should be seen as an economic good, since it has an economic value within all sectors using it.

The principles above have helped to increase the understanding and been used as a guide for decision makers within the water resource management. The implementation of IWRM is dependent on implementing the 'three pillars' correctly (see figure 2), 1) the change towards a more sustainable development and management of water resources that includes more appropriate policies, legislation and strategies, 2) adopt the institutional framework to realize the implementation of policies, legislation and strategies, and 3) establish the management instruments that the institutions demand in order to accomplish their work (Hassing et al, 2009).

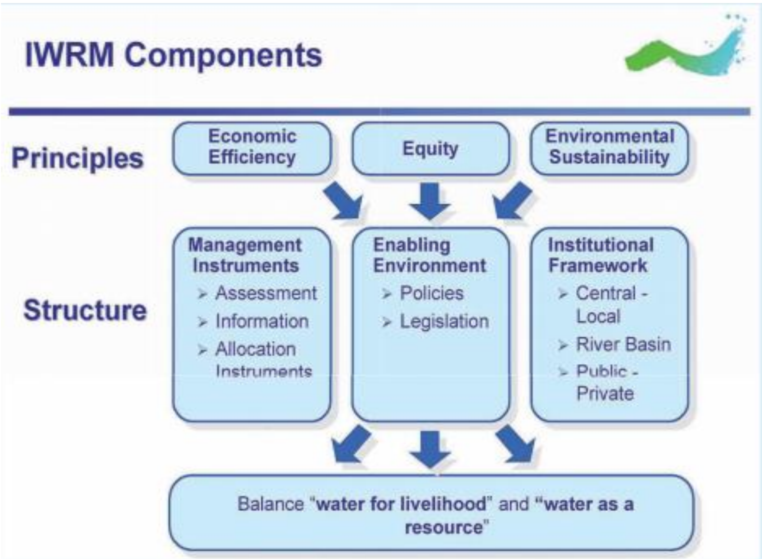

Figure 2. IWRM Components. Source: Hassing et al, 2009.

IWRM constitute more of suggestions based on common-sense regarding essential aspects for water management and is not a scientific theory. IWRM approach is flexible in the adaptation of different contexts, both on a local and national level. Appropriate reforms, institutional arrangements, management tools, etc, can differ within different political, social, cultural, environmental and economic aspects. Policy-makers are responsible to make the judgments for each context. A common language has been developed with the IWRM approach, being one of its major strengths, and can be applied on different local, regional and national levels. This creates exchanges of knowledge across regions and borders, facilitating the agreement between managers and decision-makers regarding monitoring of policies and the goals towards a more sustainable water management.

The application of IWRM also involves challenges. One of the challenges involves the actual integration and to what point it can be reached. The challenges occur due to that water management involves several institutions and that several sectors are using water. Therefore decisions have to be integrated and all aspects involved considered. Priorities have to be stated by the decision makers/managers in order to involve all essential aspects, as for example a management plan or water resource development process. Another important aspect is the consideration of other sectors priorities and requirements. This could be done by integrating water in the national economy. IWRM includes a long process that could involve many decades before reaching its final aim. IWRM needs to cooperate with the national governance structures to be successful on a national level as well as comprising an approach striving for a more formal water sector. On a local level, communities decide upon actions and initiatives to be made, whereas water resource management is still guided by the principles of IWRM. In general, a change of water laws signify an indirect change of power balance, in terms of water among diverse interest groups. The level of water scarcity, both on a quantitative or qualitative level, affects the amount of centralized influence of the water management. A resource tends to increase in value when it is scarce, in comparison to a resource rich in both quality and quantity. This results in less value if any. Regulation on the amount used has to be developed by the society and assure that the resource is used where it is most beneficial and not used on low-value uses. Small-scale use is dependent on local ownership and initiatives, whereas large-scale use is regulated on a central level. Independent on the level of regulation, the outcome of IWRM is dependent on the involvement of interest groups and water users. Dialogues on national, local and basin level between cross-sectoral and multi-stakeholders are dependent on active NGO's or other civil society organizations (Hassing et al, 2009).

3.3 Political Ecology

Political ecology is seen as an interdisciplinary approach used to increase the understanding to deal with the dynamic interactions between the human-environment relations, and the interactions of global environmental change. It integrates the perspectives of ecology and political economy. The term is used to link several different scales at different levels, such as ecosystems, geopolitical, temporal and spatial. The assumptions is based on that ecological issues are a result of social and political issues (Neumann, 2009). The different dimensions are used to create more balance and integration. The field of political ecology has been given more attention due to the understanding that policies and environmental issues are affected by the scales of ecological and social processes (Zimmerer and Bassett, 2003). Zimmerer and Basset (2003) argue that the development of human-environmental dynamics is shaped by nature and biophysical processes. The interdisciplinary field of political ecology is a rather new development. At first, the development emerged by uniting cultural ecology with political economy. In the 1950s and 1960s cultural ecology's main interest was to implement the theoretical constructs of biological ecology into the research area of nature-society relations, in particular the ecosystem concept. One of the main assumptions was that equilibrium and homeostasis characterize ecosystems (Neumann, 2009). The term 'political ecology' involves relationships of high complexity, requiring an approach able to extend interactive effects. It needs to participate in hierarchies of socioeconomic organizations as well as diverse geographical scales (Blaikie and Brookfield, 1987).

Land Degradation and Society (1987) by the two geographers Piers Blaikie and Harold Brookfield, was one of the primary works on political ecology, emerging from criticism of risk, hazard, and vulnerability studies (Stonich and Mandell, 2006). Blaikie and Brookfield (1987) defined political ecology as a combination of the concerns within ecology and broadly defined political economy.

The authors used marginalization as a key element in the formulation of political ecology. Three different conceptualizations of marginality were defined. First, the neo-classical idea was integrated regarding economic margin in which the cost of adding lower land to the production. Second, from the ecological point the authors integrated the biophysical restrictions into the geographic range of exceptional species. Third, from the political economic point the authors integrated the concept that within the economic development, particular social groups and whole regions are commonly prevented from participating in employment opportunities, sufficient health and housing services, social advancement, and political involvement. The authors argue that changes within one concept often change the status in the others, due to a relation between these. The term 'political ecology' includes a larger attention of issues facing the world and a commitment of integration of scientific research and practice. In order to create more collaboration between political ecologists and sustainability scientists, an initial start would be more studies that include risk, vulnerability, and resilience (Neumann, 2009).

Political ecology includes the importance of political geography, investigating in which terms local ecology influence politics within its structure and conduct. Another meaning of the term is applying the principles within ecology into the politics. This could be done in two ways, the first one being metaphorically, and the second one being that ecology is used as a foundation of political possibilities, but also on its restrictions (Neumann, 2009). The term has been used more commonly with the reference to environmentalism as a political movement, especially in terms of 'Green' parties in Europe. Political ecology has been defined by scholars as being a 'research agenda', an 'approach', and a 'perspective'. When studying the definition of political ecology further and dividing it into ecology plus political economy, the explanation of the relations between human-environment involves some central concepts and analytics. In particular, there is a focus on the state and the market and their roles and interactions, as well as the influences on environmental outcomes. Research on political ecology has been integrated with historical analysis. Within the approaches to political ecology, ethnography has been essential due to it’s emphasize on the varying, at times conflicting, aspects of the environment and its problems facing different actors on all levels (Neumann, 2009).

Neumann (2009) use an approach defined as regional political ecology. The adjective 'regional' involves high importance due to the essential consideration of environmental variability and the spatial differences regarding resilience and sensitivity of the land. This due to that the land is exposed by diverse demands over time. Blaikie and Brookfield (1987) acknowledge that the state has a role concerning political economy. Dominant groups and classes are generally loaned the power of the state and the tendency for accumulation could be enhanced by the dominant group’s marginalization of the losers (Blaikie and Brookfield, 1987). This can be done using different methods such as, food policy, taxation, land tenure policy and allocation of resources (Neumann, 2009). A second label for the approach of 'regional political' is the focus on temporal and spatial scales in the search for explanation and tracking the continuously changing society-nature dialectic. Blaikie and Brookfield (1987) referred to this aspect as 'chains of explanation'. The chain of explanation initiate with the individual 'land manager'. Further on, track both upward and outward the social relations of production on the local, national and global scale. The social relations of production are enclosed within certain systems of property rights. It involves for example labor, control of land, inputs, the authority of decision-making regarding investments of land improvements, etc. Environmental degradation needs to include explanations being tracked in time, since historic decisions and events could be one of the ultimate causations. According to the authors it is essential to move backward in time to understand the modern conditions and its antecedents (Blaikie and Brookfield, 1987).

3.4 Adaptation

Human activities have become connected on a global scale. These have become more intensified by the use of new technology, capital markets and governance systems. Decision making has no longer borders. Decisions in one part of the world affect nations and people all around the world. The environmental capacity appears to have been decreased, in particular in the past century with an increasing pace. This has, within several regions, resulted in high vulnerability and where the alternatives for human livelihoods are being constrained (Folke et al, 2005). Folke et al (2005), question if the capacity of humans has been adapted regarding learning and prediction to handle new situations and new challenges. According to Pahl-Wostl (2007), more attention is needed towards regimes involving more adaptive management, considering the river basins characteristics regarding environmental, economic, technological, cultural and institutional aspects. In order to make the transformation a paradigm shift is necessary moving from a water management focusing on prediction and control towards a management with an approach of learning. The definition of the transformation to adaptive management is as follows: "*learning to manage by managing to learn*" (Pahl-Wostl, 2007). As the issue of sustainable water management continuously increase, it has become more obvious that the issues need to be approached with a more integrated perspective that includes environmental, technical and human aspects. The concept of adaptive management has been discussed on the agenda during some time. Adaptive management is based on the capacity of predicting key drivers affecting ecosystems, and that the behavior and responses of systems are limited. Adaptation has to be included in the management process and include the capacity of changing management practices depending on new experiences and insights. Adaptive management can be defined as a systematic process striving towards improvement of management policies and practices. The improvements can be learned from the results of the applied management strategies. Management programs can be seen as the tool to reach the highest efficiency of adaptive management. The programs can be formed to compare the policies and practices selected, and evaluate the alternatives for the particular managed system. One of the targets is the expansion of the adaptive capacity of the (water) system. Adaptive capacity can be seen as a systems potential or ability to adapt through changes within its behavior or characteristics, to deal with stresses at present or in the future (Pahl-Wostl, 2007). Folke et al (2002) define adaptive capacity as the potential of a socio-ecological system to deal with novelty and at the same time not losing alternatives in the future. To increase the adaptive capacity within water systems significant implementation of integrated system design is necessary. These could include new socio-technical systems, constructing social capital within an actor network or restoration of a multi-functional landscape. One main issue is to assure the entire system responding to the change and not responding to undesirable affects caused by the change. Full understanding needs to be available of a basin's adaptive capacity and its vulnerability (Pahl-Wostl, 2007).

An adaptive approach aims in its first step towards increasing the water system's capability to continue being effective despite major environmental variations. The formation of technical infrastructure does not completely aim at protecting the system from environmental variations. Socio-technical means are applied to permit preservation of the functionality of the water system, even during exposure of environmental variations. One example could be to construct demand management to decrease and/or shift the demand within certain uses in case of scarcity, rather than constructing larger reservoirs to sustain supply in the occurrence of drought. In the long-term perspective the adaptive management needs to aim towards changing the structure of the system, as for example changing to different types of crops, changes of life-styles or distribution of the amount of water within certain uses (Pahl-Wostl, 2007). Pahl-Wostl (2007) describe two key requirements for a system to increase the ability to adapt to changes or to be prepared for unknown changes in the future: 1) availability of new information to the system and this information has to be able to be processed by the system, and 2) based on processing the new information the system needs to have the ability to realize the changes.

Adaptive governance systems are commonly being self-organized, as for example social networks, discussing different systems of knowledge and experiences to create common policies and understanding. The development of "bridging organizations" appears to decrease the costs regarding collaboration and solving conflicts. Also, when legislation and governmental policies are enabled, self-organization can be supported (Folke et al, 2005). Governance is a commonly used term to define alternatives within the conventional top-down government control, involving partnerships, collaboration and networks. In general, adaptive governance of ecosystems includes polycentric institutional arrangements. These are nested quasi-autonomous units within decision making, functioning on multiple scales with the aim to create balance between decentralized and centralized control. Complex adaptive ecosystems need to be governed by adaptive managers being supported by flexible organizations. Leadership is an important factor to shape change and reorganization. This since it can provide adaptive governance with key functions, such as managing conflicts, creating trust, linkage of different actors, introduce partnership between different actor groups, providing knowledge, etc. Inertia within the social-ecological systems can be caused due to absence of leaders (Folke et al, 2005).

Resilience has major importance regarding adaptation and shaping change. These are two important components when discussing resilience within social-ecological systems. Resilience is defined as: "*the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks*" (Folke et al, 2005:443). Adaptive management is seen as an approach being more realistic and promising regarding complexity of ecosystems, in comparison to management dealing with optimal use and resource control (Folke et al, 2005). Four critical factors were identified by Folke et al (2005). These interact across scales, both spatial and temporal. The factors are essential when managing social-ecological dynamics affected by rapid change and reorganization:

- Learning to live with uncertainty and changes.
- Combining diverse types of knowledge in order to learn.
- Creating possibilities for self-organization in the strive for social-ecological resilience.
- Sustaining sources of resilience to reach renewal or reorganization.

According to Folke et al (2005) management should be based on bridging knowledge from the past, collected from different sources and by using new perspectives. Management of ecosystem resilience demands the capability of observing and interpreting important processes and variables within ecosystem dynamics to generate social capacity being able to handle the environmental feedback and changes. Turbulent changes are caused by management focusing on control and stability. The solution involves a larger understanding of the dynamics within the entire system and not searching for detailed knowledge that only includes parts of the system. Scientists are given a new role within the decision making process when dealing with complex adaptive systems and rapid changes. Scientists are no longer being objective and detached specialists. The new role consists of being one of the main actors within the process of learning, development of knowledge, and delivering knowledge to managers. Other important actors consist of local groups, possessing experiences regarding management of resources and ecosystems. Understanding has to be updated and adjusted on continuous basis. Each management action has to be seen as a possibility to increase the understanding of adapting to changes. Within adaptive management, policies can be seen as hypotheses and management actions as the experiment testing the hypotheses. An additional essential part is to focus on the ability of individuals to learn from their experiences to create knowledge and skills within institutions and organizations. The process of self-organization could develop into systems of adaptive co-management. The systems of "adaptive co-management" are flexible community based systems of resource management. These systems are customized to certain places and situations and can be found within different organizations at various levels (Folke et al, 2005). Adaptive co-management is defined by Folke et al (2002) as a process testing and revising institutional arrangements and ecological knowledge. The process is seen as self-organized, dynamic and ongoing of learning by doing. Adaptive co-management depends on collaboration between different stakeholders within all levels, from local networks to international bodies (Folke et al, 2002).

4 The Guadalquivir River Basin

This section includes a general description of the Guadalquivir River Basin, the expanded irrigation within the basin, its management issues and how the basin has reached the status of basin closure.

4.1 Description of the Guadalquivir River Basin

The Guadalquivir River is situated in the south of Spain. It is the longest river within the region with a length of about 650 km. The Guadalquivir River Basin (GRB) (see figure 3 for a map of the basin) is divided between four regions, Sevilla, Cordoba, Jaen and Granada. The drainage basin covers an area of 57,527 km^2 (Confederación Hidrográfica del Guadalquivir, 2010, Bhat and Blomqvist, 2004). 90,2 percent of the basin falls within the autonomous region of Andalucía (Montesinos et al, 2011, Bhat and Blomqvist, 2004), and 9,8 percent falls within the regions Castilla-La Mancha, Extremadura and Murcia (Bhat and Blomqvist, 2004).

The basin has a Mediterranean climate and an average annual temperature of 16.8ºC. Forestry covers the largest land area in the basin (49 %), the second largest being agriculture (47%), followed by wetlands (2%), and urban areas (2%) . The annual flow of groundwater is 2,576 Mm^3 and surface water 7,100 Mm^3. Of these annual flows, half are being extracted and divided between different sectors. 87 percent of this volume is used for agriculture (Berbel et al, 2012). The average natural resources per year are about 6,701 Mm^3. The average blue resources available are around 3,287 Mm^3/year, in which 71 percent is surface water, 19 percent groundwater and 10 percent base flow. 49 percent of the annually mean inflows are withdrawn and 35 percent is estimated as regulated surface water. The annual water withdrawal is constantly increasing mainly due to increasing use of agriculture and higher demand for irrigated land than available surface water (Montesinos et al, 2011). The agricultural sector is the main user of water in the GRB consuming 85 percent, followed by domestic use with 11 percent, industrial use with 3 percent and tourism with 1 percent usage. The general water consumption per capita is 950 m^3 (Berbel et al, 2009). Table 2 demonstrates the volume (hm^3) of water abstracted from different origins by the major water users within the basin. As presented irrigation uses 2876,8 hm^3 more than the urban and industry sector together.

Origin of water (2008)	Irrigation	Urban + industry	Total
Regulated rivers	2,165.5	358.9	2,524.4
Non-regulated rivers	347.0	0.0	347.0
Groundwater	830.0	136.8	966.8
Recycled	30.0	0.0	30.0
Total	3,372.5	495.7	3,868.2

Table 2. Volume (hm3) of water abstracted. Source: Confederación Hidrográfica del Guadalquivir, 2010.

In 2005 the water consumption in the basin reached 1600 m^3 per capita (Berbel et al, 2012). An increased pressure of water is expected in the future. By 2015 the consumption of the renewable flow is expected to exceed 50 percent. Additional impacts of climate change are expected to cause lower water yields and an increased demand for irrigation use. A reduction of mean hydraulic yields reaching around 12 percent within the GRB could be realized by 2030 in case of an increase of temperature of 1^{o}C and a decrease of precipitation of 5 percent. This is higher than the average on the Spanish national level of 8 percent (Berbel et al, 2009). Berbel et al (2009) discuss the importance of water-saving measures. This in particular in the region of southern Europe, critically facing water scarcity with the need to be handled by the Program of Measures (mentioned further in chapter 5.6). The reduced availability of water and the increasing demand of irrigation will increase the importance of water saving also at the EU level.

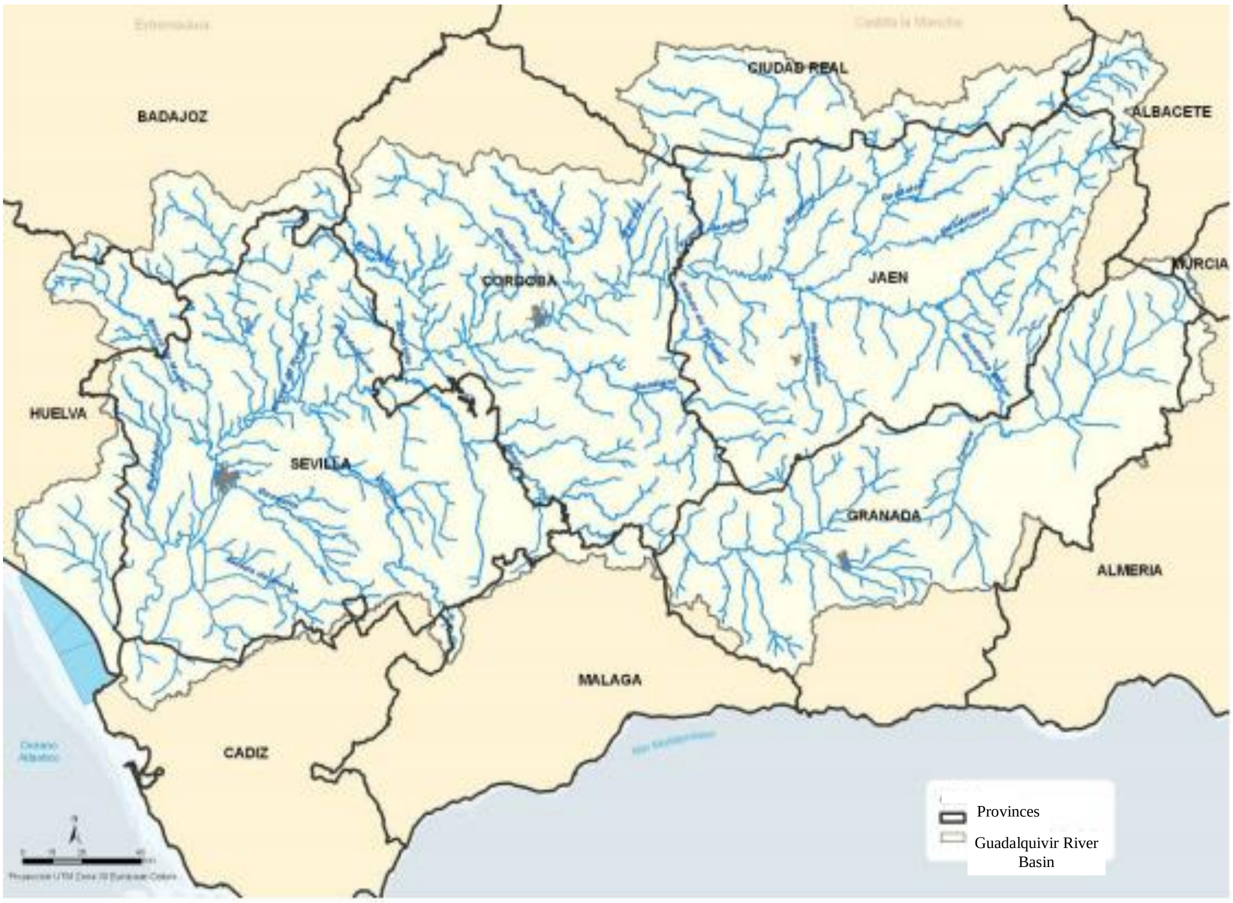

Figure 3. Territorial amplitude of the Guadalquivir River Basin. Source: Confederación Hidrográfica del Guadalquivir 2010, *Plan Hidrológico del Guadalquivir 2009-2015*

4.2 Irrigation within the Guadalquivir River Basin

The GRB is one of the more important basins in Spain, since it constitute 25 percent of the irrigated land in Spain and is the largest river in the southern region (Berbel et al, 2012). Andalucía consists of approximately 900,000 ha of irrigated area (Camacho, 2005), while the GRB consists of 700,000 ha, covering 80 percent of the total irrigated area in Andalucía (Montesinos et al, 2011). The irrigated area is responsible for 60 percent of the agricultural production and provides employment of 55 percent. Irrigation in Spain represents 2 percent of the country's GDP and 4 percent of employment. Modernization and improvements for irrigation within the entire Andalucía includes more than 400,000 ha (Camacho, 2005). Table 3 presents the amount of irrigated area and consumption divided between different water origins in the Guadalquivir River in 2008.

Water source	Ha	hm^3	m^3/ha
Regulated surface	372,412	2,148	5,666
Non-regulated surface	152,398	574	4,118
Groundwater	308,455	726	2,575
Recycled	11,402	36	3,157
Total	845,000	3,568	4,222

Table 3. The amount of irrigated area and consumption in the Guadalquivir River during 2008.
Source: Confederación Hidrográfica del Guadalquivir, 2010

The expansion of irrigation has resulted in positive economic and social effects within several rural economies. Spain is facing, due to the high dependency of agriculture, a competitive situation of water for food vs. water for ecosystems vs. water for urban use. Until present, 'water for ecosystems' has been ranked as the lowest, resulting in severe effects on ecosystems. Over-use of water for irrigation has shaped the surrounding environment and caused unwanted environmental impacts, as for example degradation of aquatic ecosystems and water quality issues (Varela-Ortega, 2008).

The most widespread crop throughout the basin is olive trees. It extends the irrigated area with more than 45 percent and has major importance for the agricultural production in the region (Montesinos et al, 2011). Figure 4 present the distribution of dominating crops, where the green area in the map represents the olive crops. The irrigation of the crops originates from surface water (66 %), groundwater (32,5 %) and recycled wastewater (1,5 %). Drip irrigation is one of the reasons for the increase of irrigated olive crops in the past decade. This due to that new irrigation technology has created water saving and made it economically feasible. Of the total irrigated land, drip irrigation covers 47 percent, surface irrigation 38 percent and sprinkler irrigation constitute 15 percent. However, these methods and systems are not sufficient to respond to the increasing demand of irrigation (Montesinos et al, 2011).

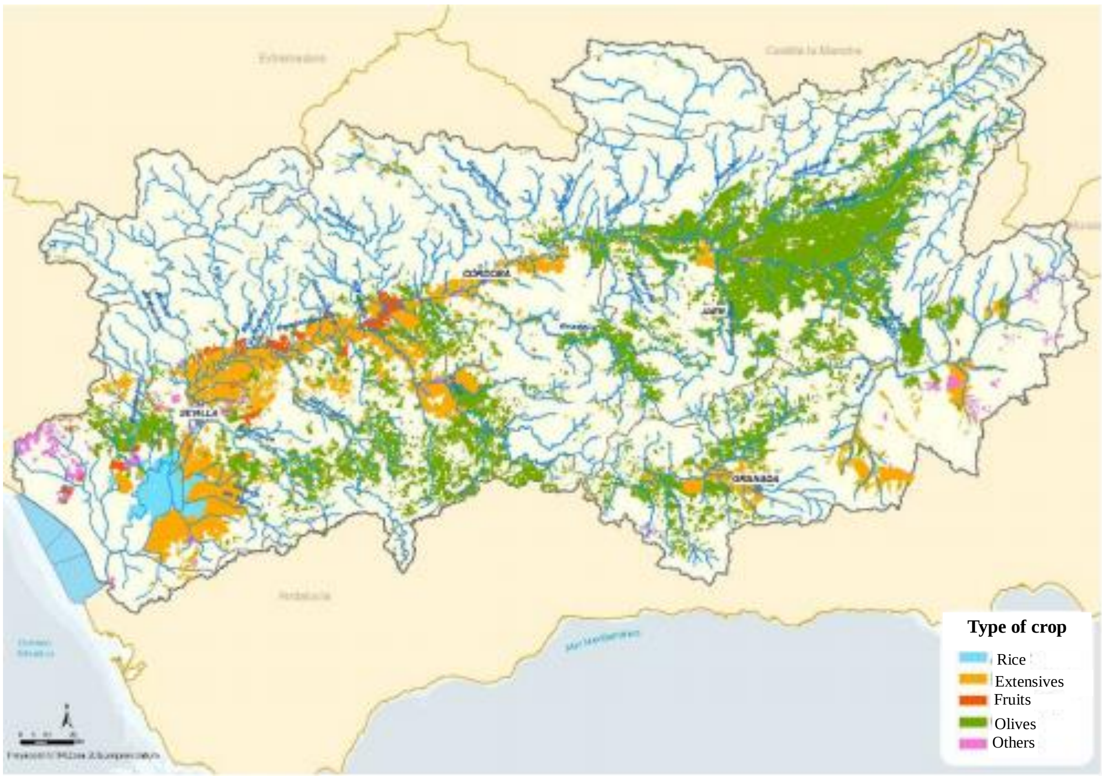

Figure 4. Distribution of dominating crops. Source: Confederación Hidrográfica del Guadalquivir, 2010

According to Garrido and Iglesias (2008), the decision of farmers regarding irrigation use depends in major terms upon the profitability of the activity, determined by the market, the availability of water, the cost included, policy and institutions. It also depends on the opportunity cost of water for irrigation (Garrido and Iglesias, 2008). Regarding impacting policy, legislation on European and national level needs to be more investigated. Irrigation is highly affected by requirements within agricultural and environmental policy. One of the major tasks is to balance trade-offs between water for food and water for nature (Varela-Ortega, 2008).

4.3 Management issues in the Guadalquivir River Basin

Irregular supply

The Guadalquivir River has a mean annual flow of 7230 Mm³/year, in which 3850 mm³ is used during an average year. The mean annual precipitation is 630 mm, though with variability's depending on the location, the season and the year (Confederación Hidrográfica del Guadalquivir 2010 and Ross and Martinez-Santos, N/D). The distribution of precipitation is presented below in figure 5. The east basin area has a mean annual precipitation less than 400 mm/year, while the mountains receive more than 1500 mm/year (see figure 5 for distribution of precipitation). The evapotranspiration (see figure 6 for annual evapotranspiration) tends to be lower on higher altitudes and higher in the lowlands and valleys, in certain years more than 1000 mm (Ross and Martinez-Santos, N/D). The highest precipitation season is during the winter period, from November to March. During this period storms can occur resulting in precipitation rates of about 150-200 mm within 24 hours, which can result in flooding of the river banks. The summer season is long and dry with almost no rainfall and high evapotranspiration (see figure 7 for index of moisture and dryness). Due to large variability's in rainfall rates, drought and flood management are facing major difficulties both for the agricultural production and the population in the basin area (Bhat and Blomqvist, 2004). The seasonal and local drought occurring in the basin results in environmental stress and salination of the aquifers (Berbel et al, 2012).

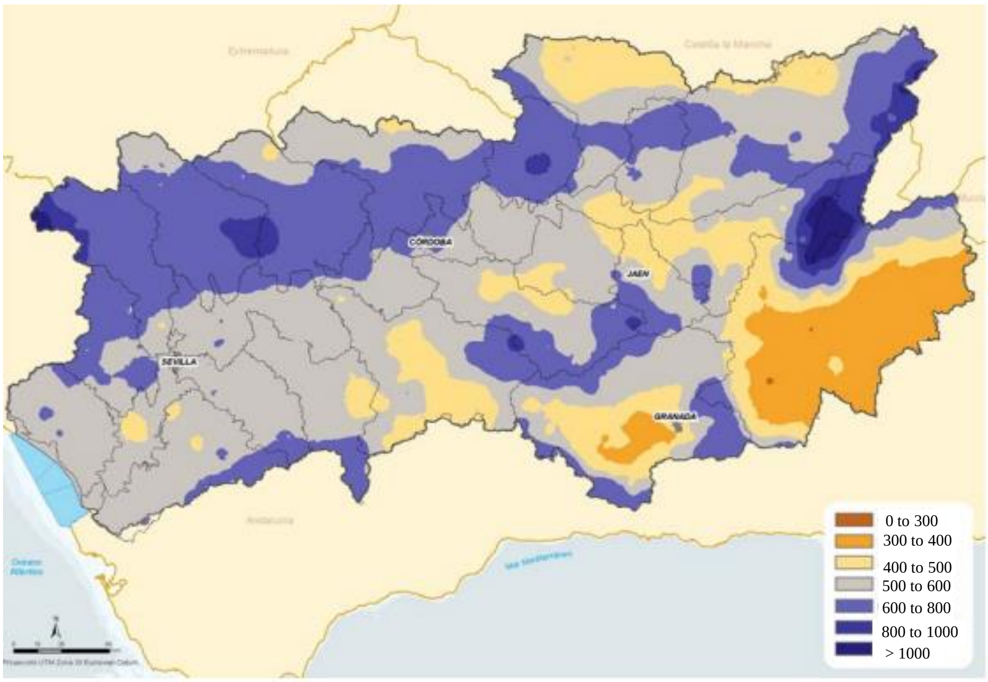

Figure 5. Spatial distribution of precipitation (mm/year). Source: Confederación Hidrográfica del Guadalquivir, 2010

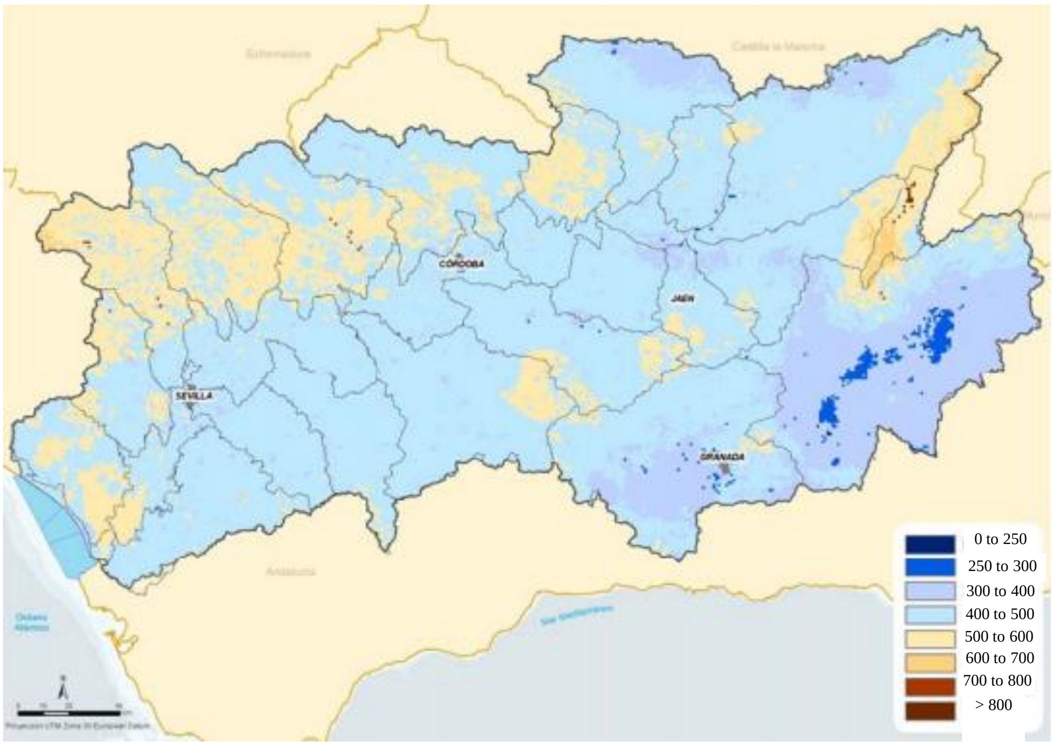

Figure 6. The actual spatial distribution of evapotranspiration (mm/year).
Source: Confederación Hidrográfica del Guadalquivir, 2010

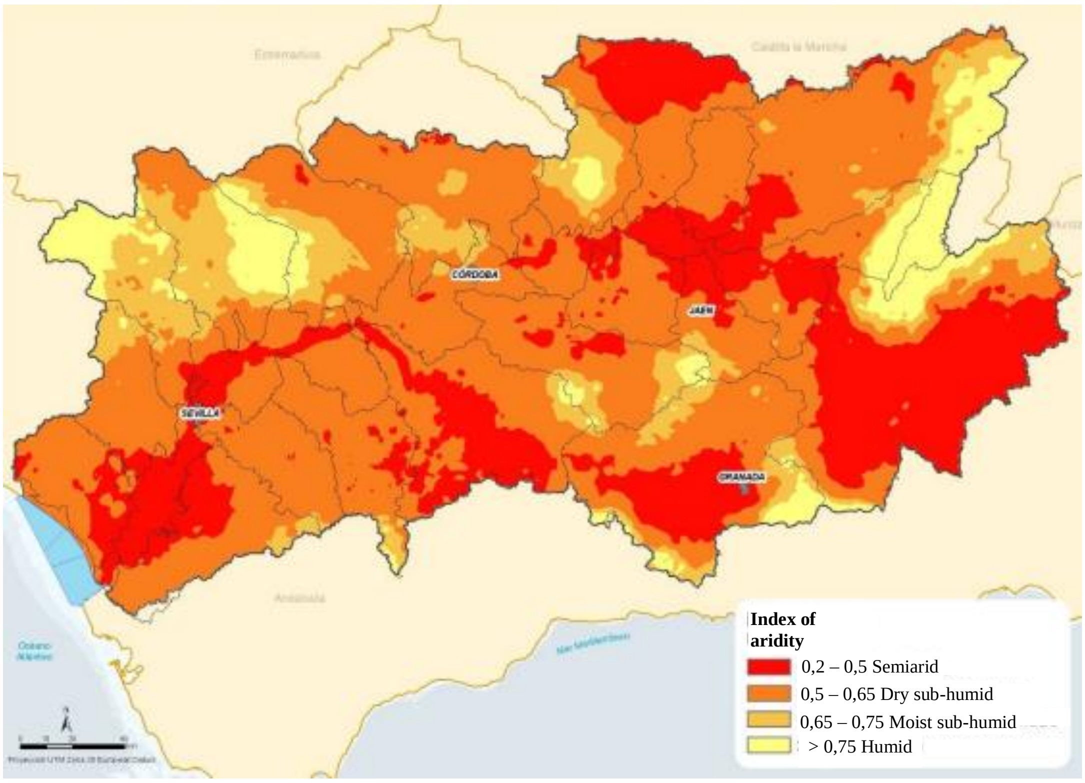

Figure 7. Climatic classification – index of moisture and dryness. Source: Confederación Hidrográfica del Guadalquivir, 2010

Increasing demand

The GRB has a high level of productivity of water, being one of the reasons for the high demand of irrigation (Berbel et al, 2012). The status of the GRB has been defined as being ”water deficit”. As already mentioned, irrigation is the major user of water, responding to approximately 80 percent. The consumptive use for industrial and municipal purpose reaches about 12 percent, while 8 percent is distributed to environmental and other water needs. Until the year 2012 the consumptive use within each sector was expected to increase. An increasing use of water would cause further imbalance between supply and demand. Land used for irrigation within the basin is expanding continuously and cultivation is introduced on neighboring hillsides and far from the river. The use of groundwater is also expanding. In the lower part of the basin there are rice cultivation of about 35,000 ha, requiring about 12,000 m^3 of water per ha. The growth rate of the population in Andalucía from 1986 to 1996 was 5,51 percent (whereas the growth rate in Spain was 3,1 percent). Approximately 4 million people lives in the basin area, about one tenth of the Spanish population. The industrial and municipal consumption of water is increasing rapidly due to a growing population and expansions in the industrial and tourism sectors (Bhat and Blomqvist, 2004). In the early nineties the growth for new irrigated crops increased. Rain fed olive groves and irrigated herbaceous crops has been replaced due to expansion of irrigated area. During the period of 1984-2008 the yield productivity increased for irrigated olive crops with 59.9 kg/ha, in comparison to rain fed crops with 50.7 kg/ha (Berbel et al, 2013).

Estimations done by the Andalusian Department of Public Works and Transport demonstrates that the available water supply in the basin is 3357 Mm^3/year, while the demand reaches 3578 Mm^3/year. This results in a negative water balance of 241 Mm^3/year. The negative balance occurs in an average year with an even larger loss in the years of drought (Bhat and Blomqvist, 2004). Restrictions for irrigation practices have been implemented as a result of water scarcity. Despite these restrictions the last decade has involved an increased irrigated area (Montesinos et al, 2011). At the same time a more efficient use of water per hectare has been implemented, resulting in a reduction of 6,893 m^3/ha in 1992 and 3,991 m^3/ha in 2008. Calculated from 1992, irrigated land has increased from 410,000 ha to 845,000 ha in 2008. The large increase of irrigation has caused an increase of the average water consumption per year with 1,2 percent. The water consumption did not increase more due to the decreased water use per ha of 38 percent between 1992 and 2008 (Berbel et al, 2013, Berbel et al, 2012).

In the GRB the average natural resources is about 5078 GL/year. This varies from 372 GL/year as a minimum to the maximum of 15,180 GL/year. In an average year, 8500 GL can be stored in a system of, in total 65, interconnected dams. The main strategy to deal with water scarcity has been to increase the capacity of reservoirs. In addition there is a natural groundwater regulation capacity of 2720 GL/year. The combination of ground and surface water reservoirs amount to the average renewable resources with 140 percent annually. In case of two consecutive years with low precipitation, this is not enough to supply the high water demand. Operation of water markets within the EU has only occurred in Spain and the GRB is the main basin for water trades (Berbel et al, 2013).

Issues with water quality

The major expansion of agriculture in the basin has resulted in significant effects of the water quality due to large proportions of agricultural runoff, such as pesticide and nutrients. Negative effects also arise from erosion and high pollution rates discharged from industrial and urban waste water (Bhat and Blomquist, 2004, Berbel et al, 2012). Figure 8 demonstrates the ecological status in the Guadalquivir River Basin.

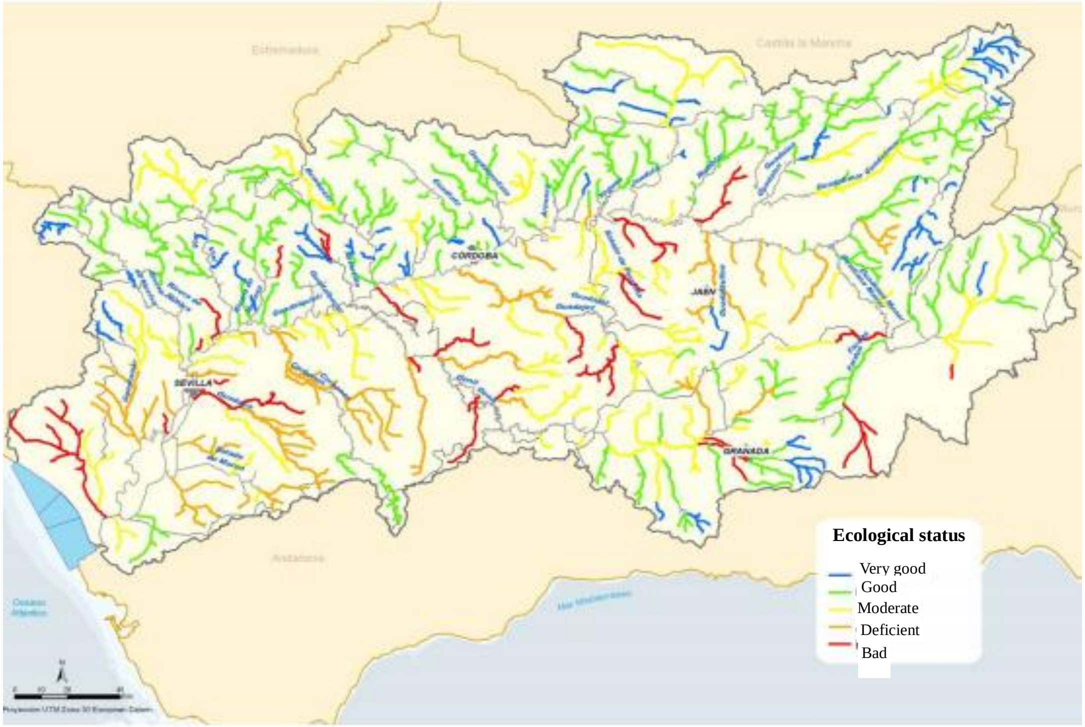

Figure 8 .Ecological status of the natural rivers. Source: Confederación Hidrográfica del Guadalquivir, 2010

Impacts of climate change

The climate on Earth has never been static. Though, scientific proof demonstrates that human activities has negative effects and causes global climate change. These effects are affecting and will have continuous severe consequences on resources, as water, biodiversity, erosion, natural ecosystems and human health. There are two major challenges. First, climate change mitigation, accomplished by capturing emitted gases and reducing emissions. The second one being climate change adaptation, accomplished by reducing the related hazards and impacts (European Environment Agency (1), 2010).

Drought is widespread in Spain as a result of major fluctuations of the natural water resources during the past 20 years. Due to its geographical location, Spain already had dry or very dry summers. Climate changes with warmer temperatures and less precipitation results in larger vulnerability towards drought. The occurring irregularities have resulted in several implementations of regulatory infrastructures to create sufficient supply and a development of policies to reduce the use of water and to achieve a more sustainable use of the resource (European Environment Agency (2), 2010). Flooding is another problem in Spain due to irregular precipitation distribution around the country. This results in overflowed river banks and severe flooding. The damages are affecting both material things and humans, in which flood plans are highly necessary to minimize the damages. These could include structural measures, such as diverted water courses, reservoirs, dikes, etc. It can also include non-structural, which are systems based on prevention and warning (The European Environment Agency, 2011).

4.4 Closure of the Guadalquivir River Basin

The situation in the GRB has been defined as the Jevons paradox or rebound effect. It implies that efficiency improvements of the use of natural resources do not correspond to the reduction expected. During a period of 80 years the management of the GRB has been through a centralized and hierarchical system, where the Basin Authority (CH) is the responsible unit for water management. Due to implementation of the Water Framework Directive (WFD) governance address a more participatory approach. This is one of the reasons for the development of an expanding and profitable agricultural sector, but has resulted in basin closure. There are two driving forces towards the strive for water saving and efficiency. The first one being increased water productivity, and the second one being a more inelastic irrigation demand. The second one could result in more vulnerability in extreme events and an increased consumption of water (Berbel et al, 2013). The concept river basin closure was introduced by Seckler (1996), meaning that water use exceeds the water supply. The definition of closed basin is that there is a small or no margin for continuous development in the area, unless decreasing demands in other areas or increasing the existing supplies (Seckler, 1996).

Molle (2003) describes four phases towards basin closure; open-traditional, open-development, open-management and closed. Phase one constitutes of the basin being in a natural stage, where human demand is insignificant and not causing pressure on the resource. The capacity of basin storage is developed due to increased human demand. Whereas there exist a strategy for the supply side, the demand side is disregarded. In general, this involves development of infrastructure to address a higher demand than the actual available basin resources and the ecosystem resilience. Demand-oriented management is in general applied when the real water resource is known. In the majority of cases, the resource is already overexploited or in the limit of closure when the society begin to discuss demand management. Basin closure can be defined as an anthropogenic process (Molle, 2003).

Berbel et al (2013) describe the main drivers, pressures, impacts and responses related to the basin's closure. The *drivers and pressures* constitute five main factors, 1) Decreasing farm income, 2) Increased irrigated area and factor intensification, 3) New irrigated crops, olive groves became irrigated crops due to implementation of new irrigation technologies, 4) New demand from other sectors, one of the reasons being that Andalucía is the region more advanced in hydrothermal power generation, and 5) Increase in environmental flow control, in southern Europe the ecological flow are dependent on quantitative aspects. The present Hydrological Basin Plan (HBP) defined the environmental flow of 50 GL with some reduction permitted. However, the new draft wants to apply a minimum flow also during dry periods. The *impacts* constitute two main reasons, 1) Reduction in water allocation. The urban and industrial sector has not been restrained by the CH, while the allocation for irrigation has been reduced from 9500 m^3/ha to 3900 m^3/ha, and 2), Increase in water cost, mainly due to higher energy demand, higher energy prices and new irrigation technologies, as for example drip and sprinkler irrigation. The *response* constitute by 1) Farmers response, being increase in drip irrigation and other water saving technologies, and mainstream adoption of deficit irrigation. With regards to the latter, olive crops that receives 1500 m^3/ha, receive according to the theoretical agronomic estimate 62 percent of the volume required, and 2) Institutional responses, which are defined as administrative basin closure due to an increasing water scarcity (Berbel et al, 2013).

5 Policies and governance of water in Spain

This section describes the political situation in Spain regarding water management, changes of the Spanish water law, responsible authorities on different levels, implementations from EU and the Hydrological Basin Plan of Guadalquivir.

Figure 9 demonstrates the institutional framework between different political levels within the water management in Spain.

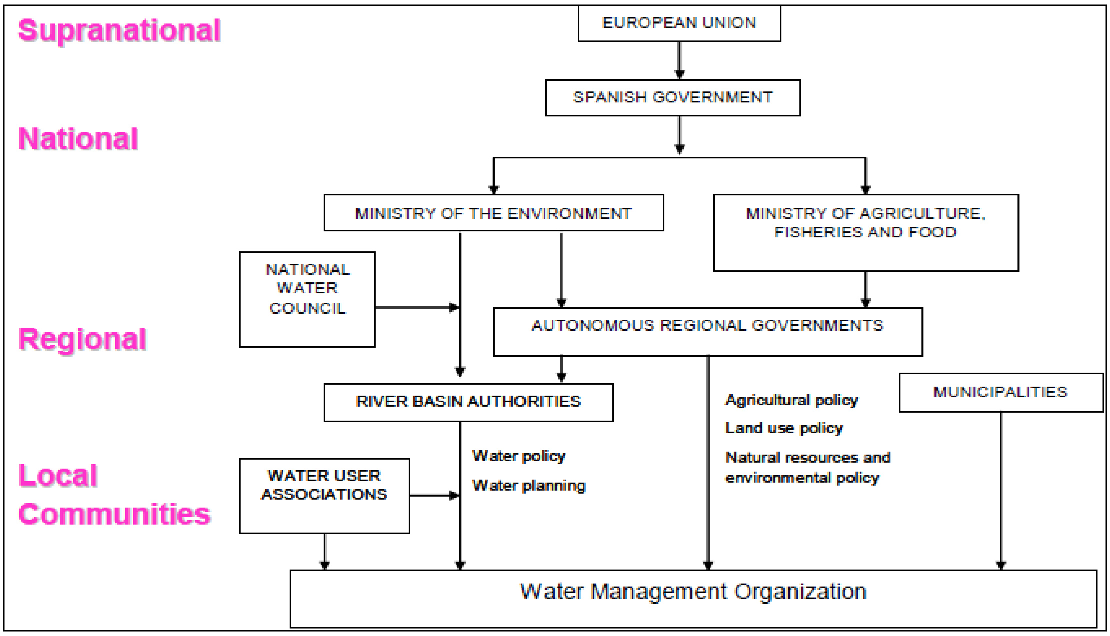

Figure 9. The Spanish institutional framework of water management. Source: Varela-Ortega, 2008

5.1 The Spanish water law and changes of property rights

The national water laws during 1866 and 1879 were planned to benefit both the national wealth and the agricultural productivity. Governmental subsidies were during the early 20th century called for investments of national water plans, especially development of new irrigation systems. An irrigation expansion plan was in 1933 implemented by the Spanish parliament. The plan contained inter-basin transfer of water, which would come to change the supply by shifting the basin with high supply to basins with low supply. This would create a higher balance of supply and demand of water within the country. It also benefited the agricultural production in the high potential southern basins (Bhat and Blomqvist, 2004).

5.1.1 The evolution of the water regime

The first water regulation, the Water Act in 1866/79, focused on the main uses such as land irrigation and population supply. As a result of changes in uses and demands during the 20th century the focus has increased to involve living environment, as for example nature conservation and landscape; farm production; irrigation of land; fishing; industries; supply for human use; production of mineral water; navigation and aquatic transportation; energy, such as water cooling and production of hydra power; conservation of landscape and nature; treatment of water; leisure; strategic reserves; and water cures. The six water uses with most importance is: living environment, fishing, irrigation, drinking water, treatment of water and hydraulic works. An important factor in the change of use rights are two financial instruments, the regulation tax and the water use rate (Costejá et al, 2002).

Since the eighties the water regime has made attempts to implement integrated approaches, by introducing new regulations and policies. Several factors have created difficulties, such as water scarcity, policy inertia, and intensive confrontation of the water resource both social and territorial. The distribution of powers within the field of water policy includes interest and territory as two of the main criteria. The exclusive authorization regarding the declaration of continental waters is in the hands of the State Administration, as a public resource. This means that the state owners control the access of the water resource, which separates the private legal trade of water. Water that pass through more than one Autonomous Community is under the responsibility of the State Administration. The responsibilities concerns planning; legislation and conceding of administrative concessions; justification of water passing more than one Autonomous Community; projection of hydraulic works in the case where being announced of general interest and in the cases where more than one Autonomous Community is affected; and legislation and planning regarding protection of the environment. The Autonomous Communities are the responsible unit for the hydraulic resources, irrigation infrastructures, and channels that are under projection, construction, exploitation and of regional interest; management and legislation involving thermal springs, mineral waters, aquaculture, fluvial fishing and shell fishing; and execution, and within some Autonomous Communities implementation of legislation involving protection of the environment. The State Administration has a majority of the powers that includes legislation, water administration and concessions. According to the State Administration, the regional administrations are not allowed to take control of water resource powers within the cases of inter-Community river basins. In addition to State and regional governments, the municipalities (approximately 8000) have powers for the water supply, wastewater and sewage system. Within these, depending on the criteria of the population, there exist strong inter-municipal differences (Costejá et al, 2002).

The property rights and the policy design within the Spanish water regime can be defined as being incremental and reactive, during a time period of 130 years. There are two major phases developed for the property rights. Initiated in 1866, when the first Water Act was implemented, in which water was used as both a private and public property resource. During the 19^{th} century some initiatives, due to crisis within the regime, were implemented which moved from a simple towards a more complex regime in the first half of the 20^{th} century. Increasing water demands, water pollution and aquifer overexploitation caused rivalry, complexities and inefficiency. This forced the water regime into a new period of transformation between the fifties and late seventies. The regime nearly remained unreformed until the mid eighties, when the second Water Act took place in 1985.

5.1.2 Development of a new and flexible regime

The new water Act in 1985 developed new modifications and changed the water resource to be a state property. This period included two stages. The first one 1985/1986 – 1999/2001 with a more rigid regime. The second one from 1999/2001 and forward which implemented a more flexible regime and strived for both integration and fragmentation. The new adoption is seen as the turning point in the water regime and changed from a complex to an integrated regime. Implementation of changes in property rights takes place under long time periods. Changes of policies are most frequently a result of changes in property rights, since it creates pressure on new transformations (Costejà et al, 2002).

The new Act is a combination of more strict controls by the State and at the same time it is more flexible regarding the water usage. This by implementing efficiency through legal techniques to create a higher availability and to supply an increasing demand. The concept of hydraulic public domain is extended by the 46/99 Act to the desalinated waters. This is done when the water leaves the plant and integrates with other hydraulic public good. The act can be seen as an expansion of the public domain that involves hydraulic natural goods. Two types of disposition rights are introduced, which to a certain point are innovative within the Spanish water legislation. On one hand, the contracts for the cession of use rights acknowledge results in larger flexibility for the concession holder's strive towards a more efficient use of water. This means that concession holders can sell their surplus water. The contracts have to include two concession holders being at the same level of priority. To close the operation it is essential with an authorization of the Hydraulic Administration. On the other hand, the figure of banks involving exchange of use rights was introduced by the 46/99 Act. The water is purchased by the hydraulic administration, which further decides the price of the resource and sells it. Before the reform in 1999, the amount of water needed for substantial hectares were calculated and water flow distributed according to these calculations. The water was not allowed to be designated to additional soils. New restrictions to the exploitation system have been enforced by the new legislation, in other words the ecological flow or environmental demand. The two concepts are recognized within the Spanish legislation. Administrative concessions are requested by the 46/99 act regarding the re-use of treated waters. Earlier it was used within the frame of a diverse administrative concession with the intention of promoting and controlling the use of all resources being available (Costejá et al, 2002).

In the new Act, water as consumption good and production factor is of less value. It introduced new approaches such as, water quality preservation, territorial planning, sanity, environmental values, and civil protection. Despite that the new Water Act defines all water resources as public goods, both surface and ground water; it still respects the preexisting traditional circumstances. This gives the owners of water the option of sustaining their private property. The private owners can choose between either that their rights could be transformed to be temporary private use rights. In this case, the occupancy and provision of the use has to be proved by the users before the Hydrographical Basin Confederations. The duration of this regime is 50 years and in the final of the period the users have the option to acquire the equal administrative concession to their use. The use rights can also be preserved as in the first Water Act. Though, if the exploitation conditions are reformed the users are expected to apply for an administrative concession and their property rights will be lost. A second choice regarding the use rights on hydraulic public domain is regulating the length of those permanent or ninety nine years of administrative concessions into 75 years as from January 1, 1986 (Costejà et al, 2002). Groundwater can be used without permits if the abstraction is less than 7000 m³/year. Exceptions exist in the case of overexploited aquifers or when risks of overexploitation exist, in which permits are necessary. According to the Water Act in 1985 and the first Water Act, the granting of administrative concessions has to be given according to priority order (Greiber et al, 2009).

5.2 The Spanish national government

The national government has since the end of 1800's had an important role within the development and management of water, and continue to be an important stakeholder both within the GRB and other basins. The president of the Basin Authority (CH) Guadalquivir is appointed by the national government, which covers the CH's budget with one third and are representative on the majority of the CH boards and councils. During decades the principal responsibility for water management was on the level of the central government resided along with the Ministry of Public Works, Transport and Environment (MOPTMA). A transfer of the responsibilities for water management was implemented in 1996 to the new Ministry of the Environment (MIMAM), being related to the CHs inter-regional level. The General Directorate of Hydraulic Works and Water Quality has the main responsibility for water management within the MIMAM. Regulations on water resources are prepared by the directorate, whom design and implement the hydraulic works. The nominees for the position of president (chairman) for inter-regional CHs is selected by the directorate (Blomquist et al, 2005).

Additional agencies with water related responsibilities within the central government consist of (Blomquist et al, 2005):

- *The National Water Council*, a consultative institution regarding water policy, bringing the representatives from the central, regional and local administrations together.
- *The Ministry of Agriculture, Fisheries and Food*, with the main task for irrigation planning and development of improved irrigation practices.
- *The Ministry of Industry and Energy*, involved within hydroelectricity, and mineral and thermal waters.
- *The Centre of Studies and Experimentation (CEDEX)*, being part of the Ministry of Development and an organization for public research and development, with interest in planning and management of water.
- *The Ministry of Health and Consumption*, responsible for drinking water, both tap and bottle, and quality of bathing water.
- *The Civil Protection Directorate*, part of the Ministry of the Interior, with responsibility of public safety, such as flood protection.

The 1978 Constitution, article 149, defines some of the responsibilities for the central government, as the following (Blomquist et al, 2005):

- Public works that are of national interest.
- Water management of river basins, being used by more than one region.
- Fundamental legislation regarding environmental protection.
- Interaction within the general economic planning.
- Responsible unit for protection of common property and public domain (water resources are included) (Article 132.1), and announcing natural resources as public domain (Article 132.2).

The Spanish Ministry of the Environment and the Ministry of Agriculture form since 2008 one ministry. This is the responsible unit of water resource issues. The Spanish territory has been divided into 15 autonomous River Basin Authorities. These function as management units with considerable organizational, functional and economic authority, supporting the units' important role in determining the legal framework. The Authorities are among others responsible for planning, construction and operation of major water infrastructure. A basin crossing more than one autonomous community is handed to the administrative authority of the national MIMAM. A basin situated within a single region, has its management under the competence of the given autonomous government (Varela-Ortega, 2008).

Irrigation in Spain is still being highly promoted, as it can offset endemic drought problems, lead to flourishing rural development, create income security and population stability. An irrigation research center has been introduced by the Spanish Ministry of Agriculture for development of irrigation technologies and extension services. The Spanish Ministry of Agriculture is in general the responsible unit for the national irrigation policy. The rapid expansion of irrigation installations in Spain until the 1990's and its severe environmental affects has been faced by the Water Framework Directive (WDF). In 2002 the National Irrigation Plan (NIP) was presented with a timeframe until 2005 and later revised until 2008. The NIP aims at the modernization of irrigation schemes with a target of 1,300 million m^3 of water savings. Some of the objectives within the plan are to guarantee water supply to irrigators, reducing the impact of climate variability, to mitigate drought effects and encouraging the expansion of irrigation. Irrigators were provided with financial incentives to adopt to modern on-farm irrigation technologies. The NIP was revised for new ecosystem objectives under severe drought periods to match those of the WDF. The objective with the plan was to reach a more efficient and sustainable use of water, recovering the overexploited aquifers and avoiding contamination of water courses (Varela-Ortega, 2008).

5.3 The regional government

The Spanish regional governments (CAs) were established in 1978 and a responsible unit within several policy decisions regarding protection of environment and public health, management of natural resources, and economic development. In the southern region, CA Andalucía is known as *Junta de Andalucía*. The responsibilities of the CA for water management coincidence with responsibilities of the CH. The regional policies developed by CH Andalucía involve the GRB and has several programs and responsibilities regarding the water management in the basin. In the CH Andalucía, the Department of the Environment, the Department of Agriculture and Fisheries, the Water Secretariat, and the Department of Health are all included (Blomquist et al, 2005).

The 1978 Constitution, article 148, defines the responsibilities of the CAs' as the following (Blomquist et al, 2005):

- Public works, within the territory and interest of the regional government.
- Implementation of environmental protection.
- Planning, construction and operation of projects involving irrigation, hydraulic works and canals.
- Thermal and mineral waters.
- Fishing, focused on shellfish, aquaculture, and fluvial fish.
- Issues involving forestry and woodland.
- Farming of livestock and agriculture, in agreement with general economic planning.
- Planning of land use
- Regional economic development, involving the objectives instituted by the national economic policy.

The responsibilities between the central government and the CA are not associated with identification of inter-regional and intra-regional basins. According to the water law in 1985, the main responsibility regarding water management within the intra-regional basins is the CAs. Within some aspects, as for example in Guadalquivir, the CA also has certain authority for the inter-regional basins. In some CH boards and commissions the CA has representatives. In the severe drought that occurred in the GRB, the Andalucía Water Council (AWC) was established in 1994. This is one of the main examples demonstrating the interest of CA Andalucía regarding water management. The AWC proceeds to organize meetings, used for public discussion and water planning. The region suffered severe water issues after the drought. This needed to be handled on a regional level together with a participatory framework, being the reason for the creation of the AWC. A large variety of water stakeholders are represented in the AWC, consisting of different views on policy and with multiple interests. Policy recommendations are presented by the AWC, as for example in 1994 in the “Andalucian agreement for water”. Though, the unit cannot make any formal decision making. A development of a regional position was in 2002 considered by the AWC for the national water plan of 2001. This involved improvements of the demand management, a higher control for use of illegal water, and promoting desalination as an alternative to the inter-basin water transfer project being proposed within the plan. Fundings has been used by the CA Andalucía to demonstrate changes in sub-basin levels within the practices of water management. Treatment plants have been financed by the CA Andalucía to improve the quality of water in the lower basin area and areas close to the coast. The unit has financed irrigation communities (CR) to implement improvements. The CRs have agreed upon to improve the management of water supplies and implement more control of the expanding water demand. Another financial investment involves projects for urban water suppliers to improve management practices, increase the conservation of water, and decrease the risk of floods. A regional water act is an additional strive of the CA. Even though the national water law cannot be contradicted by actions on regional level, the CA are able to define priorities for water policy and adopt policies not expressed in the national water law, one example being drought management. The CA is striving for that the central government allocate additional responsibilities to the unit, as for example responsible for water use licenses, developing agreements between the users regarding water transfers to manage shortages, and foundation of sub-basin management organizations. Though, additional responsibilities for the CA regarding water management in the basin are not agreed upon by all organizations within the basin (Blomquist et al, 2005).

5.4 The Basin Authority of Guadalquivir

The first governmental authority in Spain covering river basin management was developed in 1926, making Spain one of the countries with the longest history with basin management institutions. Several changes have been implemented since this period causing both reduction and expansion of the responsibilities of the basin authorities throughout Spain. At first the main tasks involved construction for water supply, its operation and facilities for storage. Large subsidies were received from the central-government to increase the development of irrigation and hydropower. The population and the economy within the basin have changed as a result of industrialization and urbanization. Changes have also been made since the 1980s within the Spanish policy. This has resulted in difficulties for the Basin Authority (CH) to make the transitions towards more focus on water demand management, ecosystem health and quality protection, to be of equal importance as water supply. Implementation of policies includes several factors, such as supply, economy, quality and environmental values. This causes more difficulties than a management solely focusing on one of these. A recognized CH does not guarantee a successful management. Other difficulties are the relationship between the CH and stakeholders and the involvement of stakeholders (Blomquist et al, 2005).

The CHs formal structure provides a larger weight to the constituency of traditional irrigation. The main interest involves the water supply expansion functions of the authority. The actual decision making within the CH enhance the favored position of the constituency. The irrigators are highly organized, with clear goals and the knowledge how to fulfill these by using the decision making processes and the organizational structure of the CH. In comparison, private and public organizations contributing or representing urban centers and environmental matters, or promoting economic aspects of water management, seems to have minor influence within the CH. These have searched for alternatives to strive for their goals. When the CH was established by the central government, it was a hydro-technical agency with the task of constructing reservoirs, dams, and water conveyance facilities. A separated agency was responsible for the management of water uses and water law administration. The common responsibility of physical infrastructure and management of water use within the basin was combined in 1985 (Blomquist et al, 2005). The CH is not sovereign, since the institutions are below the central government or the CA, depending on if the basin is inter-regional or intra-regional. The water law of 1985 has recognized 13 CHs, 4 within intra-regional basins and 9 within inter-regional basins. The CHs within the intra-regional were planned to be transcribed to the CAs. This has not been realized for all authorities. One example is the CH Andalucía, still being controlled by the central government. The water law of 1985 and the amendment in 1999 established the main responsibilities for the Guadalquivir Basin Authority. It is also affected by the Guadalquivir Basin Plan, the National Water Plan, and regulations implemented by the EU (Blomquist et al, 2005).

Blomquist et al (2005), presents the main responsibilities of the Basin Authority's:

- *Water works*: the function of hydraulic works is under the responsibility of the CHs, such as financing, constructing and operation of reservoirs and dams, to ensure water storage and flow regulation. Reservoir operations within the GRB, establish the surface water flows accessible to users.
- *Water planning*: The CHs are the unit developing basin plans and additional planning, as for example, data collection and analysis regarding water uses, the basins physical condition, indication of units within sub-basin management, and to create accordance between basin plans with guidelines on national and EU levels. In 1995 the latest basin plans were submitted to the national government, in 1998 the plans were approved, and in 2001 integrated in the national water plan.
- *Monitoring of water resource conditions*: The CH monitors the river flow to detect flooding, insufficiency, and the quality of the water in the entire basin.
- *Water licensing*: Water concessions are reviewed and approved by the CH. The priorities and objectives of the basin plan has to be corresponded with the granted concessions. To be granted concessions the user first needs to send a request to the CH. Second, the request is analyzed by the CH, involving technical viability, consistency with the basin plan, and feasible conflicts with other projects already licensed or requested. Third, publishing of the request for review and comments by the public. Fourth, completion of the technical report with further recommendations. Fifth, the CH governing board either grants or denies the request. A rejected license includes the reasons for the decision and the applicant can, in certain cases, revise and resubmit the request. In cases applying for a license of high volume, though unusual, the CH promote for formation of a water user association. The license will then be granted to the association and not to individual users. The CH handles the association, whom further handle the individual users. A register with the authorized water users has to be according to the law accessible by the public.
- *Water transfers*: The amendments of the national water law in 1999, added the CH as the unit for approval of water transfers among authorized and registered users.
- *Enforcement of Spanish and EU water regulations*: The CH is the enforcing unit, unless a different unit of government or other level is assigned. The court handles the issue when a decision by the CH is being challenged. This occurs in the case when the CH is claimed to have gone beyond the legal authority. The CHs holds power of implementing sanctions. The CH Guadalquivir is divided into staff offices, a set of boards, councils or commissions, consisting of basin stakeholder representatives and CH staff.

The operations and administration of the CH are financed by revenues both by the CH institution and the central government. The expenses has according to the law be covered by the CH. The annual budget for CH Guadalquivir reached in 2001 US$ 115,800,000. The central government covered 35 percent, the water users of the basin 30 percent, and other sources 35 percent. Residents and water users cover an essential source of income through taxes and tariffs, which includes the following (Blomquist et al, 2005):

- *Tariffs on water users*: The president approves the charge for volume of water each year, covering expenses for maintenance, operation of the hydraulic works, the facilities amortization of capital investments, and the indirect costs
- *Taxes on basin residents*: The taxes covers services performed by the CH, as for example water storage and flood control.
- *Fees* covering dischargers of treated water reaching the river.
- *Severance taxes* on gravel and sand, or additional extractive industries located in the basin.
- *Taxes* on hydroelectric power developed within the basin.

Of the above revenues, the central government does not receive any; all is distributed to the CH Guadalquivir. In 2001 the tariff for irrigation users was US$ 59,81/ha, for domestic users US$

0.355/m³, for industrial users US$ 0.516/m³, and for producers of hydroelectricity US$ 0.76/ kWh. An appropriation on annual basis is received by the CHs from the central government, being part of the budget of the Ministry of Environment. The funds received from the central government is distributed for monitoring, planning, collection of data, and other services that is not covered by specific groups of users. The CHs also receive EU structural funds by the national government, given to poorer member states to be used in economic development (Blomquist et al, 2005).

5.5 Irrigation communities

In the GRB there are more than 1000 irrigation communities (CR), representing the most prominent stakeholder group. The CR consists of groups of irrigators. These are either holder of a single water license and divide the licensed water within the group. They can also divert surface water through a single shared canal and individual irrigators' farms are distributed the water. The groups can also consist of both. The irrigation infrastructure should be maintained and managed by the members in the community. The first CR was initiated more than a century ago (Blomquist et al, 2005). All irrigators have to obtain a legal water permit. The users are charged with a regulation-levy and a water use tariff, collected by the CH. 82 percent of the farmers pay a fixed tariff per ha of irrigated area, 18 percent pay a volumetric tariff, and 5 percent pay a combination of both. The present charging system in Spain which includes preferential access to cheap water for irrigation does not comply with the terms of the WFD, which is demanding for a more appropriate remuneration and pricing system for water (Berbel et al, 2009).

The CR were recognized in the beginning of the 1900s and based in the Spanish law since irrigation is a keystone within the development of Spanish national policy. Corporations are according to the Spanish law defined as being public or private, with exception for CRs that are classified as semi-private and semi-public. The CRs are integrated within the river basin management and its institutional structure. Therefore the CHs have to approve the formal rules of the CRs. The CHs also receive a fee payment from the CRs, covering the services. The CH boards and commissions involve representatives from CR. The position of second vice president on CH governing boards is reserved for the CR. The CRs are a part of water management and part of user participation. The system for distribution of water is developed and administrated by each community. The CRs are, within the internal organization, almost identical and are codified within the 1985 water law. The members pay a fee to the CR, whom regulate the use of water, establish and enforce rules for each community. Issues arising within the water resource management are almost entirely settled within the community itself. Each CR consists of a “water police” and an irrigation court, involving the president of the community and additional members selected by the general assembly. Each CR chose its method for water management. Therefore major variations exist, some more modern with drip irrigation, pressure irrigation systems or electronic metering. Others use more old systems, as for example gravity flow and continue to distribute the water depending on the cultivated area. This causes small possibilities for farmers to conserve water and invest in new technology. In 1994 the Guadalquivir Irrigation Farmers Union (Federación de Regantes del Guadalquivir) was established, now by the name Feragua. It involves 85 CRs within the basin. The union form one of the largest communities in the basin, covering 240,000 ha (Blomquist et al, 2005).

5.6 The European Water Framework Directive

In 2000 the Water Framework Directive (WDF) was implemented with the aim to reach a more sustainable use of water, with restoration and protection of the aquatic ecosystems as an objective. The WFD has an important role to create a sustainable water quality and quantity in a long-term perspective. This means that aquatic ecosystems will be able to recover and produce ecosystem services for all actors depending on water, as well as economic activity. The water management in the WFD has become a legally binding tool to bridge an integrated river basin management with ecological and economic aspects. Some of the major pressures, identified by the European Commission, are pollution, hydro morphological pressures and over abstraction. An effective water management is dependent on strong monitoring of the resource. This since bad decisions will cost more in the long term than the cost of monitoring in the initial stage. Monitoring programs, within the WFD, can be adapted and prioritized where needed. Several monitoring programs lack information how to be used regarding pressures and characterization. They also lack how to use this information in the proceeding development of River Basin Management Plans (RBMPs) (European Commission, 2012). The member states were given a program and timetable to establish a RBMP until 2009. The aim of the RBMPs was to recognize all needed actions in the respective river basin to fulfill the purpose of the WFD. The goal for a good ecological status is not expected to be reached for a majority of the river basins. This due to that only 23 member states have adopted and reported all RBMP. At present there are 4 Member States that either adopted a few plans or none, in which Spain is included. Regarding the Mediterranean Basins in Andalucía the plans has been approved but not yet reported. The river basin district of Catalonia is the only plan in Spain that has both been approved and reported. If the implementation is delayed in the first cycle of RBMPs this has consequences in the implementation process in the second cycle. The consequences are not only for each concerned member state, but for all countries sharing the specific catchment. If the goal is not achieved on time the deadline can be extended until 2027 or beyond. Reasons for an extended deadline could be due to technical or financial difficulties (European Commission, 2012).

An additional main tool, beyond the RBMP, is the Program of Measures (PoM). It is used to reply to the identified pressures and to reach a good status of the river basin. The first step in the implementation process of the WFD begins with administrative and adaptive arrangements. The second step is defining the district of the basin. This is followed by evaluation and monitoring of the status, the objective setting, and at last implementation of the PoM. If all intermediate steps are well implemented, the planning process and the reliability of the RBMP are strengthening. If the particular pressure in overlooked in the analysis of impacts and pressures, the PoM can be constrained to address a pressure in the basin. The result could be that the monitoring process is not formed for the particular issue. There are several instruments within the PoM of each member state, such as legal, administrative, technical, infrastructure, training, etc. These are funded differently, with public budget or private operators. Other major financing contributors are the European funds, for example the Common Agricultural Policy (CAP) or structural cohesion (European Commission, 2012). The CAP has most likely the largest impact on the agricultural sector. In the 1980's and 1990's CAP subsidies were coupled on the production of certain crops, as for example continental crops (cereals, oilseed, protein crops) or olive groves. This support mechanism gave incentives to enforce production by using irrigation, resulting in increased use of water for subsidized crops. In 2003 direct payments were decoupled from production and the cross-compliance scheme was introduced. Instead of financial support, in forms of subsidies, the farmers had to create their decisions upon market signals and their decision making process included new environmental requirements. Later on environmental requirements were progressively included within the CAP and in association with the health-check. In 2007 improvements of water quality became one of the top-priorities (Garrido and Iglesias, 2008).

The RBMPs define the priorities regarding the financial decisions. Though, the majority of the plans lack sufficient information on the implementation costs and how these will be financed. The RBMPs could create an interaction between different sectors, as for example agriculture, hydropower, urban development, etc, and develop a sustainable framework. Within the RBMPs more than 90 percent have identified agriculture as one of the major pressures in the basins, due to pollution by nutrients, organic matter, pesticides and hydro morphological impacts. The pressure from agricultural practices has not addressed actions within the RBMPs. There is an absence within the plans for new projects, which risks the chance of creating a framework towards a sustainable development and a integrated water management. Economic instruments, technical and non-technical, can with a major variety be found within the PoM. Despite these some essential elements are lacking, as for example financing, timing and scope (European Commission, 2012).

According to the WFD an integrated river basin management demands a strong legal framework and a reliable structure of governance is necessary. The status quo in a majority of the Member States continues, despite significant improvements in the implementation of the WFD. One of the reasons is the lack of environmental integration in policy decisions. The decision making has to cross between sectors. If decisions for economic activity do not involve quantity of water it could result in practices with an unsustainable outcome, environmentally, economically and socially. The RBMPs should involve all uses of water. The implementation of the WFD has gone from an approach for a traditional water use to a more integrated approach. To define whether or not the water use is efficient, the volume extracted has to be measured. Though, metering of the consumption of water within for example agriculture or households in some of the Member States are not complete. The polluters' pays principle (PPP) should be implemented in for example the cost of water (European Commission, 2012). One main issue is how to achieve the objective of the WFD to create an improved status, both quantitative and qualitative, in the river basins by 2015 and at the same time remain important social and economic aspects of irrigation (Ross and Martinez-Santos, N/D). Within the EU there are several transboundary river basins. Therefore the implementation of the WFD is dependent on cooperation on a cross-border level. The international cooperation has been introduced and improved in collaboration with the WFD regarding information exchange and collective decisions. The WFD has introduced a larger extent of participation for the public and users. Another important aspect is the increase of transparency of the water management process and the decisions made. Quantitative and qualitative aspects have to be involved in a well defined water management. If sufficient quantity of clean water is lacking, the objectives within the WFD cannot be achieved (European Commission, 2012).

5.7 The Hydrological Basin Plan of Guadalquivir

Environmental objectives (see figure 10 for environmental objectives of water masses) with an integrated approach was established by the WFD, towards a more protective and sustainable use of the ground and surface waters in Europe. Depletion of water can be found throughout of Europe, mainly in the Mediterranean region. Due to climate change this could increase in the future with a more warm and dry climate. The increasing water scarcity is highly dependent on adaptation by all stakeholders, such as: increasing the supply; increasing conservation, meaning more efficient use of the existing resource; and allocating resources within or between sectors (Berbel et al, 2012).

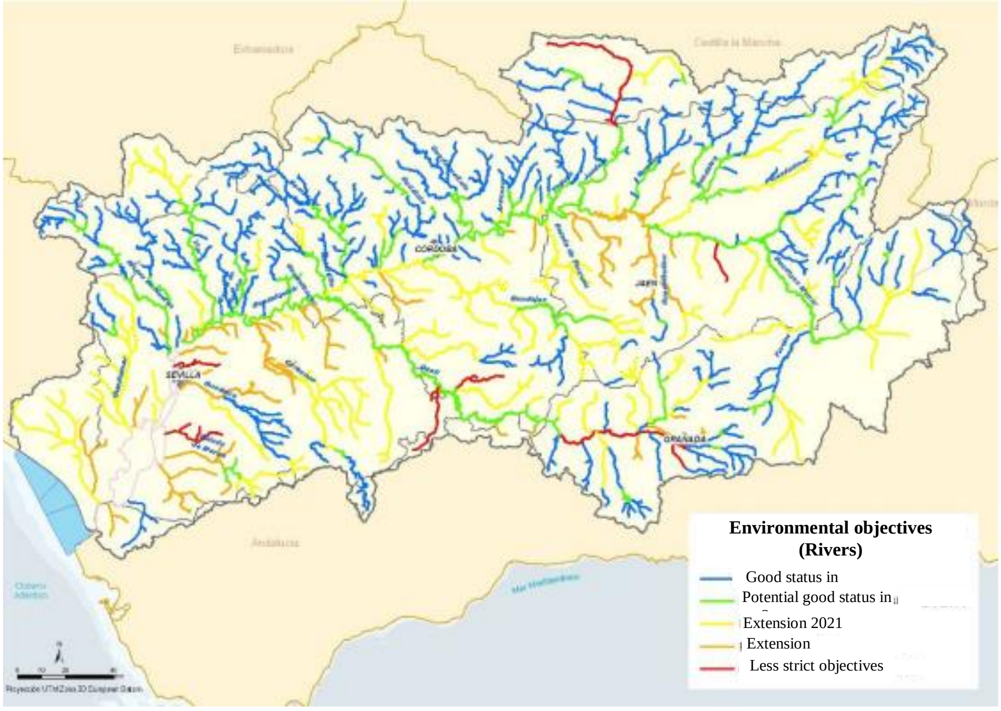

Figure 10. Environmental objectives of water masses within the category river. Source: Confederación Hidrográfica del Guadalquivir 2010, *Plan Hidrológico del Guadalquivir 2009-2015*

One of the main goals of the Hydrological Basin Plan (HBP) is water saving. It has been addressed with a combination of an increase in cost and investments in water-saving technology. The improvement of irrigation efficiency is another important factor within the HBP. The water use and water rights are planned and controlled by the CH of Guadalquivir. Public participation for decision making is defined in the water law regarding the plans in the long-term perspective and the operative management. The HBP is under the 1985 water law and the plan is being discussed to be replaced by the new draft of the HBP. The new draft includes a PoM and involves a more broad focus. It intends to aim the importance of detailed analysis of water supply that involves reliability and quantity applied to all economic services. The draft has developed a regulation to prevent and manage floods and drought. In order for the HBP and PoM to be developed, identification was made of the water bodies as well as the changes and availability of the resources. There are in total 60 groundwater bodies in the Guadalquivir and 443 surface water bodies. The draft HBP is part of a survey called the ”irrigation inventory”, which is a database with geographical references. In the database information can be found regarding abstraction from surface and groundwater bodies, consumed volume, irrigation systems, crop pattern, water rights, and farmer data. This has resulted in relevant and updated information to build the new draft upon. The HBP should according to the Spanish law be able to ensure irrigators with a water access reliability of 90 percent (and urban users 99.2 percent). In the new HBP this is achieved for the urban users, but not for the irrigators. The irrigators has before the implementation of the new draft a ”guarantee gap” of 534 hm^3. The gap should decrease after the implementation of PoM to 276 hm^3. The majority of the basin is under the management as a single unit and a common management system is applied for all reservoirs. This creates a larger reliability since locally independent systems tends to be more vulnerable than larger systems during dry periods (Berbel et al, 2012).

The HBP describes protected areas and ”river reservoirs”, defined as protected fluvial segments. The HBP includes, based on the WFD, a well developed analysis for all individual water bodies, the present environmental status and the projected situation. The goal for good ecological status could be extended if needed until 2021 or 2027 to be able to improve the situation. The improvement for groundwater quality is one example of this, which has a postponement until the measures needed comes into effect. The two major focuses in the new draft of HBP is reduction of water demand and investment in point pollution (urban sanitation). Technical measures required in the draft HBP for irrigation has resulted in that the average cost for water has increased with 160 percent. Cost recovery of new measures, required in the PoM, are the reason behind the large increase of cost. Volumetric tariffs are also one of the implementations in the PoM. As the HBP, the PoM includes an increased cost for water services, both within the irrigation and urban use. The benefits received by ensuring a good ecological status have to be compared to the budget of the HBP and the PoM (Berbel et al, 2012). In table 4 the water consumption divided between different sectors in 2008 is demonstrated, as well as scenarios for the water consumption in 2015 with and without the implementation of the PoM, and future aspects for 2027. As demonstrated in the table, there is a difference of water consumption in 2015 with the implementation of the PoM.

Sector (hm^3)	2008	2015 without PoM	2015 with PoM	2027
Urban	436.4	464.6	393.5	393.5
Industrial (large)	35.8	43.4	43.4	43.4
Energy	30.9	58.9	58.9	92.1
Irrigation	3,329.5	3,402.7	3,101.4	3,101.4
Total	3,832.6	3,969.5	3,597.2	3,630.4

Figure 4. Water consumption in 2008 and scenarios for the water consumption in 2015 with and without implementation of the PoM. Source: Confederación Hidrográfica del Guadalquivir, 2010.

The regulation in Spain share similar guidelines developed in the WFD, as for example a good ecological status, water bodies and planning mechanisms. One major difference is that the Spanish regulation has more emphasis on issues regarding water quantity. In the Mediterranean region depletion of water resources and security are highly important. Securing the demand-supply and territorial development are two essential aspects. In the GRB there are no plans regarding new sources of water and a water use reduction is under process. This is part of the implementation of the PoM, since the basin already is in its limit for extraction. The PoM will implement water-saving measures within the irrigation and urban sector of approximately 8 percent. The HBP does not allow further entrants, a result from a political participatory process and public debate, which has created the document *Agreement for water in the Guadalquivir Basin* (*Acuerdo por el Agua en la Cuenca del Guadalquivir*). There are agreements upon that new areas for irrigation are not to be introduced, with the only exception being governmental projects that in the moment are in the development progress. Though, the public still prioritize distribution of water for irrigation purpose. Reductions in return flows are the major reason for a decrease in water consumption and not due to effective water savings. Implementation of modernization has resulted in an increase, of four times larger, of the total production cost. It has resulted in an increase of energy from 10 percent before modernization to 30 percent of the cost of irrigation in total, including maintenance, management and operation. The new draft of HBP includes technical and economic measures to deal with demand control and therefore it can be seen as a good tool in the strive for a sustainable water management. The new draft can be seen as integration between new restrictions from the WFD and the traditional Spanish water planning institutions (Berbel et al, 2012).

6 Background of the aquifer 'Carbonatado de la Loma de Úbeda'

This section provides background information of the aquifer of 'la Loma' with a general description of the aquifer, its water balance and the issue of 'fracking'.

6.1 Description of the aquifer

The aquifer 'Carbonatado de la Loma de Úbeda' consists of three aquifers (see figure 11). These have different geology both regarding density and surface. The characteristics of each aquifer are also different and independent (Gonzalez-Ramon et al, 2013). The first type, the detrital, consists of the aquifers of Miocene and Triassic geologic age. These are formed by different layers of granular materials, such as sandstones, marly sandstones and calcareous sandstone. The second type is the Jurassic aquifer. It is formed by limestone and dolomite (calcium carbonate and magnesium) (Gonzalez-Ramon, 2007). The aquifers of 'la loma' are located in the Province of Jaen, about 60 km northeast of the capital of Jaen (Gollonet et al, 2002). It involves the municipalities of Baeza, Beas de Segura, Begíjar, Canena, Castellar, Cazorla, Chilluévar, Ibros, Iznatoraf, Navas de San Juan, Rus, Sabiote, Santiesteban del Puerto, Santo Tomé, Sorihuela del Guadalimar, Torreperogil, Úbeda, Villacarrillo, and Villanueva del Arzobispo (González Ramon et al, 2007). The aquifer of 'la loma' is part of the hydro geological unit of Úbeda (05.23) and covers approximately 900 km². About 50 percent of the area of 'la loma' is situated at a depth of 300-700 meters. The area has an average rainfall similar to the rest of the Guadalquivir Basin area, 525-640 mm/year, and the same Mediterranean climate (Gonzalez-Ramon et al, 2013).

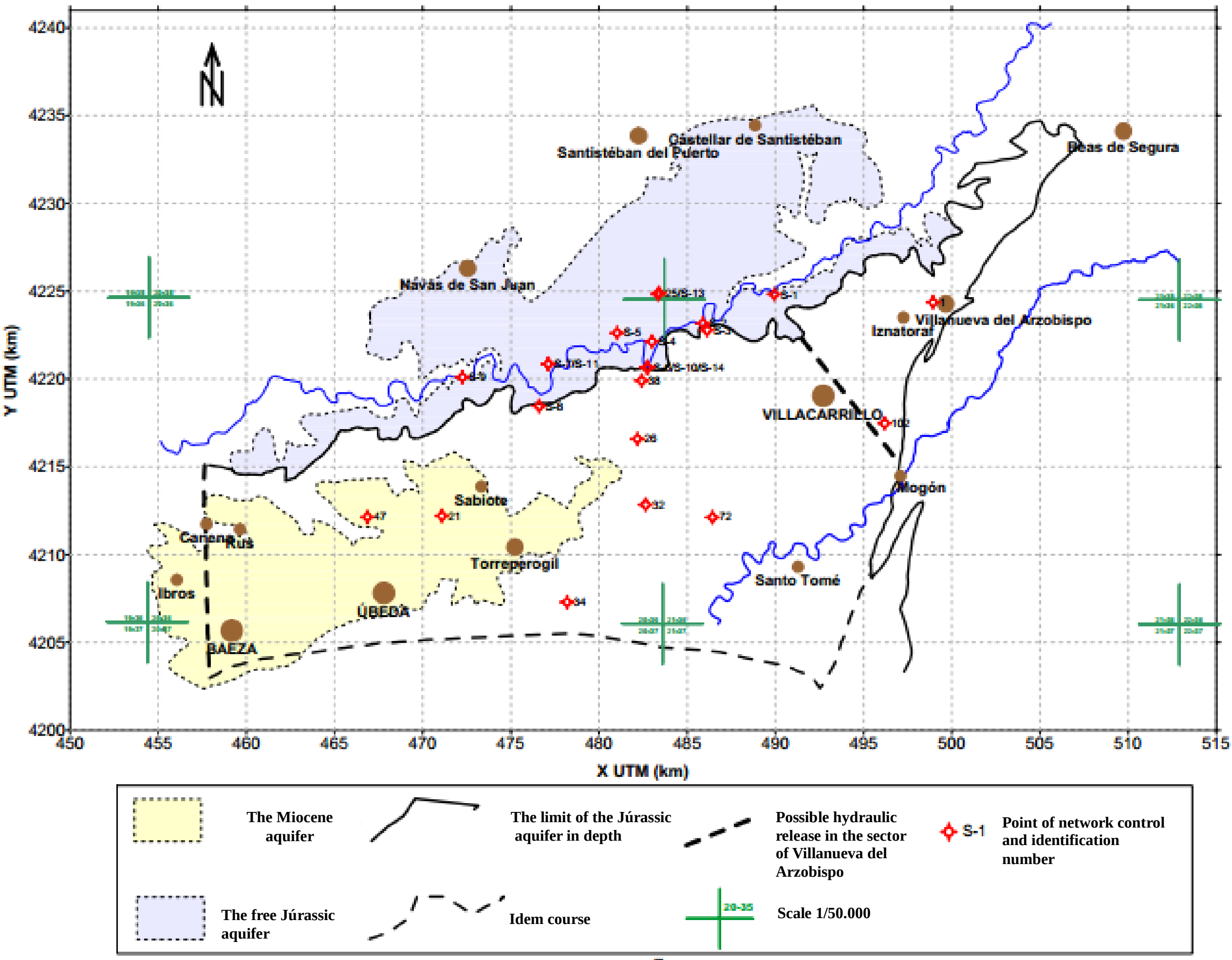

Figure 11. Aquifer ´Carbonatado de la Loma de Úbeda. Source: Moreno-Martinez, 2007

The economy in the region of 'la loma' has become dependent on the cultivation of olive crops. The use of groundwater is the factor behind the expanded production of olive oil. In the beginning of the 1990s the existence of deep aquifers in the region was unknown by the policy makers within management and planning of water. The area was defined as a 'zone without aquifers' and therefore wells could be constructed in the lack of control. Since 1996 piezometric information has been available. Systematic monitoring began in 2001 for the levels in the Jurassic aquifer, within a network of control points. The control points have over time changed. Several of the points are piezometers and private wells, some are still being used. Piezometric data demonstrate differences within levels of discharge. This is used in areas with water transfers occurring between the Jurassic and Triassic aquifers. In 1998/1999 the first research study were made in the area. The exploitation of the aquifer reached 18 hm^3 and 11,925 ha were used to irrigate olive crops. The exploitation increased up to 35 hm^3 in 2005 and 24,050 ha of irrigated olive crops (Gonzalez-Ramon et al, 2013). The majority of the water extracted is used for irrigation of olive crops. The water also supplies 100,000 inhabitants (Gonzalez-Ramon, 2007). Improvements of the hydro geological knowledge of the aquifers, an increased understanding of the hydro geological conceptual models, the geometry of the aquifers and the renewal rate of the water resources in the aquifers has been possible to obtain as a result of research by the Geological Survey of Spain (IGME) and the Centre for studies and Experimentation in Public Works (CEDEX) (Gonzalez-Ramon et al, 2013).

The Jurassic aquifer

The Jurassic aquifer is the principle aquifer in the region of 'la loma'. The aquifer outcrop from the north of Canena and Rus to the nearby Villanueva del Arzobispo (Gonzalez-Ramon, 2007). In the south the aquifer is bordered by the Guadalquivir River and in the north by the Guadalimar River. The Jurassic aquifer contains a package of highly permeable carbonates, with a thickness of 80-100 meters, covering conformably the Triassic materials. In the lower level the carbonates contains of laminated limestone, at time pseudolithic and locally brecciated. The upper level feature dolomite breccias, carioles and laminated dolomite. Miocene marls cover the Jurassic carbonates in the south. Miocene materials have a varied thickness of 200-500 meters (Gonzalez-Ramon et al, 2013).

The essential infiltration of the aquifer comes from precipitation, with 49-51 hm^3/year in an average year and with reserves of around 230 a 340 hm^3 (Gonzalez-Ramon, 2007). The obtained flows vary and are in the unconfined aquifer between 1-50 l/s, but more commonly below 10 l/s. In the confined aquifer the flow reaches between 2-105 l/s. In the unconfined aquifer specific flow rates are 0,5 l/s/m and in the confined 3-5 l/s/m (Gollonet et al, 2002, Gonzalez-Ramon, 2007). The water flow varies between 300-500 m^2/day; but it can reach 1000 m^2/day. The water level in the unconfined aquifer is around 400-500 meters a.s.l (above sea level) (Gonzalez-Ramon, 2007).

The Miocene aquifer

The Miocene aquifer is located in the southwest. The south of the aquifer contains of Miocene marl. The character of the Miocene aquifer is multilayer constituting of calcarenites and sandstones with intercalated marls. It is located between 600-785 m a.s.l. The drillings in the past were first identified in the Miocene aquifer. The aquifer occupies an area of 168 km^2, with a thickness of 100 meters. (Gonzalez-Ramon et al, 2013, Gonzalez-Ramon et al, 2007). The permeable level normally does not reach beyond 20-30 meters. The limits of the area are delimited by contact with tertiary marls. This creates the impermeable substrate and constrains the contact with the Jurassic aquifer within the confined area. All the productive levels are connected due to a large number of operating wells being poorly designed (Gonzalez-Ramon et al, 2013).The majority of the infiltration comes from precipitation. The renewable resources reaches about 7,6 hm^3/year. The discharge is naturally produced be several springs. The water flow reaches between 1-4 l/s and around 100 m^2/day.

The Triassic aquifer

The Triassic aquifer contains of multi-layers of sandstones inserted in clays, which shapes the exploited lower level. It is positioned at greater depth and has a thickness of 200 meters (Gonzalez-Ramon et al, 2013). Around 70-80 meters of clay confines the majority level of sandstone. Gypsum appears in the top of the aquifer, resulting in that the water has a higher pressure than the atmospheric. The water quality is poor due to the existence of gypsum. The infiltration of water comes from the outcrops in the north and northwest (Gonzalez-Ramon et al, 2007).

The aquifer is still quite unknown regarding its water flow and discharge, since there are no specific studies of the aquifer. Though, it has potential to contribute with additional groundwater resources in the region (Gonzalez-Ramon et al, 2013). A layer with a thickness of 50-95 meters, containing low- permeability evaporitic shales, separates the Triassic aquifer from the Jurassic aquifer. The lithology and geometry of the Triassic aquifer is recognized to be cut by multiple drillings situated on the left (south) bank of the Guadalimar River, and mostly by borehole drillings situated on the right (north) bank, where the main aquifer is exploited (Gonzalez-Ramon et al, 2013).

Water balance in the aquifer

González Ramon (2007) presents the water balance in the aquifer estimated in 2007 (see table 5).

	The free aquifer in the right river bank	**The free aquifer in the right river bank**	**The confined river**
Inputs	• Infiltration of precipitation: 22 hm^3 • Infiltration of precipitation: 22 hm^3	• Infiltration of precipitation: 22 hm^3 • Infiltration from the Guadalimar River 2,9 hm^3 • Recharge from the right river bank: 10,6 hm^3	• Infiltration from the free aquifer: 16 hm^3 • Recharge from the Miocene aquifer: 3,3 hm^3
Outputs	• Extraction from pumping: 3 hm^3 • Discharges from springs: 2,4 hm^3 • Discharges from the Guadalimar River: 7 hm^3 • Volume that pass to the left river bank: 10,6 hm^3	• Extraction from pumping: 3,3 hm^3 • Discharges from the Guadalimar River: 4,5 hm^3 • Discharges from the confined aquifer: 16 hm^3	• Extraction from pumping: 32,6 hm^3

Table 5. Water Balance of the aquifer 'Carbonatado de la Loma de Úbeda`. Source: González Ramon, 2007

As demonstrated in the table above the free aquifer in the right river has a surplus of 21 hm^3 and the free aquifer in the left river bank a surplus of 11,7 hm^3. The confined aquifer has a deficit of 13,3 hm^3 and the extraction source is solely from pumping of water.

6.2 'Fracking' in the aquifer

Previous threats towards olive production has been seen as the increased expansion of Chinese crops, the production in Morocco, the decreased prices and the reform of the CAP. At present another more severe threat is discussed, *fracking*, also known as hydraulic fracking. The term was introduced by the company Oil & Gas Capital, Ltd. The technique is used for extraction of natural gas by drilling of a well, in the beginning vertically and later on horizontally. Sand and water is mixed and with high pressure pumped inside the well, with about 400 chemicals of different types. The depth of the wells is normally 2000-3000 meters, but could reach 5000 meters. The release of natural gas occurs when the slate breaks. In the province of Jaen several permits has been granted for exploitation of gas using this technique. (Catena-Viedma, 2013).

Catena-Viedma (2013) investigated the area of the Jurassic aquifer in Úbeda and defines the case as "*a huge carbonated and highly fractured aquifer that meets the requirements for bearing the brunt of all the negative impacts this technique can cause*" (Catena-Viedma, 2013). The situation can result in negative effects of the production, in particular within the municipalities of Villacarrillo, Úbeda and Baeza. The aquifer of Ùbeda covers around 20,000 km², includes about 300 wells, and provides 20,000 ha of olive groves with irrigation. The aquifer can suffer from severe affects if wells, using the fracking technique, are drilled in this area. Several areas can suffer from pollution, depending on the flow directions of the aquifer. These areas include (Catena-Viedma, 2013):

- The aquifer itself, consisting of 880 km² (involving both the confined and unconfined parts).
- The Guadalimar River, linked to the aquifer and used as a natural water discharge.
- The Giribaile reservoir, having direct contact with the aquifer and collecting water from the Guadalimar River.
- The Lower Guadalquivir, since its main tributary is the Guadalimar River.
- The carbonated surface of the area of Beas de Segura, since it possibly is connected to the aquifer.
- The Miocene aquifer of Úbeda, since it has connection with the deeper carbonated aquifer through wells.

In table 6 below the development of olives crops are presented counted from the year 1901 until 2000. The table demonstrates that the surface in the province of Jaen has increased with 430,546 during this period.

Year	Area (ha) in the province of Jaen	% relative in Andalucía	% relative in Spain
1901	152.736	20,37	12,03
1930	300.350	31,53	15,95
1960	357.660	31,42	16,65
1999	492.757	38,8	23,23
1997	552.804	39,54	24,24
2000	583.282	42,05	25,99

Table 6. Index of concentration of olives in Spain and Andalucía within the province of Jaen during the 20th century. Source: Jiménez et al, 2002.

Catena-Viedma (2013) argues for that irrigation of highly polluted water will affect the olive production negatively, since it cannot be published as a good product. In addition to pollution, another negative affect could be increased such as the seismic activity. There are several smaller sized faults; in addition there are three main faults. The deeper materials are affected by these main faults and can be reactivated due to the lubrication originated by the fluid injection. Experts are speculating in that the major changes in water levels, the hydraulic fracking and the explosions causes' seismicity. The aquifer and its overlying and underlying units have to be considered to not reactive the faults or develop new fractures. The seismicity could increase as a result of decomposition of a immense quantity of evaporates, situated in the geological unit below the aquifer. This occurs when large amount of water is extracted, going through the fractures in the lower levels. It may collapse, cause movements and increase the quantity of earthquakes (Catena-Viedma, 2013).

7 The case study of 'la Loma'

This section involves the actual case study. The following information was provided during the interviews, providing information regarding the expansion of irrigation in the area, the role of the Association and the Basin Authority, implemented changes for use of water, and the future aspects of the aquifer.

7.1 Farmers expansion of irrigation in 'la Loma'

During the drought in the early 1990's the farmers began using wells due to lack of water in order to continue the cultivation and increase the profit. Several of the wells were constructed during the night to not be discovered. The wells normally reached up to 500-600 meters and at times up to 1000 meters. The Basin Authority (CH) was not given time to respond to the large expansion of wells and farmers begun asking permission first after the wells were in use. This resulted in that about 5000 wells were defined as illegal and more wells existed than could be handled. The growth rate was facilitated due to the access of irrigation. The average yield was multiplied by three in comparison of data in the period of 1987-1995 and the period of 1996 and 2007. The result has been major extractions of groundwater without concessions. The aquifer involves a large area of 14 municipalities and about 10,000 farmers using the water in the aquifer for irrigation. The aquifer supplies approximately 40,000 ha, making water management an important task. From the farmers perspective some of the major issues is the low cost of the product and the high extraction cost of water, reducing the profit. Therefore some farmers have been forced to return to rain fed agriculture. Legalization was intended with temporal concessions to control the use of water in the aquifer, but was in the final not realized. The user Association of 'Carbonatado de la Loma de Ùbeda, by pressure from the farmers who had began to unite, began to exchange information and performed an investigation in collaboration with Geological and Mining Institute of Spain (IGME). This due to lack of cooperation from the CH. The result was that for the first time the real situation was determined regarding the water used for irrigation in the aquifer. After this the farmers who had joined together decided not to wait for the CH, with the belief that the issues in the aquifer only could be solved by acting together.

At present the situation has reached severe difficulties due to that several wells are drying up. The question is whether this prevents the continuation of constructing wells. The Geographic Information Systems (GIS) has been used as a tool and increased the control of water use in the area. Despite being basic it has facilitated and improved the water management. The Management Program of Irrigation Communities (GESTAGUA) is another tool for water management. It focuses more on surface water and only minor part on groundwater. Until recently the Association has not yet been using it for groundwater use. In general, olive crops needs less amount of water in comparison to other crops, being one of the reasons for the major extensions of olive crops in the region of Jaen. Irrigation is used for about 6-7 months per year. The major benefits received by the farmers are mainly economic, since they are able to increase their production and social benefits since it creates more employment. Despite the high amount of water used within agriculture, the Association and the users believe that the agricultural sector only has a small, if any, effect in reducing the availability of water for other sectors. There is no belief that lack of economic value of water has resulted in over-exploitation and inefficient use of the resource, since water has a high economic value due to high extraction costs. It is argued that the issue depends more on bad management of the resource. Before the cost of water extraction was lower, possibly giving it a lower economic value, but today the cost has increased due to a large increase of the energy price. If the users do not manage the resource well, it will cost them more than the profit of the product. The price on energy has been multiplied by 2 or 3 compared to when the farmers first began to use irrigation. This has resulted in that the extraction of water today costs about 5-6 Euros/olive (1,20-1,28 Euros per m³). For example, 1 ha that has about 100 olive crops costs about 500-600 Euros.

7.2 The user Association of 'Carbonatado de la Loma de Ùbeda'

The Association was created on initiative of the farmers in 2001, due to the drought in the early 1990's. One of the main tasks of the Association since its inauguration has been to be recognized by the CH to fulfill that each of the users is legitimized. The CH is the responsible authority for control and decisions regarding water management. In the beginning of 2007 the Association requested recognition as a community user of the aquifer of 'la Loma', but the authority would not approve any farmer that did not have title or their use legalized. This has resulted in that even today the constitution for the community users are still in process and the main problem still remain due to a slow administrative process. The absence of concessions from the CH is one of the main political issues. The constant political changes are one of the major issues related to a possible improvement of the utilization and the management of water in 'la Loma'. It needs to be mention that at present nobody receives concessions due to the basin closure in 2005. Despite this, unless the politics change it will be difficult to realize any significant changes. At first, too many requests were sent to the CH for approval of wells, resulting in that the authority turned down all requests with reasons as for example distance between wells or other technical reasons. According to the Association the stated reasons lacked reliable investigation. Another reason behind the decision not to recognize the Association was the belief of not enough water in the aquifer for the volume asked for. The farmers were asking for 1500 m³/ha, but the CH was only willing to give 1000 m³/ha. There is belief in that 1000 m³/ha could be enough if the resource is managed well. An additional issue has been that 90 percent of the polls have lacked administrative concession. The Association state that this has been reduced to about 80 percent. Another issue has been the large number of duplicated files with 7000 m³. This situation has been improved and the reason was that the farmers began to use wells in lack of concessions, which resulted in duplication due to request from the CH plus the wells.

The past years have not been easy, nor for the users or the Association due to the difficult relation with the CH. Despite disagreement between the different actors an agreement upon actions for conservation of the aquifer has to be made, which is what all partners are striving for. The status of the aquifer is highly depending on the decisions implemented today. The problems faced both in the past and today are complex and to precede irrigation in the future these problems requires a solution that are definite and immediate. From the point of view of the Association, one of the reasons for the slow political process is due to several changes within the CH. During the 10 years that the Association has been trying to be recognized, the political and administrative requirements have constantly brought new ideas and new restrictions. Each time the requirements from the CH has been accomplished additional requirements has been added, resulting in the Association spending a lot resources, both time and labor, without progress and constantly starting from the beginning. The Association considers that recognition by the authority would facilitate and improve the water management in 'la Loma', but they have not been facilitating the process and instead added more challenges. The farmers do not, due to lack of recognition, receive subsidies for use of water nor for investment in wells and irrigation systems.

The absence of recognition has resulted in that neither the farmers nor the Association have rights for participation in modifying the operational rules. The aquifer and its users have a major importance in terms of water management and a major economic importance, concluding that these actors should not be ignored. The decisions by the CH are accepted by the farmers and both actors tend to be in agreement on improving the water situation on a long-term perspective. Though, there is a lack of relation, confidence and dialogs between the different actors, affecting the management. The dialogues taking place only reach a limited extent and do not have further continuation nor result in action. Trust and transparency are important factors within the strive for a more sustainable water management. Arguably, trust exists between the users and the authority, but the users have been fighting to obtain their rights for almost a decade. This has resulted in frustration of all partners involved. Local knowledge are of importance within resource management and an interchange has to be included in the decision making process. Local users need to have access to complete information about their situation and legal rights. At present there does not exist any direct benefits or compensation for the users who contribute or invest in water saving measures.

7.3 Monitoring and implementation of new restrictions

Major exploitations of the aquifer 'la Loma' have existed during a long period without any kind of regulation and without clear limits of water extraction. In 2007 the official newsletter of the Province of Jaen published the new conditions for granted concessions in the UH 5.23. This resulted in a reduction of concessions from 1500 to 1000 m^3/ha/year. Appropriation and provision rules are defined by the Water Law and the HBP to be congruent with the social and environmental conditions. In terms of private water, this has been one issue less for the CH. This since before the implementation of the water law in 1985 the use of wells for irrigation in 'la Loma' was minimal and private water was not representative in the aquifer. Therefore the area of 'la Loma' was neither affected by that the catalog for private waters was paralyzed and unsolved since 1988.

The CH is the unit monitoring both the users of the aquifer and the water resource. A plan has been formed by the CH to reduce the water right doses. The majority of farmers in the area of 'la Loma' do not have access to concessions and thereby considering not being affected by this reduction. One major problem in terms of control is that the CH within the entire province of Jaen only has five persons to control the use of water. Despite that all wells has volumetric counters installed to control the volume of extracted water, the lack of resources in terms of labor create major difficulties in controlling and managing the users and the resource. In addition, about 200 wells are private, meaning that there is no control in the volume used. In the province of Jaen there are about 200-300 request for construction of new wells each year. In the area of 'la Loma' there are about 8 requests per year. These are all denied, since it is no longer legal to implement new wells. The financing of the wells has since the initial been private and not been a cost for the State of Spain. Due to lack of monitoring, water from the aquifer has been extracted with high volumes. Major costs are now facing the area, since the wells in 'la Loma' are drying up. The CH is the unit entitled to sanction illegal users and the sanctions given depends on the amount of water used. Illegal users has been reported and paid large amount of sanctions, though in disagreement by the Association. The reasons for the sanctions according to the CH are illegal water use, since the wells are not legalized. The disagreement from the Association is based on the slow administrative process, changing politics and the unwillingness of the authority to recognize the Association.

7.4 Future aspects of 'la Loma'

There is lack of data on the amount of water extracted in the aquifer, making it more difficult to assure whether or not the extractions are sustainable. The last study that includes the actual water balance in the aquifer is from 2007, which then was 14 hm^3. The water balance today and whether this has changed or not is unknown. Despite the uncertainty of the water extraction there are different views on the water situation and the sustainability. According to the Association sufficient measurement of groundwater use do not exist, making it more difficult to control it and improve the management. One reason could be that there exist more studies regarding surface waters in comparison to groundwater, something that needs to change.

One option for the farmers to balance environmental and efficiency pressure with their own need to maximize the performance of the irrigation business is to investigate in technology together with their neighbors. Another solution proposed for a more sustainable use of water and to decrease the risk of overexploitation of the aquifer is to recharge the aquifer in years with high precipitation. This is planned to be made through artificial recharge of the aquifer. Plans are already made to fulfill the project, but it does not exist any pre-study or an economic analysis. At present no concrete project exists, but there has been several discussions regarding construction of dams (more correctly micro-dams), with capacity of 500,000 and 1,000,000 m^3. If implemented these would be used during the winter season. Geotechnical and environmental aspects needs to be considered, since these constructions could have major effects on the surrounding land. Cost estimations for a dam with capacity of 0,5 hm^3 is €1,15 millions and for 1 hm^3 €1,65 millions. As mentioned, a reduction of concessions was implemented from 1500 to 1000 m^3/ha/year. Estimated for 20,000 ha this will reduce pumping of water with 10 hm^3/year, resulting in a lost of production with a cost of €3,5 millions/year. To respond to the reduction of 10 hm^3/year about 13-26 dams would be necessary to construct, with a cost of €21-30 millions. The WFD and HBP both strive for improving the use of water and create a more sustainable management, which includes water saving technologies through modernization to increase the water supply. For farmers without financial help in the implementation of these new technologies it can cause more difficulties to implement these.

8 Analysis and discussion

8.1 Management of the commons in 'la Loma' – Ostroms eight principles

Effective solutions can be difficult to achieve when managing CPRs, as for example water. One of the reasons is that there is no guarantee that an implemented solution will be error-free (Ostrom et al 1999). It has been stated that overexploitation is due to a lack of ownership and that the competition over resources causes conflicts between the users (Söderqvist el al, 2004). Competition over limited resources tends to cause users to be less restrictive in their consumption, due to the risk that others might continue to use the commodity unrestrained and thereby gain larger profits. The example can be seen in 'la Loma' and is a probable reason for the overexploitation of the aquifer. It is true that the lack of ownership can result in overexploitation of a resource, since nobody can be excluded from using it and payments are not required. Privatization was the solution mentioned by Hardin (Ostrom et al, 1999) to deal with these issues, since it could create more control of the resource. In the case of 'la Loma' the amount of private wells is small, but the majority of them are not controlled in terms of water quantities. Therefore the solution of Hardin, regarding privatization, can be discussed whether or not it is the most effective. Ostrom (1990) proposed another solution, being effective governance (the eight principles mentioned earlier). The question is whether or not these solutions are difficult to achieve. Privatization and national government are discussed by Dolsak and Ostrom (2003) stating that external authorities have to regulate a resource in order to manage it. The use of water creates competition between users, which in turn creates conflicts. If conflicts result in self-interest, how can the resource be managed effectively, if individuals look at short-term solutions or benefits. Regulation by external authorities could easily be affected by self-interest or conflicts of interest. This since agriculture in Spain is an essential economic factor dependent on irrigation. The national economy is dependent on a continued production with low prices in order to compete on the international market.

Mentioned by Dolsak and Ostrom (2003), different areas and different parts of the world have diverse conditions and characteristics and therefore depend on a management customized for the particular case. It is of high importance that responsible authorities customize the management and not create solutions based on one-size-fits-all. It is important to include all actors, from small scale to centralized government. Lessons can be learned across sectors and political levels. In the decision making process it is essential to include considerations from the local knowledge and experiences. Local users in 'la Loma' could contribute with information not available or known by the central government. At the same time, actors on a small scale might be easier to control. If looking at the situation in 'la Loma' the lack of centralized government has resulted in a lack of control and overexploitation of the resource. Something being argued by Ostrom et al (1999), one cannot exclude the other. They go hand in hand and resource management depends on cooperation of institutions at different levels. Ostrom et al (1999) mentioned that self-organization has managed CPRs in the past, but can we continue to rely on self-organization at the present time? The question is if the water, as well as other resources, can continue to be self-organized when reaching its limit. Actions need to be taken before the resource is depleted and becomes unusable.

Institutions within countries and between countries need to be nested in order to create solutions that can be implemented according to the decision making process. It can be stated that globalization is affecting the use of water and water management. Also, global commons constitute more complexities, requiring global action. Despite the importance of global action, the focus on local level and specific local solutions is required. Technology is often referred to as a solution to the problems, leading to improvements in the ability to monitor and identify resources (Ostrom et al 1999). Can technology be relied upon to solve the water issue? Technology versus decision making has been discussed by Ostrom et al (1999) with arguments that technology cannot be seen as a substitute for decision making. Technology is an important factor and has lead to improvements, such as different water saving measures, etc. Though, to solely rely upon technology could cause more danger, since it could result in a lack of decision making and necessary implementations of new restrictions or actions. Precaution has to be taken to not act without knowledge of possible consequences.

Water is essential in the everyday life and the water demand is increasing with population growth. If the water resource is scarce today, how can over-use be prevented in the future with a continuously increasing use and need for clean water? To this question one of the solutions mentioned by Ostrom et al (1999) is to restrict access to the resource to solve the issue of CPRs. The question is how to restrict access of a resource that is considered to be a common property. The farmers in 'la Loma' constructed wells to facilitate the extraction of water and increase production. Despite the lack of permit, the wells have been operating since the early nineties. The reduction of water use has not been realized due to restricted access, but rather increased price of extracted water. At present the use of water is dependent on the price. In case of a reduced price this could result in an increased use of water again. Therefore it is important to create an effective management when the resource is scarce to guarantee a continuous restricted use when the resource once again is sufficient. A second solution mentioned by Ostrom et al (1999) is to create incentives, making the users invest in the resource and prevent overexploitation. This in turn does not directly create restricted access. It more likely creates an understanding and knowledge regarding the limits of the resource and the importance of not overexploiting it. Making investments could be a difficult task, due to the risk of free-riding. One user might not make an investment unless all users make investments. There is a risk that everyone waits for others to act first. In this case trust is an essential factor. Smaller groups could be more easily handled than larger groups, since it would be easier to get together and make agreements. In the case of 'la Loma', both the irrigated area and the amount of irrigators involved are large, making it difficult for the responsible authorities to have conversations with every individual user. There are also difficulties in getting people to know each other and to get them to trust one another. For example, one neighbor using a well might cause other neighbors to do the same in order to gain the same benefits. The question how to prevent over-use is highly difficult. Norms are not sufficient to guarantee the prevention of over-use. Rules could create certain limitations, as for example the right of access, sanctions, etc, but to be efficient the use of water must be monitored. As stated earlier by Ostrom et al (1999) the implementation of rules needs to be effective, legitimate and fair to users and at the same time take consideration to complex interactions and dynamics of the resource. The definition of fair varies between individuals and if all definitions of fairness need to be considered it will be highly difficult to make any kind of implementation of restrictions. Each individual also defines effective and legitimate differently, creating difficulties in involving each and every individual. The process of creating rules and restrictions needs to primarily consider the environmental aspects and the limits of sustainability. If nature cannot continue to provide a resource other aspects are no longer applicable. Despite restrictions and limitations on EU, national, regional and local level, monitoring is lacking in 'la Loma', which has resulted in a more free use of the water resulting in water scarcity. Laws also require strict monitoring in order to make sure they are followed and clear to all concerned. There must be consequences for when these rules or laws are not followed. The central authorities should not be seen as the only decision makers. Effective rules can be adopted by the users, whom can hold essential knowledge of the particular case from a local/user perspective.

An additional important factor is the price of the water. It has been argued that a higher price of water will encourage better management, while a lower price will reduce organization and the guarantee of a continuously available resource in the future (Ostrom et al, 1999). Price is a difficult topic due to the present economic situation in Spain. As mentioned, the price of water has increased a lot for the irrigators in the area of 'la Loma', causing several issues for the farmers depending on the resource. This is one incentive to save and use less water within agriculture. In the case of 'la Loma' the high consumption of water during a long period of time has caused challenges for the aquifer to recover. Lessons have to be learned from the past and precautions need to be taken. Attention must also be given to challenges in the future since environmental change is not linear, and will likely require global institutions to deal with new water management issues.

The table below indicates the management of the aquifer 'Carbonatado de la Loma de Ùbeda', within the perspective of the principles developed by Ostrom of managing the commons. It demonstrates the responsible management regime within each principle. The principles used in table 7 were redefined by Cox et al (2010), whom divided some of the principles into two parts.

Name	Principle Description (Cox et al 2010)	Aquifer 'Carbonatado de la Loma de Ubeda' (ACLLU)	Management regimes
1A User boundaries	1A User boundaries: Clear boundaries between legitimate users and nonusers must be clearly defined.	No	The Basin Authority
1B Resource boundaries	1B Resource boundaries: Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.	Yes	Research by Instituto Geologico Minero de España (IGME) / Hydrological Basin Plan Guadalquivir
2A Congruence with local conditions	2A Congruence with local conditions: Appropriation and provision rules are congruent with local social and environmental conditions.	Yes	Water Law / Hydrological Basin Plan Guadalquivir
2B Appropriation rules proportional to effort	2B Appropriation and provision: The benefits obtained by users from a common-pool resource (CPR), as environmental conditions. determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.	Argubly	Value of water extracted = f(inputs, capital)
3 Collective-choice arrangements	3 Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying the operational rules.	No	Indirect participation of the irrigation communities by the Asociation
4A Monitoring users	4A Monitoring users: Monitors who are accountable to the users monitor the appropriation and provision levels of the users.	Argubly	The Basin Authority
4B Monitoring the resource	4B Monitoring the resource: Monitors who are accountable to the users monitor the condition of the resource.	Argubly	The Basin Authority
5 Graduated sanctions	5 Graduated sanctions: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.	Yes	The Basin Authority
6 Conflict-resolution mechanisms	6 Conflict-resolution mechanisms: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.	Yes	The user Asociation of 'Carbonatado de la Loma de Ùbeda'
7 Minimal recognition of rights to organize:	7 Minimal recognition of rights to organize: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.	Argubly	Included in the Hydrological Plan / Tha Spanish Constitution
8 Nested enterprises	8 Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises	Argubly	Irrigation communities / The user Asociation. / The basin Authority/ Junta-Andalucía-Ministerio Medio Ambiente
OTHERS	Supply increase /water saving technonlgies	Argubly	Irrigation communities / The user Asociation. / Water Framework Directive/ Hydrological Basin Plan

Table 7, Management of water as a common pool resource in the aquifer 'Carbonatado de la Loma de Ùbeda'. Source: Cox et al, 2010 and own construction.

Principle 1: Well-defined boundaries

Principle 1 was divided into two parts. It separates user boundaries and resource boundaries allowing them to be analyzed in more detail.

Regarding principle 1A, well defined boundaries are, according to Ostrom, necessary to separate the legitimate users from the non-users. In the case of 'la Loma', 90 percent of the polls have lacked administrative concessions. This is one of the reasons behind the lack of control and the lack of clear user boundaries. In the beginning the users were able to extract water without limitations and they used the amount of water that was most beneficial for them. Without solving these issues a solution to the problems is difficult to find. Another issue is the small quantity of water in combination to the high profitability, resulting in that the wells are drying up and causing a more unsustainable situation. Administrative arrangements are necessary to create clear user boundaries.

Regarding principle 1B, there exist clear boundaries in 'la Loma'. This defines the resource system and separates it from a larger biophysical environment. The research done by the Geological and Mining Institute of Spain (IGME) has increased understanding of the situation in the area and the actual resources available. The implementation of the Hydrological Basin Plan (HBP) has defined the boundaries of the resource system, which strives towards a more efficient and sustainable use of water.

Principle 2: Congruence between appropriation and provision rules and local conditions

As for principle 1, the second principle was divided into two parts.
Regarding principle 2A, appropriation and provision rules have been set by the Water Law and the HBP of Guadalquivir. This was applied in the area of 'la Loma' by the Basin Authority (CH). A new limit of concessions was implemented, from 1500 to 1000 m^3/ha/year to be congruent with local environmental and social conditions. To create a better congruence between appropriation and provision rules and local conditions, solutions based on local conditions need to be in focus instead of one-size fits all. This requires further research in order to increase knowledge of the boundaries in the particular local areas. The research needs to be shared between all involved stakeholders on different scales. The solutions need to be customized for the particular area and issue per se. If applicable, it could later be applied to other areas on a national or global level. A match between the local and scientific knowledge to reach agreements that result in action is necessary.

Regarding principle 2B, the value of extracted water has changed since the farmers first began irrigation. Previously the obtained benefits from extracting water were higher than the cost of water, making the inputs more profitable. The negative aspect of a low cost of a common resource is the lack of consideration to environmental conditions. This is one main issue in the management of public resources, since there is no price and no exclusion. As mentioned by Ostrom, free-riding becomes an easy way to receive benefits from using the resource without paying its price. A higher price on extraction of water has resulted in that farmers tend to use less when possible, to reduce the final cost. Though the actual cost of water is not covered, the extraction cost in terms of energy consumption is.

Principle 3: Collective choice arrangements

Principle 3, collective choice arrangements is not applied in the case of 'la Loma'. The irrigation communities (CR) have an indirect participation through the Association. The majority of the members are farmers or owners of one or more wells. Without being recognized by the

Administration, the Association does not have the right to participate in modifying the operational rules. Operational rules could be more effective and better addressed if local knowledge were to be considered. This since the local population could provide useful knowledge regarding the more severe issues and of where action is needed.

Principle 4: Monitoring

Principle 4 was divided into users and the resource.
Principle 4A is arguably applied in 'la Loma'. The CH is the responsible unit for monitoring the users. Each well is provided with volumetric counters to control the amount of water extracted. In theory it is possible, but in practice the control is not complete due to lack of employment. There are major difficulties in monitoring all users with only five people controlling the use of water within the province of Jaen.

Regarding principle 4B, it is arguably applied in 'la Loma'. Piezometric information is available to control the resource. Though, the effectiveness depends on the actual controls being applied and how the information is used for further action. The data is available, but the question is how it is implemented to create a more rational and effective way to better manage the commons.

Principle 5: Graduated sanctions

Graduated sanctions have been applied in the area of 'la Loma'. Due to disagreements within the Association not all sanctions have gone through. The case of 'la Loma' is rather complicated. Farmers want their wells to be legalized, while at the same time the CH cannot legalize them all due to major amounts of already existing wells. Neither can all the wells in use be closed. At the same time the situation for the farmers is difficult, since the situation at present cannot be changed, and the operational rules need to be followed. Not fulfilled sanctions do not deal with the existing conflicts of the water resource.

Principle 6: Conflict-resolution mechanisms

Conflict resolution mechanisms are applied in 'la Loma', which are the locals maintained by the Association. This is handled by local members of the Association and provides fast and low-cost access to locals to solve conflicts. The members of the Association organize meetings to discuss the current situation and future aspects. At present not much has changed and the members do not believe in any major changes in the future until recognized by the CH. A recognition is seen as a major step towards improvement in the water management, but local actions are also of high importance.

Principle 7: Minimum recognition of rights

Principle 7, minimal recognition of rights to organize can arguably be applied for the case of 'la Loma'. The area is included in the HBP and within the Spanish Constitution. Though, the legalization process has been challenged due to a slow administrative process and constant changes of the political requirements. Transparency and trust has been discussed as two important factors within governing the commons. According to members of the Association there is a lack of both factors, affecting the improvement of water management. This needs to be addressed through more dialogs between the individuals concerned, in order for all to understand the situation and the actions needed to solve the issues.

Principle 8: Nested enterprises

The institutions involved in the aquifer of 'la Loma' are the Association, the CH, the CA, and the CR. Institutional nesting is an important factor since it could result in nesting different aspects. At present the institutions representative in 'la Loma' are facing difficulties in being nested. Despite working towards the same goal, progress towards sustainable development is being restrained due to the lack of control and collaboration. At present there is more institutional nesting between user groups than compared to the past. The reason is that the groups are more united and trying to solve the issues within the CR and the Association. It could be more effective if the user groups became more nested with the larger governmental jurisdictions.

Others

The farmers in collaboration with the Association have an interest in increasing the water supply in the area in order to continue the olive production. Projects that include construction of several small dams are intended to create an artificial recharging of the aquifer. Though pre-studies are highly necessary to gain knowledge regarding potential negative effects on the river and affected ecosystems. The objectives within the WFD and the HBP are also striving for a supply increase and implementation of water saving technologies. There is a major need for more studies in the area to gain more knowledge about the amount of water being extracted from the aquifer and to make estimates of what extraction is sustainable.

8.2 Towards a more integrated management of water

The term Integrated Water Resource Management (IWRM) has reached a global status and is an essential step in striving towards a more sustainable use of water. Integrated management is seen as a tool in adapting to climate change and securing the production of food. All components of IWRM (as seen in figure 2) need to be integrated, which includes equity, efficiency and environment. As stated earlier, effective governance can be reached through integrated, adaptive and ecosystem based approaches. As mentioned, methodologies for governance focusing on water management, in particular IWRM, has not been developed in the same manner as measurements of governance (Allan and Alistair, 2010). Putting more effort and resources into developing stronger and more effective water management techniques can be seen as an essential factor in achieving sustainable water management. To increase the understanding of good governance and to effectively succeed with its implementation is of major importance. The term good governance is vague and unclear, both its meaning and in how to achieve it (Van DoeVeren, 2011). Despite the criteria developed by the World Bank (mentioned earlier) it could cause confusion in what actions and restrictions to implement. Other main issues are deciding what requirements should be fulfilled. As mentioned by Allan and Alistair (2010) new criteria and guidelines need to be implemented within the EU. The EU has a major role for including all member states and to guarantee that each one implement the restrictions developed and continue to strive to improve and to reach a sustainable level of water management. Clearly this involves difficulties due to several countries involved and it could be of importance to look at each country, since different conditions require different actions. As mentioned, technology is seen as a tool to solve the water issue. Though, if the resource is governed better this could, by itself, lead to more sustainable water management and more efficient use of water. Technology could be implemented as an additional improvement to effective water management.

Spain is a country with a high dependency on water and on improving the situation regarding the management of this resource. Though, Spain has a developed knowledge of managing the water resource. It can be questioned how a country like Spain, with a hot and dry climate has been able to develop such a large amount of agricultural production. The reason could be due to good resource management. Though, the water supply is limited, which the area of 'la Loma' is dealing with. The high use of water and the lack of control have caused a major decline of water in the aquifer. As mentioned, the major issues started in the early 90's with the combination of a major increase in olive crops and a low amount of water control. The production rate is the same today, but the water is consumed more carefully due to higher cost and lower profitability of the production. As mentioned by Hassing et al (2009), a scarce resource results in increased value, while a rich resource results in less value if any. It can be questioned whether or not a rich resource of high value and subjected to good governance reaches scarcity. If the water use in 'la Loma' had been regulated from the beginning, the aquifer might not have been exploited to the point of water becoming scarce. Hassing et al (2009) argues that small-scale use is dependent on local ownership and initiatives, whereas large-scale use needs to be regulated on a central level. The majority of the water in 'la Loma' is common property and therefore lacking local ownership. Initially, initiatives were lacking until the Association was created with the intention to change the situation and create a more sustainable level of water usage. Even though regulations exist on regional, national and on EU level, it is not enough to have sustainable management. Lack of monitoring and implementation of regulations, as in the case of 'la Loma', results in that the goals of IWRM are not reached. The implementation of IWRM requires a long process. Dialogs, cooperation and involvement of all actors are of high importance within and between all levels, from basin to EU level. Priorities have to be taken, in particular since multiple institutions and sectors using the resource are involved. This causes challenges in trying to create an integrated management. The decision making process needs to take all of these aspects into consideration.

Political ecology also includes integration and an increased understanding between different sectors at different levels. An increased understanding and collaboration is essential in striving towards more integrated water management. Water is continuously moving and without cooperation between different cities, regions or countries, sustainable management is difficult to reach. As mentioned, the management of water is highly affected by different factors. Some of the factors are according to Hassing et al (2009) more controllable, as for example the demand on a resource. Others are less controllable, as for example climate change. It can be discussed whether or not the demand on the water supply is actually controllable. For example the demand from agriculture is difficult to control. The world's population and the economy are highly dependent on the production of food. As a population and its welfare increase, the demand on food production also increases. This causes a tremendous demand on the water resource. And drought as the result of climate change, will be an additional strain on the water supply. An increase of water consumption affects the supply of drinking water and the quality of the water becomes more polluted due to pesticides, etc, used in agriculture. Therefore it is important to create an integrated water resource management, where all factors are included. Exclusion of one factor may result in negative consequences later on.

Despite that the principles of IWRM have been applied across sectors and on a global scale, the increasing use of water, in particular by irrigation, require additional restrictions regarding efficient use and sustainable management. Even though IWRM is not a scientific theory, it provides essential suggestions for water management and the development of sustainable use. At the same time as the guidelines of IWRM could be seen as vague, it gives flexibility in the adaptation, depending on the case per se. Different geological conditions or different levels can require different actions. As mentioned by Hassing et al (2009) an assessment of each situation is required in order to implement appropriate reforms, institutional arrangements and management tools. It is important since there are many aspects to consider, as for example political, environmental, social, economic and cultural (Hassing et al, 2009).

As mentioned, the use and management of water consumption involves several aspects, all of which influence the water situation as a whole. One factor affects or is dependent on other factors since there is a relationship between these (Neumann, 2009), making management a difficult problem to solve. Without understanding the past, the present and possible future outcomes of water management is hard to predict and good management hard to accomplish. Therefore knowledge and understanding of the relation between different aspects and possible consequences are of high importance in order to successfully implement customized actions where needed. Environmental issues contain high complexity with continuous changes over time. Management regimes struggle with different geographical scales and hierarchies of socioeconomic organizations. Therefore approaches such as IWRM and political ecology are essential in order to create interdisciplinary understanding and cooperation.

IWRM and political ecology are not scientific theories but are still essential, not solely regarding water management, but regarding environmental issues in larger terms as well. Blaikie and Brookfield (1987) discuss the importance of 'chains of explanation'. In simple terms this explains and tracks the constantly changing society-nature that begins on the individual level, for example the 'land manager', and continues up to the global scale. To understand the case of 'la Loma' it is important to start at the beginning of the chain and investigate the individual farmer to gain knowledge of the number of hectares irrigated in the area and the amount of water used for irrigation. The chain continues with restrictions and laws decided on the regional, national, and EU level. This since the state, according to Blaikie and Brookfield (1987), has an important role concerning political ecology, as for example the implementation of food policy, taxation, land tenure policy and allocation of resources. Even if the state has an important role in regulation, conflicts of interest could affect the decision making, which is one possible reason for the over-use of water. Irrigation increases the production, increased production results is lower prices, which creates competition on the international market. In the end this benefits the national economy. The question is to what extent economic growth should be in focus. Economic growth depends on a continuous production, causing continuous demands on the water resource. It is of high importance to investigate economic, environmental and social limitations within a country in order to design a system of resource management customized to these limitations.

Environmental degradation can also explain past actions and decisions. As stated earlier, lessons can be learned from the past. Environmental degradation in the past might result in consequences in the future. Precautions have to be taken and knowledge should be acquired before implementing actions. Environmental effects are not always linear causing difficulties when trying to predict the consequences of a continuous extraction of water in 'la Loma'. If finally the aquifer dries up completely it will for sure not only affect the farmers, but also the land surrounding the area and ecosystems depending on the aquifer. The principles of ecology need to be applied in politics for decisions to be based on robust knowledge. As stated by Neumann (2009), a larger focus on ecological and social aspects regarding approaches and methods are essential to gain more profound knowledge regarding environmental degradation. Another important aspect is to understand the resilience and sensitivity of the land, due to factors such as environmental variability and spatial differences. The land is exposed by diverse demands, causing different effects and consequences. Each demand needs to be investigated further in order to find the correct solutions and where and when restrictions are necessary.

8.3 Adapting to future changes

As discussed earlier, human activities have a major global impact on the environment and decisions made in one part of the world can have effects in other parts. Sustainable water management has become an increasing issue not only in Spain but around the world. This has created a need for an integrated approach to deal with these issues, but also the need to be able to adapt to changes. Folke et al (2005) claims that the issues have become more intensified due to use of technology, capital markets and governance systems. As stated before, new technology has enable water conservation within irrigation, use of less energy, reduction on CO^2, etc. The environment is facing higher vulnerability being a result from a decreased environmental capacity, a result of reaching certain limits and no longer being able to recover to its initial stage. Society's ability to adapt is dependent on that it learns to predict, and that it predicts the necessity to adapt to new conditions and changes. According to Pahl-Wostl (2007) adaptation to change is dependent on knowledge and prediction of the key drivers affecting the ecosystems. Another important factor is that the behavior and responses of ecosystems are limited. For sustainable development it is essential that adaptive management involves all important aspects, for example environmental, economic institutional, technological, etc. (Pahl-Wostl, 2007). An additional important aspect is the importance of implementing a focus on learning within the field of water management, instead of only predicting and controlling (Pahl-Wostl, 2007). Certain changes can neither be predicted nor controlled, but knowledge about the changes can possibly be obtained. By learning the reasons behind the changes the possibility of improving the situation increases. Thereafter the situation can be more easily controlled and future changes can be more easily predicted. For example, if knowledge is obtained on how extraction of water affects the area of 'la Loma', knowledge is simultaneously gained about where control is required. With more knowledge predictions concerning the aquifer's future can be made. While learning to adapt, improvements to management can be achieved.

New experiences and changes require adaptation. This in turn requires an evaluation of alternatives for the particular case, area or system to be managed, since each case needs to adapt to the surrounding conditions. Adapting to new changes could result in that some ecosystems are not able to continuously change their adaptation capacity. This could result in ecosystems reaching certain limits and finally collapsing. The question is how to reach the highest efficiency of adaptive management. Pahl-Wostl (2007) states that this could be done by using management programs as tools to compare policies and practices, and to evaluate alternatives (Pahl-Wostl, 2007). Each comparison and each implemented practice needs to be customized to the particular case, being one of the issues at present where time is constrained along with the need to be cost effective. The question is to what point it can be assured that a system will be able to adapt to new changes. If environmental change is not linear, the exact change in the future cannot be predicted. Predictions based on the past are not a guarantee. The situation constantly changes and there are larger environmental impacts today in comparison to the past, causing new changes. Another question is if an entire system will respond in the same way. Several ecosystems are involved in a system. A reaction in one ecosystem could cause a negative reaction in another ecosystem dependent on the first one. The result could be a collapse of an entire system. Some ecosystems are more vulnerable to changes than others. Pahl-Wostl (2007) argues that a system is not entirely protected against environmental variations due to technical infrastructure. Therefore solutions can not solely rely upon implementation of infrastructure. Infrastructure can be used as a tool to improve different factors, but it needs to be combined with good management of the resource and adapted to new circumstances. Demand management has been mentioned as an important factor. This is an example of managing the resource better in terms of decreasing the demand instead of constructing larger reservoirs (Pahl-Wostl, 2007). Larger reservoirs do not solve the issue of water use, but might instead give an incentive to use more water. This since larger reservoirs provides higher quantity of water, and as mentioned a resource being more available tends to be less valued until reaching scarcity. It can be discussed whether or not larger reservoirs decrease the value of water, resulting in increased use of water. Is the solution then a continuous construction of larger reservoirs or would a solution in the long term be a change towards a management focusing on integration and adaptation? An important aspect is that once the management is developed research needs to continue in order to develop new regulation for a constant improvement of water management.

A few of the solutions discussed are the changing of crops, the changing of life styles, and the changing of water distribution for various uses (Pahl-Wostl, 2007). A change of crop to a kind that uses less water is one example. One problem could be the demand of a certain crop. A continued demand combined with a reduced supply could result in a higher price for the crop. A change of life-style is another example, though certain life-styles may be difficult to change. One example is ecological versus conventional products which tend to have a difference in cost, with the possibility of price affecting the choice for some. Regarding distribution of the amount of water, the issue is which sector should receive higher amounts, agriculture to produce food or drinking water supplying the world's population and health? This is a major dilemma since all sectors are dependent on water and the people are dependent on food as well as clean water for drinking, cooking, etc. Higher demand on the resource due to an increasing population and higher environmental vulnerability increases the need for solutions and good governance. The governance needs to involve perspectives of both top-down and bottom-up. Incentives, restrictions, monitoring and sanctions needs to be implemented on a top-down level. At the same time as these incentives and restrictions need to be guided from a bottom-up level, since local knowledge could be of high value when formulating restrictions. Another important factor requires collaboration between different groups, for example scientists, local groups, managers, etc. Collaboration is dependent on understanding and a common language in order for the participants involved to learn from experiences and to be able to share this knowledge from one sector to another. Individuals can provide knowledge and information to institutions and organizations. An additional essential factor is the importance of leadership, mentioned by Folke et al (2005), with the role of managing conflicts, creating trust, linking of actors, providing knowledge, etc.

The world today consists of many uncertainties and involves continuous changes to which societies need to adapt, and more importantly need to take precautions to reduce possible negative effects. A system's resilience must be analyzed to determine to what extent it can absorb a disturbance and retain the same function and structure. In the case of 'la Loma' the aquifer was reaching its limit, which could cause major environmental, economic and social consequences. Due to a reduction of extracted water there is now a possibility that the aquifer will recover. Despite this, it needs to be determined to what extent the situation might change in case of a reduced water price in the future. Predictions can be made, but a complete answer cannot be given. To reach a sustainable use of water it is important to understand the entire system and not solely parts of the system. According to Folke et al (2005) major changes are a result of management with focus on control and stability. Poor management could easily result in important factors not being considered and necessary actions not taken. Present and future uncertainties and changes cannot be completely understood based upon knowledge of the past. Rather the knowledge needs to be updated and adjusted to a particular case or area.

As mentioned by the interviewees, there is a lack of studies in this area and lack of statistics concerning the amount of water used at present. Studies to gain more knowledge are highly necessary, but financing these studies could prove difficult due to the current economic situation in Spain. The striving towards a sustainable use of water in 'la Loma' has been challenged by the lack of several important factors, for example the lack of control, the lack of leadership, the lack of good governance, etc. This has caused an unsustainable situation in the area. The important step now is to create an adaptive and integrated management and to focus on changing the situation. If the focus is set on who to blame or what could have been done differently, the issues will not be solved. The focus needs to be set on the present situation and future possibilities. Solely focusing on problems of the past will not bring future solutions. The problem in 'la Loma' is clear, over-use of the water resource and lack of control. Now the focus needs to be on how this can be solved and how over-use in the future can be prevented.

9 Conclusions

The present study investigates the policy and management of water as a common pool resource in the area of the aquifer 'Carbonatado de la Loma de Úbeda'. Findings showed that water management involves several complexities, increasing the difficulties for a rational planning and development of an effective regime. The Guadalquivir River Basin has reached its limits and a basin closure has already been realized. Further actions are strongly needed to create a more sustainable use of water in the area of 'la Loma'. The requirements to be cost-effective cause more difficulties within the implementation process, partly due to the economic crisis occurring in Spain. At the same time improvements are time constrained, since the resource is already over-extracted, causing vulnerability for the surrounding ecological systems. The challenges in 'la Loma’ is partly a result from human development, causing both environmental and social challenges, and partly a combination of climate change. One of the major challenges is how to respond to these issues and at the same time continue towards an economic growth and social welfare. The farmers in 'la Loma', the regional and the national levels are dependent on the water resource in terms of economy and employment. Improvement of conservation is highly necessary, which needs to be done through good governance. The policies implemented to regulate the irrigation use are mainly the European Water Framework Directive and the Hydrological Basin Plan of Guadalquivir. These policies are complemented with actions and restrictions on local level.

The study also involves the main actors involved within the water management, which includes several different levels. The first level being supranational, EU. This is followed by the national level, constituting of the national government, involving the Ministry of the Environment, the Ministry of agriculture, fisheries and food, and the National Water Council. The third level is regional where the River Basin Authority and the Autonomous Regional Government can be found. The fourth level is the local communities where the water users association and the municipalities are included. In the final level the water management organizations can be found. Despite being part of different levels these are all connected. Therefore, cooperation between all actors involved is of high importance to reach a change towards sustainable development today and in the future.

An additional aspect in the study is the future alternatives discussed on the political agenda. The solution discussed on the local level is construction of dams. Though, there is a major lack of studies to make this project, both regarding environmental and economic aspects. On a short term perspective it might secure the water demand. The question is whether it is sustainable on a long term perspective and also if it is economically feasible. Despite using less water in the aquifer the situation in ´la Loma´ continues to be unsure due to lack of control of the water use as well as political conflicts.

To finalize, it is most important to create a change in the water use, but more important to develop knowledge regarding the water resource and its limit in order to conserve the resource for a continued use in the future. The study demonstrates the importance of actions from local to global level as well as good leadership to manage the water resource and to create a sustainable development.

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Appendix I. Interview the user Association and the Basin Authority

1. What is the task of the Association? Which are the difficulties in completion of the tasks?

2. Which are/were the technical and administrative difficulties and which still remain? How has these been addressed?

3. When and why did the first famers begin to irrigate in 'la Loma'?

4. Has the water management changed during and after the drought in the beginning of the 1990´s?

5. From 1987 to 1995 until 1997 and 2007 the production has increased by three? What is the factor behind the increase? How has this affected the formation of the water management? Are there any new restrictions?

6. Who make the decisions regarding the water management and water pricing? Is it allowed to drill new well? Is there any control?

7. Which are the major administrative and juridical issues/juridical difficulties regarding water use and management? How has these been addressed? Which still remain?

8. Regarding the water right/allocation, can changes be made by others than the decision makers? Are the users involved in the decision making? If yes, how? Which are the difficulties in establishing adaptive and effective management regimes?

9. Before the initiative in 2001 there were major exploitation of the aquifer without any regulation. What has changed? What regulations exists now? Is the water used more efficient? Which were the new regulations implemented in 2001? Have they been renewed after? How has the water use changed after the formation of the Association?

10. Which are the restrictions for the amount of water a user is allocated?

11. Who is empowered to sanction illegal users? Are the illegal users denounced?

12. Are stakeholders/users views considered in policy making/implementation?

13. Which are the major issues regarding water use and management? Which are the major economic, social, environmental and political challenges and benefits?

14. What is the volume for exploitation of groundwater? What volume is optimal for a sustainable exploitation?

15. How much groundwater is extracted? How much water is used for irrigation? How much water is available? Are the estimates for a sustainable yield agreed on by the users and the authorities?

16. How has the GIS facilitated and improved the water management? When was it implemented?

17. How has GEST-AGUA helped to improve the water situation in la Loma? What decisions has been made? Which are the improvements and challenges? Has the management gone

from being basic towards more improved/advanced?

18. How is the water divided between the users? How is it financed? Is the water subsidized? If receive subsidies, how are the subsidies managed? How much would it cost without? How would a loss of subsidies affect the users?

19. How can the farmers balance environmental and efficiency pressure with their own need to maximize the performance of their irrigation business?

20. Is there more attention of groundwater or surface water? Is there a sufficient measurement of groundwater use?

21. Are there benefits/compensation for the users who contribute/invest in water saving measures?

22. Are the directions from the authorities' followed/agreed upon by the users? Is there agreement upon the importance of controlling the water use by the different actors? Is there trust between users and authorities? How has this affected the water management? Does it exist dialogs between the different actors?

23. How many farmers are there in 'la Loma'? How many use irrigation? Is it possible to communicate with all of them? Are there forms of feedback to improve the management?

24. Is there belief in that agriculture is reducing the availability of water for other sectors?

25. Belief in that lack of economic value of water has resulted in over-exploitation and inefficient use of the resource?

26. How can the risk of overexploitation of the aquifer be prevented?

27. How can water use efficiency in agriculture be improved and which are the possible solutions to create a more sustainable use of water? What local actions could further improve the water efficiency? Which are the alternatives discussed?

28. How could modernization of irrigation techniques be implemented/improved in order to make water use more efficient? Is this a solution?

29. Which are the barriers for adaptation of sustainable irrigation practices and which are the future alternatives?

30. What is the solution to respond to an increasing demand of agriculture and irrigation? Which water saving measures has been implemented/could be implemented? Which are the major challenges to tackle in the future?

Appendix II. Interview the users of 'la Loma'

1. How has the water use changed after the drought in the 1990's and the formation of the Association?
2. Which were the new regulations implemented in 2001? How have they been renewed after? Which were the regulations before 2001?
3. Which are/were the technical and administrative difficulties? How has these been addressed? Which were they from the beginning and which still remain?
4. Before the initiative in 2001 there were major exploitation of the aquifer without any regulation. What has changed? What regulations exists now? Is the water used more efficient?
5. Are you using the aquifer for irrigation? If yes, since when? Did you begin to use it due to the drought in the 1990's?
6. Are there any rules or restrictions for the amount a user is allocated?
7. Are the users participating in the decision making regarding the management of the aquifer? How are the users of water involved to improve the situation?
8. Which are the major social and economic benefits from using irrigation? Are there benefits for the users who contribute/invest in water saving measures?
9. How much is the limit for extraction of water? How much is the difference in price from the beginning until today?
10. How much water is used per ha? From where is the water extracted? What type of irrigation system is used? What is the cost of extraction?
11. Is there more attention on groundwater or surface water? How does this affect the management?
12. Is it obligatory to be holder of water license? What does it mean?
13. Is it allowed to drill new wells? Is there any control?
14. Is the water subsidized? How much? If yes, how are the agricultural subsidies managed? How much would it cost without? How would a loss of subsidies affect the farmers?
15. Are the directions from authorities followed/agreed upon by the users? Is there agreement upon the importance of controlling water use by the different actors? Is there trust between the users and the authorities? If not, have this affect the water management? Does it exist dialogs between the different actors? Is there any conflict resolution mechanism?
16. Belief in that lack of economic value of water has resulted in over-exploitation and inefficient use of the resource?
17. Is agriculture reducing the availability of water for other sectors?

18. How can the farmers balance environmental and efficiency pressure with their own need to maximize the performance of their irrigation business? How can farmers optimize their access of water?

19. Is the estimates of sustainable yield agreed upon by the users and authorities? How can the risk of overexploitation of the aquifer be prevented?

20. How can water use efficiency in agriculture be improved and which are the possible solutions to create a more sustainable use of water? What local actions could further improve the water efficiency? Which are the alternatives discussed? Which are the major issues and which are the possible solutions to create a more sustainable use of water?

21. How could modernization of irrigation techniques be implemented/improved in order to make water use more efficient? Is this a solution?

22. Which are the barriers for adaptation of sustainable irrigation practices and which are the future alternatives?

23. What is the solution to respond to an increasing demand of agriculture and irrigation? Which water saving measures has been implemented/could be implemented? Which are the major challenges to tackle in the future