Lund University International Master´s Programme in Environmental Studies and Sustainable Science

DROUGHT MANAGEMENT IN CATALONIA

A case study in Riudecanyes and its water basin towards reducing vulnerability to water stress

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Abstract

The effects of climate change in Spain are changing weather patterns, especially the amount of yearly precipitation in the south and east of Spain. Facts and figures are presented in this paper on what climatic changes scientists believe is happening today and what may happen in the future, which is basically an increase in water stress. Climate change is not the only factor increasing water stress, also the high increased consumption of water and the implementation of inadequate measures and policies are important factors.

On a macro scale, this paper focuses on the region of Catalonia. A specific focus will be on why water consumption is higher compared to other European countries and what are the mitigation and adaptation measures taken by the authorities of Catalonia to lessen future droughts, such as the Decree of Drought (2005) and Water Directive Framework (WFD) in Catalonia. Although the government of Catalonia has taken new actions to reduce droughts in this region, the implementation of the complete Drought Management Plan (DMP) has still not been made.

Actions that are prepared at a macro scale are not always adequate or efficient when implemented at a micro scale. Many times the need of decentralization is necessary. Therefore, the use of a case study in the town of Riudecanyes and in the Riudecanyes water basin will enable to go deeper into a micro scale and analyze the interactions between all stakeholders involved.

The main authority that regulates water management in Catalonia is the Agency of Catalan Water (ACA). Due to increasing droughts in this region, ACA has taken steps forward by creating measures and policies to reduce vulnerability to water stress in all Catalonia, including the town of Riudecanyes in which the use of all water (household, irrigation, and non priority use of water) is regulated by ACA. This paper will look into the measures and actions taken by all stakeholders to reduce the consumption of water as well as the relationship between them. Thus, analyzing whether these actions have been efficient or not, as well as finding missing links that could further reduce vulnerability to water stress in this town. To reach this goal, a stakeholder analysis is presented in this paper, starting from the bottom (locals and farmers) all the way up to the main water regulating authority- ACA. The relationship among all stakeholders is important to understand why certain measures or policies are not working efficiently and to reach a common goal to reduce sustainable levels the consumption of household water and irrigation and using more efficient techniques for agriculture.

Key words: climate change, water stress, drought, water and drought management, and water sustainability

List of Acronyms

ACA	Catalan Water Agency (Agencia Catalana de Agua)
CLD	Causal Loop Diagram
CUSA	Committee for the Sustainable Use of Water (El Consejo para el Uso Sostenible del Agua)
DMP	Drought Management Plan
EEA	European Environment Agency
EU	European Union
ET	Evapotranspiration
GDP	Gross Domestic Product
GENCAT	Generalitat de Catalunya
IPCC	Intergovernmental Panel on Climate Change
SR	Stern Review
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive
WSDG	Water Scarcity Drafting Group

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1. Introduction

Climate change has become an important topic around world. The causes and effects of climate change have lead to social, economical, environmental and political debates. One of the main causes observed by many renown scientists and organizations are the anthropogenic emissions of CO2, leading to many environmental changes on our planet (SR 2006a:5). One of them is the increase in droughts in many areas worldwide (SR 2006a:12).

This paper will first as a background-summarize the common knowledge on climate change, what is the evidence and what are the future climate change impacts on water in Europe (taking into special focus the Mediterranean region of Catalonia in Spain). One of the most important effects that will make Mediterranean countries more vulnerable to water stress is drought, that according to many scientists will increase due to climate change (SR 2006b:8). Catalonia, which is a Mediterranean region in Spain, has already started to experience water stress. Each year water basins and rivers in Catalonia experience great uncertainty whether they will be able to cover the demands of water to farmers, industries and households (ACA 2007). There are several reasons to why droughts are becoming more frequent in this region, such as meteorological and hydrological droughts, high consumption of water, as well as the lack of accurate measures and policies in water and drought management in Catalonia. Water and drought management are key words in this analysis.

This paper aims to describe what are the measures and policies taken by the Catalan government, especially by the Agencia Catalana de Agua (ACA), the main water management governmental organization in Catalonia. This paper will analyze the different mitigation, adaptation and preventive or preparedness[1] measures implemented by ACA, under the scope of the ´precautionary principle´ adopted by the Stern Review (2006c:18), which involves aversion to risk. Mitigation "is short and long term actions, programs or policies implemented during and in advance of drought that reduce the degree of risk human life, property, and productive capacity" (Wilhite 2000:15), while adaptation refers to ways in which people adapt and cope with a certain condition (SR 2006d). According to Wilhite (2000:16), ´preparedness´ "refers to pre disaster activities designed to increase the level of readiness or improve operational and institutional capabilities for responding to an emergency", for example, early warning systems.

Although ACA has implemented new mitigation, adaptation and preparedness measures in the last 7 years, it is important to analyze how effective they are, as well as to review the whole Drought Management Plan (DMP) in search of tools or mechanisms that are been applied or are lacking.

[1] Preventive measures are referred as ´Preparedness´ by D. A. Wilhite 2000.

Specific Research Questions

1. Why is there water stress in Catalonia?
2. Is drought going to become more frequent in the future due to climate change in this area?
3. How is the lack of adequate water and drought management affecting the Riudecanyes water basin and its people?
4. What could be the solutions to avoid future droughts and to reduce the use and consumption of water in Riudecanyes?

2. Methodology and Materials

The type of assessment used in this study is of two types. The first type of assessment is a literature review that is used to introduce to the reader a general scope of how and why climate change is increasing water stress in the Mediterranean, mainly in Catalonia, Spain, and future predictions. The literary review contains assessments mainly from the Stern Review Report, the Fourth Assessment Report from the IPCC, the EEA, among others. This literature review covers chapter 3, 4 5 and 6. A literature review has also been undertaken to assess which different actions that have been taken by the Spanish government to reduce the vulnerability of water stress in the Catalonian region, this covers chapter 7. The second part presents a case study in the town of Riudecanyes in Catalonia. The combination of these two methodologies is used to answer the research questions. The use of a case study provides a more in-depth analysis, in other words, to which extent regional and local measures are interacting and if they are actually decreasing water stress in Riudecanyes and how efficient these are.

The case study in Riudecanyes is first presented by a description and presentation of the town and its water basin. An interview with Miguel Angelo Prats, Administrator of the Riudecanyes water basin, and information from official websites provided such information. Secondly, the use of systems analysis allows to analyze in an organized manner the actual problem in Riudecanyes, thus enabling the reader to follow the problem through a CLD. It describes why the water basin has experienced low levels of water and why in some years the supply of water has not been enough to satisfy agricultural needs. The CLD is qualitative and uses systematic and holistic thinking to understand complex relationships between factors to present a mental model (Haraldsson 2006). Literature reviews found in ACA´s and GENCAT´s official websites, as well as observations and interviews in situ enabled this study to create such mental model. Thirdly, a stakeholders analysis shows the different interests of each actor and their role and participation into reducing water stress, creating a debate to whether these are accurate or contain a missing link. It also analyzes what are the roadblocks for each stakeholder for reaching a common goal: reducing water consumption and vulnerability to water stress. The stakeholder analysis is based on the model of the Cycle of Disaster Management proposed by Wilhite (2000:15) in which the drought cycle is reviewed and also on points stated by WFD. The main stakeholders in this analysis are the Riudecanyes water basin (partly independent from ACA´s governing), ACA, farmers and local citizens. The collection of information was obtained through observations and interviews in situ. Interviews account for an important

part of this research study, especially for the Riudecanyes case study. Representatives of all the stakeholders were interviewed and recorded. To read the questionnaires refer to Appendix 1 and 2. The interviews can be divided into three groups A, B and C.

A. These interviews were designed in open format questions (Walliman et al. 2006:90) (see Appendix 1) and conducted in situ. These interviews were previously set by formal meeting appointments. Each interview lasted around 1 to 1 hour and a half.

Description of people interviewed for the stakeholders analysis:

1.Stakeholdes from: Riudecanyes water basin

Objective: to learn about the physical characteristics of the water basin and to know more about the history of droughts in the past and present, the measures taken and future plans. Another objective was to learn about how effective the cooperation between ACA, the water basin and the locals is.

Person: Miguel Angelo Prats, Administrator of the Riudecanyes water basin

2. Stakeholder: Agencia Catalana de Agua (ACA)

Objective: to understand why there is a drought in Catalonia, especially in the Riudecanyes area. Another aim is to understand the organizational structure of this entity, its functionality, effectiveness, etc. and how their planning and preventive measures are reaching the locals of Riudecanyes. The questions provided useful information for analyzing whether the measures and policies taken by ACA are actually reducing vulnerability to water stress.

Person 1: Andreu Manzano Rojas. Project Manager for the Planning Department of Water Sustainability. (ACA Barcelona)

Person 2: Jose Manuel Sánchez. Technical Engineer of Public Services. ACA Tarragona

3. Stakeholder: Farmers in Riudecanyes

Objective: to understand from first hand what is the opinion of the farmers as well as to learn what measures and strategies they use when there is a drought or low levels of water in the basin that supplies them water.

Person 1: Josep Anton Caballe Godall. President of the Riudecanyes Agricultural Cooperative (Cooperativa Agrícola de Riudecanyes)

Person 2: Joan Llobreira. Farmer

Person 3: Anonymous. Farmer

B. The interviews for this section were designed in open format questions (Walliman 2006:90) (see Appendix 2). Surveys were conducted to ten local people from Riudecanyes. The interviewees ranged from the age of 35 to 55, both men and women. Each interview lasted around 10-15 min.

4. Stakeholder: Local citizens from Riudecanyes

Objective: to learn about the general feeling of ´water´ in Riudecanyes, whether people are conscious about saving water and how they feel water could be consumed in lower quantities. Another objective was to find out whether people feel that ACA´s campaigns are effective and if there is enough cooperation between ACA and the locals of Riudecanyes.

Person 1: Joan Llobreira. Farmer
Person 2: Dolors Teigell. Shop assisstant
Person 3: Pilar Roige. Shop assistant
Person 4: Miguel Seuba. Mechanic
Persons 5-8: Anonymous (They preferred not to give their names). 1 housewives, 1 restaurant waiter, 1 salesmen, 1 farmer

C. The purpose of the interview conducted with Eduardo Soler, Consultant in Limonium Consultancy (Spain) was to find additional information related to household water consumption in Riudecanyes. This brief interview was conducted through a telephone conversation.

Fourthly, the worst case scenario is introduced by presenting second case study in the town of Brunyola, which exposes the vulnerability of Riudecanyes of experiencing emergency water stress in the near future. The information on this case study was provided by Vicent Sos Bravo (lawyer from the Municipality of Brunyola) through telephone conversations and a questionnaire via internet (see Appendix 3).

Finally, after the analysis of the Riudecanyes case study is made and using a CLD, recommendations are provided in an attempt to reach sustainable solutions that require cooperation among all stakeholders, in order to reduce vulnerability to water stress in the following years. A conclusion is given to comment on some final ideas of how the region could move towards a more sustainable water and drought management process.

Cycle of Disaster Management.

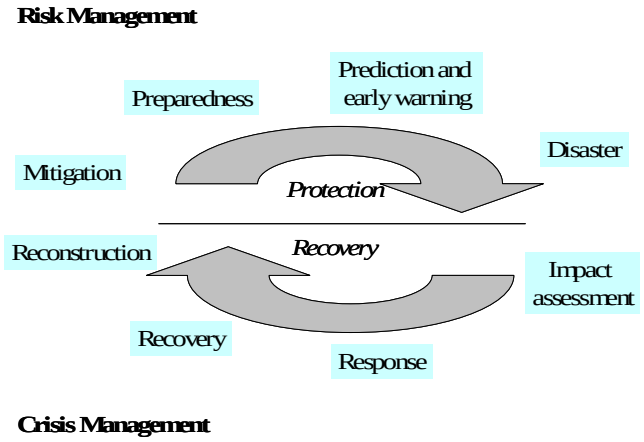
It is necessary to integrate different disciplines for tackling the complex issues associated with detecting, responding to, and preparing for the inevitability of droughts. Crisis management is a subset of drought management which deals with the response, recovery and reconstruction of droughts (Wilhite 2000:15). In the past, the main focus has been to deal only with crisis management. In other words, governments would deal with a drought only after its manifestation. This resulted in moving from disaster to disaster with little attention to risk management which includes: mitigation, preparedness, and prediction and early warning. The Wilhite´s Cycle of Disaster presents an explanation of each step and actions that can be adopted to reduce vulnerabiltiy to drought.

The analytical structure of the stakeholders analysis, follows the the Cycle of Disaster Management (see Fig. 2.1) suggested by D. Wilhite (2000:15), in which human intervention can actually reduce vulnerability and impacts in a short and long term. ACA has taken several steps towards reducing water stress in Catalonia and its measures and policies are clearly defined according to this model. One of the most important features in this model is that it emphasizes the importance of adopting mitigation measures to reduce

water stress. It also presents a compilation of different strategies in each step of the model, thus creating a general outline of how vulnerability to water stress may be reduced.

Fig. 2.1 Cycle of Disaster Management

source: Wilhite, 2000



It is important to define each of the steps in a Drought Management Plan (Wilhite, 2000) because they it will be used as a model in the case study to anaylze the full drought management plan that exists in Riudecanyes.

Steps in the Cycle of Disaster Management (Wilhite 2000:15):

1. *Mitigation:* includes short and long term actions, programs and policies implemented during and in advance of drought that reduce the degree of risk to human life, property, and productive capacity. Such actions may include (WFD): reducing leakages in the distribution networks, improving irrigation techniques (e.g. optimizing soil water utilisation and irrigation) and setting up new programs of practical research in order to reduce water consumption (e.g. crop rotation, generic variety), promoting improved waste water reuse where appropriate, evaluating the advantage of setting up water banks and quota systems, setting up an adapted tax and price policy system to encourage investment development and on the other hand to lower the consumption of water where possible, development of education and awareness campaigns, preservation of the functioning of natural catchments, aquifers and restoration, improvement of an efficient use of existing water infrastructures, and water recharge aquifers (Wilhite 2000: 15).
2. Preparedness: it refers to pre-disaster activities that will increase readiness or improve operational and institutional capabilities for responding to a drought (e.g. early warning systems, operational plans). Contingency plans are useful for assigning operational responsibilities, improving information flow on severity, impacts, and policies between different governmental levels, as well as cooperation among all stakeholders (Wilhite 2000:16).

3. *Prediction and early warning:* probability of a drought happening is highly variable for droughts in all parts of the world. However, there is an important distinction between forecasts of meteorological drought and those of hydrological drought. A clear example is when snow pack in mountains is a critical element of the hydrological system in a certain region. Information on the status of snowpack conditions can give a valuable time lead for making reliable forecasts of below-normal streamflow and reservoir levels. This information can be quite useful to alert decision makers to be prepared for a forecoming drought. The information can be used by planners, emergency managers, policy and decision makers and other stakeholders involved in this process. To collect this information it is necessary to have monitoring centers where data is collected and analysed. Data includes physical data related to droughts as well as social and biological data that can be vulnerable to such hazard. A comprehensive drought monitoring system would include the collection of climatological data (e.g. temperature and precipitation), streamflow, reservoir, and groundwater levels, soil moisture, snowpack, and data from satellites. This data is useful for making agricultural and hydrological drought forecasts (Wilhite 2000:16).
4. *Impact assesssment:* are the actions related to the early costs and losses associated with droughts. These can be associated to economic, social and environmental impacts. However, these tend to be difficult to estimate due to their nonstructural nature (Wilhite, 2000).
5. *Response and rehabilitation:* refers to actions that restore critical life-support systems, such as transportation and communication services, emergency medical care, temporary housing, and water supplies. Most of the response, rehabilitation and mitigation programs aim to reduce drought impacts and minimize the recovery time (Wilhite 2000:16).

3. Climate Change

The following three sections will provide background information on climate change which will enable us to understand how climate change is making droughts more common in Catalonia, what is the evidence for such claims and what are the future climate predictions.

3.1. Evidence of climate change

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) "climate change" was defined as "a change of climate which is attributed *directly* or *indirectly* to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." Further research and documentation supports this definition. The Stern Review Report concluded that the main reason for climate change is due to the anthropogenic increase in greenhouse gases[2] (SR 2006a:5). The level of greenhouses today is higher than any other in at least the past 650,000 years (SR 2006a:2). The main reasons are due to human activity and are caused by the burning of fossil fuels, deforestation and other changes in land use. However, it is important to mention that natural changes in Earth which are associated mainly with explosive volcanic eruptions (which produce dust and aerosol layers in the stratosphere) and changes in solar irradiance are also contributing to climate change (Jeftic et. al. 1992:19 and Olsson 15 Feb. 2007).

Although some people still refuse to believe or to admit that global climate change is occurring now due to their political or economic agenda (Olsson 15 Feb. 2007), there is an overwhelming body of scientists and organizations that believe the contrary. During the last 30 years, the world's temperature has increased rapidly and continuously at around 0.2°C per every 10 years, which is the warmest level reached since the current interglacial period, which began around 12,000 years ago (SR 2006a:4 and IPCC 2007:12). In Europe, CO2 emissions have caused a 0.5°C warming in the last 50 years and it could double in the next 50 years (Climate Change Impacts and Responses 2004). Most climate predictions indicate that a doubling of pre-industrial levels of greenhouse gases is very likely to rise the mean Earth temperatures between 2-5°C. These levels are likely to be reached between 2030 and 2060. If there is a global warming of 5°C, it would be far outside the experience of human civilization and it would be comparable to the difference between temperatures during the last Ice Age and today (SR 2006a:1).

For some parts of Europe, a warmer climate might seem like a good idea in the sense that we would have fewer deaths due to cold snaps, a longer annual farming season and more bird species surviving winter, however, the negative impacts are far worse than the positive (EEAa).

[2] In 2001, the IPCC stated that there is new and stronger evidence to prove that most of the global warming observed over the past 50 years is attributable to human activities. This key conclusion has been also supported by the Joint Statement of Science Academies in 2005 and by a report from the US Climate Change Science Programme in 2006.

The climate change impacts that will be most certainly experienced by people will be through lack of excess of water (SR 2006a:12). These impacts on water are already visible in Europe. There has been an increase in precipitation in some northern countries during the past decades, especially in winter, however, during summer a significant decrease in rainfall has been observed in southern and central Europe (see Fig. 3.1 and Fig. 3.2).

Fig. 3.1 Changes of the mean annual river discharges over the twentieth century
source: EEA-EPAEDIA
http://epaedia.eea.europa.eu/page.php?pid=345#gallery

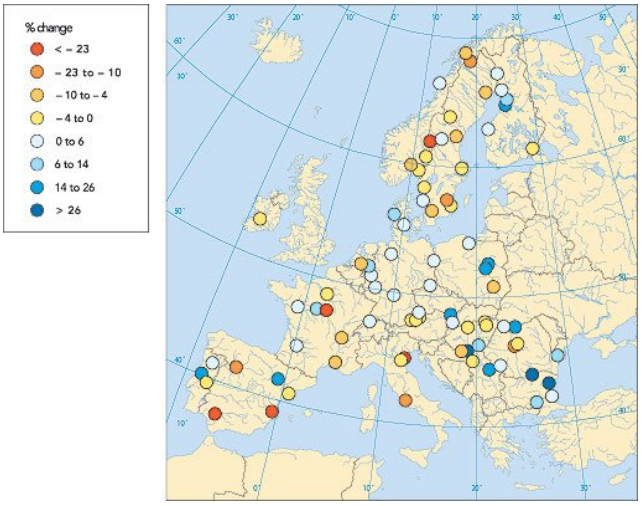
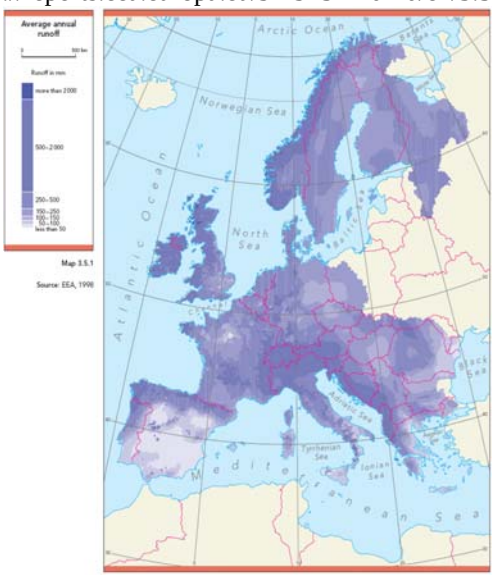


Fig. 3.2 Average Annual Runoff
source: EEA, 1998
http://reports.eea.europa.eu/92-9157-202-0/en/3.5.pdf



3.2. Future Climate Change Impacts on Water in Europe

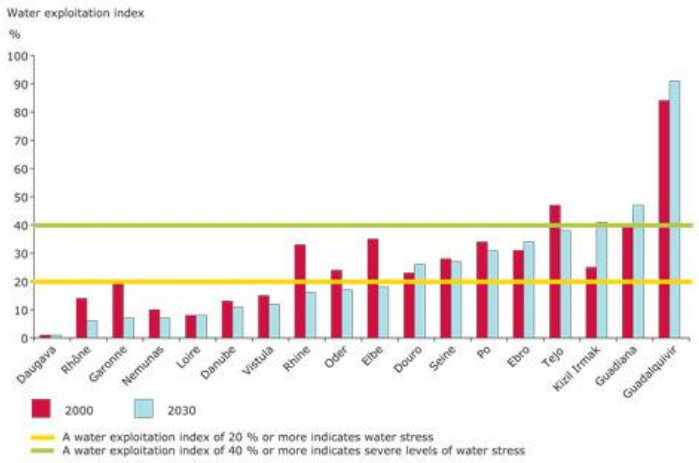
The predictions of the IPCC (2001) models show an increase in surface temperature in Europe by 2100 between 2.0 and 6.3°C above 1990 levels. The largest increase will be felt in eastern and southern Europe (EEAb). Some scientists believe that if the climate rises 2°C it is sustainable, however, if it goes higher, extreme conditions could become more frequent rising the seas to dangerous levels (EEAb). According to the Stern Review (2006b:8), if the temperature rises 2°C, around 1-4 billion people will experience growing water shortages. This water shortage will be felt in southern Europe.

Global warming is likely to intensify the water cycle, accentuating the patterns of water scarcity that we have today, thus increasing the risk of droughts as well floods. Rainfall is expected to increase at high latitudes, while regions in the Mediterranean climate will experience reductions in precipitation. Preliminary reports calculated that by the end of this century, the percentage of land in extreme drought will increase from 1% to 30% (SR 2006a:1).

According to the EEA (c), in southern Europe the combination of less rainfall and more evaporation will reduce by 10% or more the run-off in many river basins in Greece, southern Italy and Spain, and in some parts of Turkey.

These changes are already happening but can be accelerated by future emissions of greenhouse gases. The situation will be worse in southern European countries due to the farmers demand of more water to irrigate their crops. It is expected to result in an increased water stress in many river basins in these regions (EEAd). The reduction in the availability of water in rivers and water basins is already present in the Iberian Peninsula. The Guadalquivir and Guadiana rivers in Spain are some of the most noticeable examples. In the graph below (see Fig. 3.3), one can observe that the Guadalquivir River has reached over 40% of water exploitation, which means it is under severe levels of water stress, while two of the most important rivers in Spain, the Guadiana and the Ebro, rivers are on the verge of changing from a water stress level to a severe level (EEAd).

Fig. 3.3 Water Exploitation Index
source: EEA EPAEDIA
http://epaedia.eea.europa.eu/page.php?pid=520#galleryhere



In general, we will have two Europes divided by opposite climates. Northern Europe will become more prone to floods and southern Europe to more droughts (EEAd) and (Climate Change Impacts and Responses 2004). In southern Europe, water will have to be piped and desalination plants will have to be built, while in northern Europe there will be a loss in agriculture production due to floods (Climate Change Impacts and Responses 2004).

4. Increasing Vulnerability to Droughts: High Demands of Water in Spain

It is important to mention that Spain ranks as one of the highest in household water consumption in Europe. In 1998, the average water consumption was around 280 liters/person/day (see Appendix 4a). While in Denmark, after having a significant increase in water prices, water consumption decreased from 196 liters/person/day in 1982 to 122 in 2002 (EEAe). Water price in Spain is almost half times cheaper than in Denmark (see Appendix 4b), however, Denmark does not have water stress problems and Spain does.

Even though household water consumption in Spain is very high, irrigation water for agriculture plays an even higher role in the total consumption of water (see Appendix 5a). It accounts for 68% of all water consumed in this country (around 9% for industry) (Krinner 1999:6). This is a marked contrast to northern and eastern European countries where, on average, 10% of the resources are used for irrigation (Krinner 1999:6). Agriculture is still a very important economic sector in Spain, where its GDP accounts for around 4% (see Appendix 5b). It is due to its Mediterranean climate and long tradition. The amount of water needed for irrigation depends on the climate, the crop being cultivated, the area being irrigated and the method of application (Krinner 1999:6).

Over the past decades, tourism has become very important in Spanish national economy, accounting for over 4% of the countrys GDP (EEAe). The majority of tourists tend to visit the eastern and southern coasts, areas which are already suffering from water stress. The high tourist season in Spain is usually during the summer, which is the period in which there is less precipitation, thus intensifying water stress. Consumption of water by tourists also increases water stress. Tourists usually consume nearly two times more water than local consumers and they often require large volumes of water for recreation such as swimming pools, water parks and golf courses. The amount of water needed to irrigate a hectare of golf course is around 10,000 m3/year, the same as for a well irrigated agricultural system (EEAe).

Water resources in Spain under increasing demand are about to become a major challenge regarding development and security over the next decades. If water demand from all these sectors continues as it is or even increases, the appearance of droughts will be more frequently experienced.

5. Drought

To proceed further in this paper, it is important to understand that there are the different meanings of the word drought. The definition of “drought” given by the UN Convention to Combat Desertification is “*drought* is the naturally occuring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.” However, drought affects many economic and social sectors, thus creating different definitions for the word ´drought´. In addition, because drought happens with different frequency in varying regions with different economic systems and in developed and developing countries it is unrealistic to have a universal definition (Wilhite 2000:8).

5.1. Types of Drought

Drought has been grouped in four types: meteorological, hydrological, agricultural and socioeconomic (Wilhite 2000:10-12). It is important to briefly define them as they will be mentioned further in this study.

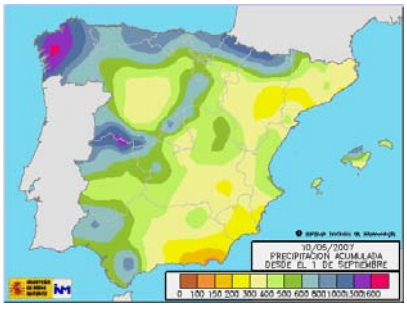
1. *Meteorological drought* is the result from precipitation deficiency. It is also the degree of dryness (often compared to some normal or average amount) and the duration of the dry period. (Wilhite 2000:11)
2. *Hydrological drought* are linked to the effects of periods of precipitation shorfall on surface or subsurface water supply (i.e. streamflow, reservoir and lake levels, groundwater) rather than with precipitation shortfalls (Wilhite 2000:11).
3. *Agricultural drought* is the result of deficiency in soil moisture. It focuses mainly on precipitation shortages, differences between actual and potential evapotranspiration (ET), soil water deficits, etc. Agriculture is mainly the first economic sector to be affected by drought because soil moisture supplies are often quickly depleted. This usually occurs when the period of moisture deficiency is associated with high temperatures and windy conditions (Wilhite 2000:11).
4. Socio*economic drought* is related to the supply and demand of some economic good or service with elements of meteorological, hydrological and agricultural drought. For example, the supply of hydroelectric power depends on weather. If the demand for hydroelectric power is higher than the supply (due perhaps to an increase in the population), then there is a socioeconomic drought (Wilhite 2000:12).

5.2. Drought in Catalonia

According to the Catalan Water Agency (ACAa), the availability of water resources in Catalonia has always been uncertain, especially in the inland basins with a Mediterranean climate and where demand for water is very high and the average inflow is low. In these regions, the demand for water is higher than the supply. In reservoirs there is a difficulty in predicting the future inflow, which makes it harder to restrict the amount of water that is supplied.

Meteorological drought has been experienced for many years now in Catalonia, but the most recent has been in 1990-95 (see Appendix 6) and in 2004-2005. In this last period, Catalonia had an average rainfall of 200-500 mm (see Fig. 5.1). The average rainfall expected any year in Catalonia is about 500 mm/year.

Fig. 5.1 Pluvometric map after the 2004-2005 drought
source: Meteored
http://foro.meteored.com/index.php/topic,29142.0.html

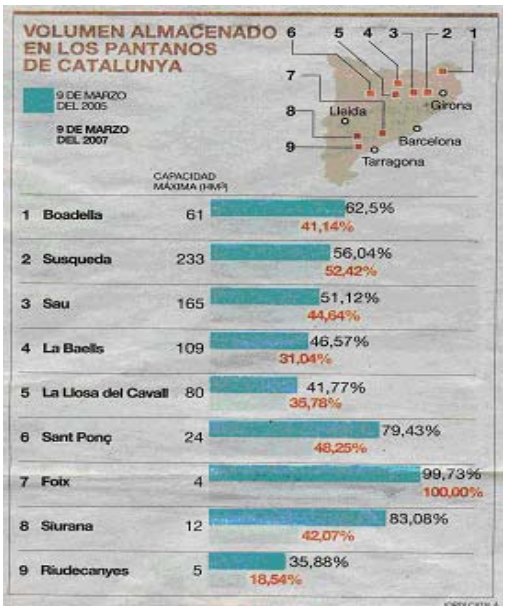


Hydrological drought in Catalonia in 2005, reached a low level of water in several basins to 53.2% of their capacity. This forced the Generalitat of Catalonia to create a ´Decree of Drought´ to adopt measures to protect the hydrological resources. These measures led to restriction in the use of water for agriculture, parks and gardens, among others. In January 2006, the situation was more optimistic. The water basin reserves had 48.81% of their capacity, however, it rained a lot that month which in return collected 141 liters/m^2 , when the historical average in the last 40 years had been 35 liters/m^2. The following months were very dry, but due to the melting snow from the Pyrenees in March, the Catalan water basins reached a 69.77% of their total capacity. Capturing snow is important because it is one of the principal water sources in spring, when snow melts and it comes down as runooff (Barrena 2007).

However, on March 10, 2007 the capacity of the water basins decreased to 43.2%. This decrease has not been linear, since on January 1, 2007 the water reserves reached 51.56% of its capacity. However, in only 70 days, 16.2% of the water from the basins has been consumed, due to one of the warmest winters in years. Very little storage of snow in the Pyrenees. Therefore, it has been declared that if it does not rain in the forthcoming days then it will be necessary to reintroduce the Emergency Decree (Barrena 2007) (see Fig. 5.2).

Fig. 5.2 Water stored in the Catalan water basins

source: El Periódico, March 10, 2007



6. Mitigation and Adaptation

Climate change is altering the climate consequently there is a need for countries to change as well, in order to deal with these different and new climate situations. There are two major strategies to follow, mitigation of climate change and adaptation to climate change. Mitigation is of course very important but mitigation strategies are not the only path to follow especially in regions which are already under severe water stress. It is imperative for especially those nations to also ´adapt´ to these new situations (Olsson 13 March 2007).

Adaptation is therefore a key word when we refer to climate change and a future sustainable world today. According to Lennart Olsson, twenty years ago when climate change came to the international agenda, the main focus on how to tackle this problem was based on mitigation. This meant how we could reduce the effect of climate change. People then had a wishful thinking that if we could mitigate we could prevent climate change from happening. However, now people agree that even if we are successful at mitigating we cannot prevent climate change from happening. Even if we stop using fossil fuels today, which is almost impossible, but even if we did we will still have a warming of the climate for at least half a century (Olsson 13 March 2007). Therefore, we need to use adaptation strategies in a sustainable manner to meet society´s needs without endangearing our planet anymore. Adaptation strategies might seem costly, however, cost effective studies have shown that it would cost 20%-30% of the GDP to adapt in 2050, and the cost would be very low if we adapt today (Olsson 15 Feb. 2007).

In regard to adapt to water scarcity**,** the world is taking adaptation actions in several countries at different levels and at a different speed. According to Jacqueline McGlade, more comprehensive National Adaptation Frameworks have been adopted by Finland, Portugal and Spain and in France, Norway and the UK they are still in the process of adapting such frameworks (Climate Change Impacts and Responses, 2004). J. McGlade stated that Europe is not leading in the world. Many other developing countries already have their own National Adaptation Plans of Action under the UNFCCC (this includes Bangladesh, Madagascar, Malawi, Niger and Samoa). She also emphasises that the European frameworks should not be so much about how to tackle a drought in the future but more on how to implement the frameworks now (Climate Change Impacts and Responses, 2004). They should be sustainable and be consistent with mitigation strategies. Increasing water supply and improving water quality using more energy inputs is for example not sustainable. J. McGlade believe that what we need are integrated sustainable solutions that can protect and restore ecosystems which in turn may provide land and water resources. It is also necessary to close gaps between water supply and demand by creating measures that will reduce the demand of water. J. McGlade stated that is important to note that the EEA feels that many adaptation activities are focused on flood management and defence, while measures relating to drought and water scarcity are not yet widespread.

7. From Crisis to Drought Risk Management

In Catalonia drought management policies are usually directed to react in a drought episode through a crisis management approach by declaring a national and regional drought program to alleviate drought impacts (Decree of Drought of Catalonia), or by transporting water from different rivers or water basins to another location, such as from the Ebro river (Marti 2007), instead of creating sustainable short and long term drought mitigation and preparedness policies and plans of action that could reduce the vulnerabilities of droughts. According to the WSDG, drought planning has to include risk management, together with sustainable short and long term drought mitigation, adaptation and preparedness policies and plans of action.

The WFD believes that drought is a complex phenomenon that includes social, economic and environmental aspects. An approach to strategic planning of water resources management should not only account for preparedness but also include mitigation and adaptation strategies.

Long term actions should be focused in reducing the vulnerability of water supply systems to drought. Reliability to meet future water demands should be met by setting appropriate structural and institutional measures. Some options to meet future needs are water conservation and demand management, including efficient use and resource protection, educational programs, public awareness, and research (WSDG).

Short term actions should respond to an impending drought event within an existing framework of infrastructure and management policies. It usually includes a contingency plan. The main aim of these actions is to reduce socio economic and environmental drought impacts (WSDG). This can be achieved through monitoring systems, impact assessment systems and response systems which include national legal framework, organisational structure and measures and infrastructures (WSDG).

7.1. WFD Water Pricing

The WFD is based on the idea that modern water management needs to include water pricing as a measure to reduce water demand. The WFD requires that EU Member States shall not subsidize the price of water (EEAf). There has been a general trend towards higher water prices throughout Europe over the past 20 years (EEAf). In several countries, increased water prices have decreased household water use significantly (see Appendix 4a). In many eastern European countries, the price of water was subsidized until 1990. During their transition to market economies, after 1990, the price of water increased, lowering the use of water. In Estonia, for example, water prices increased after subsidies were removed, which led to more than 50% reduction in water use during the last 16 years (EEAf).

7.2. Price of Water in Catalonia

In Spain the money paid to consume water in households, for irrigation, for industrial purposes, etc. is a tax that covers the supplying services, sanitary costs, among others (Sànchez 6 March 2007). However, sanitary costs are usually the most expensive. WFD states that all member countries should not subsidize the price of water in order to create an incentive for people to consume less water (ACA Barcelona). However, in

Catalonia the price of water is still partially subsidized by the government. The average price of water today is around 1.2-1.4 Euros/m^3. This price is very low compared to the price of water in France which is almost two times more expensive. Catalonian authorities are studying the possibility of raising the price for non priority private use of water (Manzano 7 March. 2007).

Nowadays the price of water is divided in two different price rates. In most parts of Catalonia the first price rate is fixed and it is considered to be very cheap by authorities and citizens, this means that citizens are allowed to use a certain volume of water, but once this volume is exceeded than they would have to pay a variable price rate that starts to increase in price the more water is consumed (Manzano 7 March. 2007).

7.3. WFD Criteria

The WFD strongly believes that EU members and stakeholders have an important role in the implementation of a new vision for water resource management. In other words, water should be regarded as a scarce and valuable resource that must be carefully managed in the long term and not only in the short term. Such measures should respect the following conditions (WSDG):

- Water supply should fulfill socio economic and environmental needs. It is important to prioritize the uses, including the environmental use.
- Participation, partnership and cooperation are necessary to promote sustainable water management within all stakeholders (from locals to governmental authorities).
- Sustainable water management should make accurate estimations of water needs for aquatic ecosystems and human activities.
- In case there is an overexploitation of resources, authorities should implement demand and supply measures for all users. There must be equilibrium between water supply and demand, in which there are enough human resources and funding to cope with this situation.

Long and short term actions in Catalonia have experienced growth and changes during the last decade along with the WFD criteria. However, there are still measures to include or to modify to reach water sustainability and reduce vulnerability for droughts in Catalonia. Measures and strategies undertaken by the different stakeholders will be analyzed further on in detail in the case study.

7.4. Decree of Drought and Emergency Decree in Catalonia-Preparedness measure

Due to a lack of rainfall, a decrease in water reserves in basins and forecasts that the demand of water would be greater than the amount of available water on a short and medium term, led the Government of Catalonia together with the ACA in 2005 to take action by creating and adopting preparedness measures Decree of Drought (GENCATa)[3] and later on the Emergency Decree (GENCATb)[4]. The objective of these decrees is to

[3] Approved on May 17,2005.
[4] Approved on September 27, 2005.

create measures that will protect the available water by keeping it at a ´safe´ level and to use the stored water more efficiently *until* the superficial and underground water, as well as the stored water in basins acquire acceptable levels in order to preserve the supply for *domestic use* (GENCATa).

7.4.1. Decree of Drought

The Decree of Drought applies to all Catalonia and it is supervised by the ACA. It regulates the use of water and restricts non priority uses to meet demand. On Article 2 of the decree, there are basically three different scenarios:

- *Exceptional scenario- level 1.* If the levels of water are lower than the first threshold in the basins, than water restriction measures are set on the supply of each water basin[5] in order to preserve it. The purpose of this scenario is to guarantee the supply of water on a medium term (see Appendix 7).
- *Exceptional scenario- level 2.* If the level keeps decreasing and crosses the second threshold in order to guarantee the supply of water on a short term.
- *Emergency scenario.* If the level of water reaches the third threshold than the Emergency decree is activated, thus further restricting the use of water and providing aid to supply water to regions where basic needs cannot be met.

The main key points of interest for inland water basins are mentioned in the Decree of Drought are the following[6].

- Increase cooperation with all authorities and the ACA, as well as with the citizens (Introduction).
- Create water sensibilisation campaigns to reduce water consumption at home (Introduction).
- Farmers are obliged to use reused water[7] (partially or entirely[8]) for irrigation (Article 15)).
- Farmers are obliged to reduce their use of water for irrigation 20% on exceptional scenario 1 and 40% on exceptional scenario 2 (ACA Barcelona).
- Economic drought impacts are not economically compensated by the Government (Article 10.1).
- Emergency supplies of water to regions where there is not enough water will be brought in tanks and the ACA will pay for this service. ACA will also cover the expenditures to produce reused water (Additional Dispositions-5).
- Water awarded in a concession to farmers shall be restricted while any of the scenarios is activated. Failure to do so will lead to a severe punishment. ACA is in charge of the surveillance that such measures are obeyed (Article 4).

[5] Each water basin has a different threshold.
[6] The other points mentioned in the Decree are related to rivers in general and to specific water basins in Catalonia.
[7] This reused water meets the quality requirements specified by the Department of Health of the Government of Catalonia.
[8] This action is analized and set into motion by the ACA.

- Municipalities that have more than 20,000 inhabitants must create their own contingency plan and present it to the ACA. This will be reviewed to determine the minimum supply of water needed and that will be allowed to be used in a certain town or area (Article 12.1).
- Contingency plans must include (Art. 12.3):
    - Description of the water supply network
    - Definition of the services where water is supplied
    - Number of users (people) to which water is provided
    - Identification and assessment of water that is used in hospitals, public places, water deposits for fire hazards, etc.
    - Assessment of possible obstacles in the water network that could interfere in the application of the measures established in the different scenarios
    - Preventive measures, method of application and an assessment of their efficiency
- Maximum of quantity of water that can be supplied is 280 liters/person/day (Art. 12.4). The ACA guarantees that water for public use should reach a minimum of 75 liters/person/day (Art. 12.6).
- Each municipality will be in charge of managing and re-using water from public and private swimming pools, restricting the use of water in private gardens, and the optimization of the use of water in water parks and other non priority venues, while taking into consideration sanitary standards (Article 12.5).
- Water used for irrigating golf courses must come from reused water when the exceptional scenario level 2 is activated (Article 16.4).
- On a temporal basis, all rights for the extraction of water from wells, mines, etc. will be confiscated (Art. 12.8).

7.4.2. Emergency Decree

While in 2005 the drought situation was becoming worse, the Emergency Decree was created on September 27, 2005 to regulate the use of water in order to extend the availability of water and to preserve domestic supply as much as possible (ACA). The measures in this decree were mainly directed to the application of progressive restrictions for urban water supply. Although this decree is for all Catalonia it accounts for specific characteristics of each region. In comparison to the Decree of Drought, was directed towards the water supply network and not to water basins. Fortunately, there was no need to implement it in Catalonia (ACA), although in the Llobregat it was about to be activated in 2005.

8. Case Study- Riudecanyes and Riudecanyes Water Basin

8.1. Background of Riudecanyes

Riudecanyes is situated 195 meters high in the county of Camp-Baix which belongs to the province of Tarrragona in Catalonia (see Fig. 8.1and Fig. 8.2). It is a small town of only 1000 inhabitants hidden in the mountains but not far from the sea- The Costa Dorada. Riudecanyes is attractive to visit both for its historical buildings and natural sites.

Fig. 8.1 Catalonia
source:
http://content.answers.com/main/content/wp/en/thumb/6/65/320px-Catalonia2.png

Fig. 8.2 Riudecanyes Catalonia
source: map-of-spain.co.uk

Although its population is not big compared to other cities in Catalonia, it is growing at a fast rate. The reason is due to people from Reus[9] that retire and move to Riudecanyes because life there is calmer and cheaper. The main economic activity in Riudecanyes is agriculture. The main product is olive oil, almonds and walnut, which is one of the best and most highly-appreciated extra virgin oil, recognized by the olive oil of

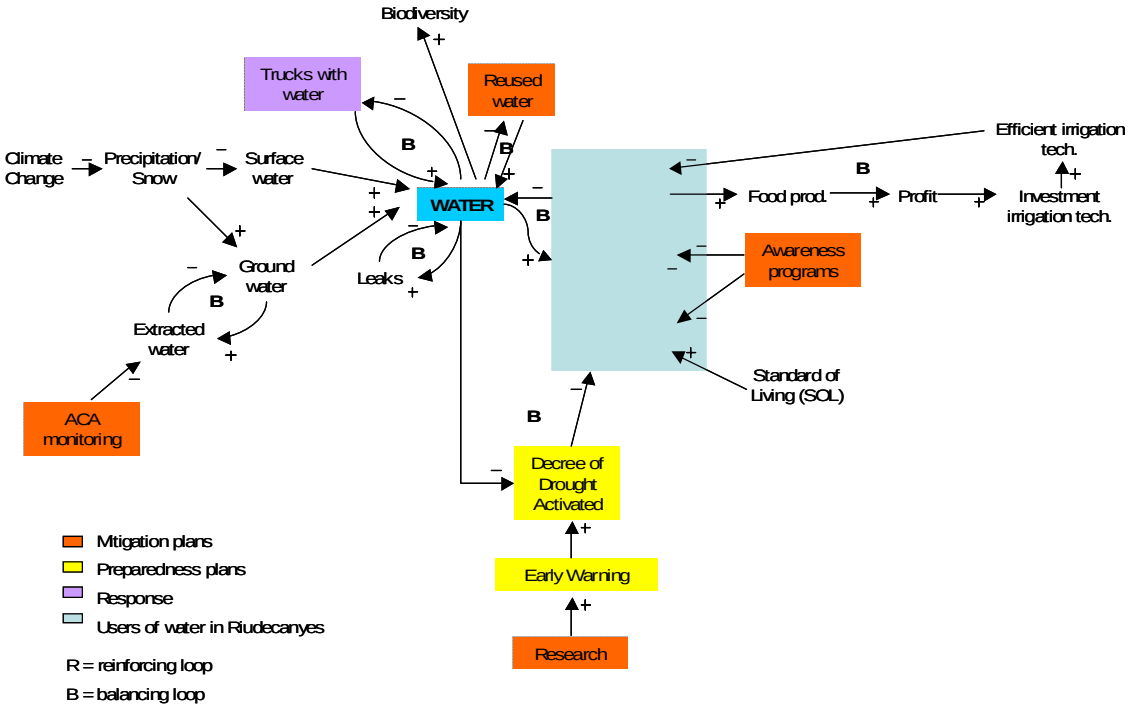
[9] The second most important city in Tarragona Province, which is approximately 17 kms. away from Riudecanyes.

origin (Ajuntament Riudecanyes[10]). The average rainfall is about 605 mm/year and 44 hm^3/year (ACAb:60).

8.2. Present situation in Riudecanyes- Causal Loop Diagram (CLD)

ACA, the Riudecanyes water basin and the municipality of Riudecanyes have been working together to improve water management measures and policies. These actions are shown and higlighted in colored boxes on the CLD. The diagram also shows the cause and effect of these measures and policies on farmers and citizens, in regards to the amount of available water. The way in which water is driven from one source to another is also shown. The CLD highlights the steps that have been taken in Riudecanyes, following the Wilhite´s Cycle of Disaster Management (see Fig. 8.3). These steps include mitigation, preparedeness, early warning and response after a drought.

Fig. 8.3 CLD
source: V. Smith



[10] www.riudecanyes.altanet.org

Description of the CLD:

The description of the CLD will present an organized mental model of the relationships between factors and the present measures or policies adopted to reduce vulnerability to water stress.

- While temperatures increase due to climate change there will be less precipitation due to evapotranspiration and less snow in the mountains. The lack of snow will reduce the amount of water runoff melted in spring, a season with low levels of precipitation. If there is less precipitation and snow then the availability of surface and groundwater (wells and mines) water will be less, which could lead to water stress.
- Leaks are still a problem in the distribution of water in the city, thus wasting unnecessary water. However, no entity has taken control of this situation.
- The more groundwater there is. farmers extract more water from wells or mines because it is cheaper.
    - Even though ACA has a monitoring system, it is not implemented accurately in Riudecanyes because many farmers do not state that they have found a well and ACA´s monitoring is not frequent
- A decrease in the water available in Riudecanyes, means that there will be less biodiversity and less water for agriculture as well as for households.

    - ACA is working to improve their Early Warning system. The more research may lead to more precise predictions and prompt Early Warning. This will also lead to the timely activation of the Decree of Drought (Preparedeness measure) that will reduce vulnerability to water stress.
    - If there is a lack of water, reused water can be used for agriculture (Mitigation policy).
- The more water there is in Riudecanyes for agriculture leads to more production of dry fruits, thus returning a higher profit to farmers. If farmers have more profit, then they can invest on more efficient irrigation techniques to use less water and also to repair the leaks in their water pipes.
- Consumption of water is increasing in Riudecanyes. A reason is the building of chalets that have gardens and swimming pools. The standard of living is increasing in this town due to well off retired people from the neighboring town Reus that are moving to Riudecanyes. Another reason is that people are not conscious about saving water.
    - ACA is creating public awareness programs to reduce water consumption (Mitigation measure).
- In an emergency situation in which water would not be enough to supply the households needs, then bringing water with trucks (Response measure). Luckily, Riudecanyes water levels have not reached this emergency state.

8.3. Stakeholders Analysis

The following stakeholder's analysis is the product from the interviews and surveys conducted, as well as from documents collected during the field research. The stakeholders include the Riudecanyes water basin, ACA, farmers and local citizens.

8.3.1. Riudecanyes Water Basin

On March 5, 2007, I had an interview with Miguel Angelo Prats, administrator of the Riudecanyes water basin. The interview took place in the city of Reus where their headquarter office is located. Miguel Angelo Prats has been the administrator of the Riudecanyes water basin for more than 8 years and all information below was provided by him. Additional information was provided by Eduardo Soler, consultant in Limonium Consultancy (Spain).

The construction of the Riudecanyes water basin was finished in 1918 and today it is a public administration that is included in the ACA Hydrological Plan[11] (Prats 5 March 2007). It is located right next to the town of Riudecanyes. The basin´s water capacity is 5 hm^3, smaller compared to other basins in Catalonia (see Appendix 8). Due to a meteorological drought in 1948, the basin reached very low levels and it failed to satisfy the demands of water. In 1972, after several proposals it was agreed to transport water from the Siurana water basin[12] to the Riudecanyes water basin. Siurana supplies almost half of the water in Riudecanyes, only if there is enough water to supply from Siurana (Prats 5 March 2007). The high precipitation months in this area are generally from mid March to early June, and from mid September till the end of October (Prats 5 March 2007). There are consequently two ways in which the Riudecanyes water basin receives water, through precipitation and through the transportation of water from Siurana water basin. However, there are plans to transport water from the Ebro if there is a severe water stress situation in domestic use (Prats 5 March 2007). The supply of water is usually 70% for agriculture and the rest for domestic use.

Hydrological droughts in Riudecanyes water basin are not uncommon. The main reason for droughts in this region is due to its Mediterranean climate and that it is drier than other places in Catalonia. The drought experienced during the 80´s was worse than what it is now. It is seen as a cyclical behavior, in which some years are better than others. The administrator of the Riudecanyes water basin considers that climate change is not an issue related to meteorological drought in Riudecanyes. On September 2006, the situation improved and the Riudecanyes water basin reached 52.48, due to high precipitation levels in autumn reaching safe levels (ACAc). It is important to mention that 40% is considered ´normal level´ (Garcìa 2007). The level of water on March 9, 2007 has reached 18,54% in Riudecanyes, which is almost one third less than what it was during the 2005 drought crisis in Spain. In 2005 the level of water in Riudecanyes was 35,88% (Garcìa 2007). In a lapse of 10 years it is clear that the average level of the basin in Riudecanyes has been 55% about 3.3 hm^3/year (ACAd), while experiencing critical low points, as it happened in September 2005. During an interview with the Administrator of the Riudecanyes water basin and with Jose Manuel Sánchez. Technical Engineer of Public Services in ACA Tarragona, both

[11] This plan was published in 1999.
[12] It has a capacity of 12 hm^3.

suggested that one way for supplying water 100% for agricultural purposes would be pumping water from a desalination plant that is located on the Costa Dorada, however, this option is very costly.

The demand of water from households has always been met (Prats 5 March 2007). After a drought in the mid 80s, where water was supplied only 3 hours per day in the city of Reus, made it possible for the locals to become more aware of the water scarcity situation, thus reducing the amount of water consumed even after the drought to around 148 liters/person/day (Soler 10 March 2007). The same reaction corresponded to Riudecanyes, thus turning Riudecanyes and Reus in two of the cities where household water consumption was the lowest in all Catalonia. However, this amount has increased to an average of 197 liters/person/day and people who live in a chalet and have a garden consume around 266 liters/person/day, even though the latter are not the majority of locals living in Riudecanyes (Soler 10 March 2007). Another reason why the demand of water has always been met in Riudecanyes is that priority of supply has always been given to fulfill households needs opposed to agricultural ones and also because household demand accounts for only 30% compared to 70% for agriculture (Prats 5 March 2007). Therefore, the supply of water for agriculture from the water basin has never been enough. An example is the cultivation of hazelnuts, which are the second most important dry fruit, together with almonds, grown in Riudecanyes after olives. If an irrigated land of hazelnuts needs between 4500-5000 ha/year, the basin will be able to provide only around 1200-1300 ha/year (Prats 5 March 2007). The rest of water needed will be responsibility of the farmer to extract from wells or mines on their own expense. However, it is important to mention that there is no environmental impact assessment of the effects when water is extracted from wells or mines (Prats 5 March 2007). The administrator of the Riudecanyes water basin considers that there is no real need for such assessment since all water, 90-95% used for agriculture, is filtered back again to the aquifers.

8.3.2. Agencia Catalana de Agua (ACA)

On March 6, 2007 an interview was conducted with Jose Manuel Sánchez. Technical Engineer of Public Services. ACA Tarragona and on March 7, 2007 an interview with Andreu Manzano Rojas, Project Manager for the Planning Department of Water Sustainability in ACA Barcelona, took place in his office in Barcelona.

The ACA is a public Catalan organization in charge of administrating all hydrological resources in Catalonia and it was established on December 31, 1998 by the Generalitat of Catalonia (GENCATc). It was the result of combining the Ajunta d´Aigua (branch of the Public Hydraulic Service Department) and the Ajunta de Sananmiento (branch of the Catalan Environmental Department). The main headquarter is situated in Barcelona. One its main objectives are to enhance cooperation between the ACA and the rest of the hydraulic administrative entities in Catalonia and with farmers and local citizens. When it was first established one of the aims was to decrease the centralized regime that it had before when all basins were governed by the Generalitat of Catalonia, therefore the ACA was divided into six different entities all around Catalonia (Manzano 7 March 2007). Riudecanyes water basin reports to ACA Tarragona and Siurana water basin to ACA Girona. Each ACA entity is in charge of inspecting and surveilling the basins (e.g., controlling the extraction of water) and to provide in specific cases economic aid for development and emergency situations, such as a drought (Manzano 7 March 2007).

The following analysis follows the structure of the Cycle of Disaster Management suggested by D. Wilhite (2000:15) which will enable to find the weak and strong drought management measures and policies implemented by ACA.

8.3.2.1. Mitigation

Andreu Manzano and Jose Manuel Sanchez believe that drought is not a result from climate change. They explained that droughts are merely cyclical events that have existed all along history. A. Manzano mentioned that ACA has taken into consideration historical statistics that date back 200 years ago. The result shows that during this lapse of time, droughts have also occurred in the past. A statement that carries in congruencies towards climate change science. Because the availability of water is not going to improve in the coming years, it is vital for Catalan authorities to understand that global warming is happening now. If authorities become conscious about this situation then they will understand the importance of creating mitigation plans to reduce drought vulnerability in a long term, because climate temperature is going to increase and preparedness measures will not be enough to prevent having water stress.

Water saving measures is an important factor for drought mitigation. Although household water consumption in Riudecanyes was very low-148 liters/person/day in 2001, compared to the rest of cities in Catalonia (more than 200 liters/person/day), in 2006 it increased to 197 liters/person/day (Soler 10 March 2007). The main reason for this increase in Riudecanyes is due to a rise in the standard of living. In the past 5 years, people have built bigger houses (chalets), many with a swimming pool and a garden, which need more water. The price of water in Riudecanyes and in all Catalonia is very low, around 1.3 euros/m^3, compared to other European countries (see Appendix 4). In the Decree of Drought, the maximum quantity of water allowed to consume is 280 liters/person/day and the average consumed in Catalonia is more than 200 liters/person/day, however, this value is still very high compared to other European countries. If these levels are not reduced in Catalonia, they could affect the Riudecanyes water basin by having to transport water in the future from this basin to satisfy the high demands of other Catalan cities. At this rate water stress will be suffered with more frequency.

Good news is that ACA and other authorities are searching for options to avoid water stress by bringing water from other sources (Manzano 7 March and Sanchez 6 March 2007). Desalinated water and reused water are some of the options, although the price of water would have to increase to pay off these expensive processes. A. Manzano commented that in the province of Baix-Camps, where Riudecanyes is situated, there is a project funded by the European Community to produce reused water for industrial refrigeration of almost 20 hm^3/year. This is double the amount of water that is extracted from Riudecanyes on a yearly basis. This project is independent to the fact whether there is a drought or not.

The Decree of Drought stipulates that farmers are obliged to use reused water for irrigation (sometimes partially and others entirely) only when the decree is activated. However, this decree has only been activated one time during the 2005 drought. A. Manzano said that the reused water is not used because farmers prefer to irrigate with water from the water basin because people that buy their dry fruits believe that reused water is not safe. This increases the probability of water stress in the future, by using water from the basin. However, A. Manzano stated that ACA is planning to publish a new version of the Decree of Drought this year, which will require farmers to use reused water for irrigation at all times. This could create a problem for farmers when they would like to sell their

products. Many people doubt the sanitary condition of reused water and might refuse to buy any product that has been entirely or partially irrigated with reused water, thus worsening the economic state of farmers. A. Manzano stated that the quality of reused water varies from place to place. Water that is treated will have different qualities after the process due to the chemicals that it had before it was treated. This not only makes it very difficult to reach a general sanitary standard agreement but also the Department of Sanitation is very strict when it comes to quality sanitary standards, thus increasing the price of reused water and making it more expensive for farmers to afford. Reused water for non priority purposes, such as swimming pools, private and public gardens, water parks is only used when the Decree of Drought is activated (Manzano 7 March 2007). For golf courses (which use large quantities of water) reused water is only used when the exceptional scenario reaches level 2. The economic profit in golf courses brought by tourists is perhaps the incentive that keeps the ACA (governed by the Generalitat of Catalunya) from imposing any real water restrictions for its irrigation, considering that it is a non priority issue.

A. Manzano said that ACA has helped to renew the water pipes in the Riudecanyes water basin that had leaks of almost 20% in the past and this percentage today has been reduced to almost none. However, while farmers cannot afford to invest on technology that could maximize the use of water by consuming it more efficiently, crop insurance does not exist in Catalonia, thus increasing socio economic drought (Manzano 7 March 2007). In some causes leaks have been reported but farmers cannot afford to repair them or buy new pipes. If ACA cannot economically help farmers, then it is important to implement crop insurance in order to trigger a mechanism in which farmers are not economically ruined and they will be able to invest in more efficient techniques to save water.

Even though Catalonia suffers from droughts, some farmers are forced to waste water that has been awarded to them as a right by ACA. J.M. Sanchez commented that ACA awards a certain amount of water that each farmer can use for irrigating purposes each year as they think is best. However, if times are not good for cultivating and a farmer decides not to use this water, than the ACA can take away his right. Therefore, farmers are afraid of loosing this right are forced to take the water and simply throw it away to the fields, action that is not punished by any authority. Other farmers sell their water at double the price to other farmers, which is illegal by law. If farmers have an excess of water they are supposed to donate it to ACA, but little surveillance is made on behalf of ACA to regulate this situation. J. M. Sanchez added that the extraction of water is at all times checked randomly by ACA, however, there are many times in which farmers do not report the fact that they have found a well and they are extracting water from it, thus making real figures of water levels less certain and making early warning less precise.

For several years, water conservation programs have been important for ACA and many Catalan municipalities. A. Manzano stated that ACA Barcelona has organized since 1999 the Festival of Water for adults and children. Its objective is to sensitize people about water issues and to create a space for children to learn in a didactical way how to save water. There have been many TV and radio campaigns and schools have also taken the responsibility of teaching children to take care of water. However, when A. Manzano was asked whether ACA had conducted any survey to assess to what extent their conservation programs for the public have been effective, the answer was no.

One of the points that is emphasized by the WFD is social participation and transparency in water politics. Therefore, ACA has established 6 months ago CUSA (El Consejo para el Uso Sostenible del Agua) (ACAe). It is a group integrated by ACA

authorities, water supplying associations, locals, farmers, etc. The aim of this group is to gather and talk about water and hydraulic proposals, projects, their efficiency to save water, and how each stakeholder is affected by new measures.

A. Manzano stated that drought mitigation plans by ACA are mainly targeted to supplying water for domestic and industrial use because its focus is on urban cities like Barcelona in which 80% of water supply is for domestic and industrial use and 20% for agriculture. The reason for this might be unknown interests behind and a still centralized view in ACA. J.M. Sanchez agreed by saying that ACA is still centralized and needs to be decentralized. However there are many small rural communities in Catalonia, in which these figures are around 70% water supply for agriculture and 30% for domestic use. ACA believes that mitigation programs for agriculture are secondary compared to household use (Manzano 7 March 2007).

8.3.2.2. Preparedness

ACA is aware of the meteorological, hydrological, agricultural and socio economic droughts that are taking place in Catalonia as are occurring almost every year.

The Decree of Drought and the Emergency Decree correspond to "Preparedness" management in the Cycle of Disaster Management flow. Medium and short term solutions are described. The Decree of Drought states that its objective is to create measures that will protect the availability of water by implementing mechanisms to use these water more efficiently *only* until the superficial and underground water, as well as the stored water in basins acquire safe levels. This is a temporary measure that will only create water sustainability while there is a drought, instead of creating sustainability at a long term. Also, these measures are mainly directed to provide water for households, which accounts for only 30% of the water supplied in Riudecanyes.

Water efficiency in agriculture is very important and it is not mentioned in the Decree of Drought, perhaps because ACA does not want to make itself responsible for bearing the costs of more efficient techniques for irrigation. However, due to the low market price of olives, hazelnuts and walnuts and the economic disaster that is implied during and after a drought, it is virtually impossible for a farmer to invest in such farming efficiency techniques, thus increasing water stress[13].

A contingency plan which is also part of Preparedness management is the responsibility of each municipality to write and send to ACA, however, does not exist in Riudecanyes. The reason behind this is that communities where drought is more often experienced, are much better equipped to cope with periods of water stress than those accustomed to more secure conditions, and can offer more localized solutions than the general ones that ACA could provide. Nonetheless, ACA should also take part in the creation of contingency plans. It could, for example, suggest the implementation of economic instruments that could lessen the drought impact, such as providing water from desalination plants, among many other alternatives. A. Manzano stated that ACA makes contingency plans only for municipalities that consist of less than 20,000 people. However, these contingency plans should also include the participation of farmers and locals from this area. The process of writing and adaptation of a contingency plan should be made in a holistic approach in which all stakeholders are involved.

[13] This discussion will be thoroughly reviewed in chapter 8.3.3.

8.3.2.3. Prediction and Early Warning

Drought assistance of any kind is more effective if the information on which it is based is timely (Wilhite 2000:16). A. Manzano commented that early warning systems in ACA are still under development. Nonetheless, ACA is planning to publish a new Decree of Drought this year which will include that all municipalities or hydraulic entities in Catalonia should send ACA all necessary data (such as quantity of stored water, quality, etc. in water basins) with more frequency in order to create a faster and more efficient early warning system response that can react to water stress situations. In 2005 when the Decree of Drought was activated it included all Catalonia, however, prediction, bureaucracy, and a slow response failed Riudecanyes (Prats 5 March 2007). The main problem experienced in the Riudecanyes water basin that year is that even though the level of water was low when the decree was activated, it soon recovered reaching a level of 80% of its capacity. However, due to bureaucracy the restriction was kept for several weeks, even though the levels of water were two times higher than the decree's threshold. This in return created an economic loss for farmers that were restricted to use water, especially during the summer season (Prats 5 March 2007).

A. Manzano said that ACA also runs models that simulate on a monthly basis the demand of water versus the historical demand of water using figures since 1940. He commented that it is quite difficult to change in the Decree of Drought the thresholds in which the supply of water needs to be restricted. Once the Parliament has approved a decree it can take a long time to make a change due to bureaucratic processes. Therefore such models are run to be able to anticipate a change in the demand of water, thus giving extra time to apply for a change to the Parliament. A. Manzano stated that climate prediction is still very difficult to do; however, ACA is working with atmospheric pressure which seems to be an important variable for a correlation in order to establish analog prediction models. ACA has also conducted a pilot test near Barcelona to predict climate variability, taking into account the three different IPPC scenarios from the third report. The result was very ambiguous giving a 5-30% margin of error. However, ACA is still planning to make another pilot test which will include more detailed variables.

As mentioned before, public awareness conservation programs are an important mission for ACA. This year, ACA has created a pre-alert system. When ACA predicts that there is the possibility of a future drought in the short-medium term then such programs are intensified trying to reduce water consumption while there is a water shortage (Manzano 7 March 2007).

8.3.2.4. Impact assessment

A. Manzano commented that ACA considers that it is not their responsibility to carry out any impact assessment. For environmental and agricultural drought impact assessment it would be responsibility of the Department of Environment and the Department of Agriculture to carry out such duties. However, it should be the responsibility of ACA to assess the economic and social drought impacts, in order to decrease drought vulnerability within their mitigation and preparedness plans and actions in all Catalonia. An example would be to assess the extent to which droughts affects farmers economically and try to find a mechanism or aid to help them.

8.3.2.5. Response and rehabilitation

Since droughts in Catalonia have not reached a levels of extreme natural disaster as it has, for example, in Morocco (Wilhite 2000:279) it has not had to take response actions such as restoring transportation and communication services, emergency medical care, temporary housing, etc. The only two main actions taken by ACA have been the supply of water to small regions such as in the town of Brunyola (in the province of Girona), this year and also covering the expenditures of producing and bringing reused water, only when there is water stress in a certain area (Manzano 7 March 2007).

A. Manzano considers that rehabilitation has always been fast due to the measures taken such as contingency plans, the Decree of Drought, etc. to reduce consumption of water. However, this is difficult to state since socio economic drought impact are not quantified but it will certainly be necessary to do so in the following years when climate temperature will increase thus prolonging the time needed for drought rehabilitation.

8.3.3. Farmers in Riudecanyes

On March 9, 2007, I visited the town of Riudecanyes and the water basin. I had the opportunity to interview Josep Anton Caballe Godall, President of the Riudecanyes Agricultural Cooperative (Cooperativa Agrícola de Riudecanyes), as well as 2 farmers who own olive and almond plots of land for many years in Riudecanyes. Farmer 1 is Joan Llobreira and farmer 2 is anonymous.

The Agricultural Cooperative of Riudecanyes is an association that gathers all farmers in order to talk and compromise on different common agricultural issues. This is the only association of farmers in this town and all farmers belong to it. The three interviewees are males and are about 40-50 years old. All of them were born and raised in Riudecanyes.

As mentioned before olives are the main agricultural production in Riudecanyes. However, almonds and hazelnuts are also grown in this area. According to Josep Anton Caballe, many years ago farmers used to cultivate vineyards but this was not profitable. He added that when vines became old they had to be torn out and farmers had to wait until the soil became fertile again, thus decreasing their profits. Although olives, almonds and hazelnuts are dry fruits and need very little water to grow and there is no need for crop rotation, cereals consume less water. However, these are not produced in Riudecanyes due to its mountainous landscape, which is not appropriate for cultivating cereals (Caballe 9 March 2007).

J.A.Caballe explained that water is pumped at a very high pressure from Riudecanyes water basin to the top of the mountains and then the water is distributed downwards from a plot of land to another. Dry fruits do not need a lot of water. Irrigation is used only as a support mechanism mainly during January and in summer (time when dry fruits start to blossom), time when meteorological and hydrological droughts are more frequent (Caballe and farmer 1, 9 March 2007). J.A Caballe stated that ACA has an agreement with farmers to the months when they are allowed to use their concessioned water and this time is usually in summer. However, if a tree is very weak from a past drought, it will be very difficult to recover and produce the average quantity of its dry fruit next year. Therefore, J.A. Caballe explained that ACA and farmers have agreed that if there is enough water in the water basin, farmers can buy water on any other season, but the cost of this water is too expensive thus difficult for an average farmer to afford. Therefore, the

dream of a farmer is to find water in a well or in a mine, but it is very difficult to find. Finding water in wells or mines enables farmers to extract as much water as they want or they can find. According to J.A. Caballe and farmer 1, water from wells and mines is cheaper than water from the Riudecanyes water basin. Farmer 1 said that the extraction of water from such means is not regulated by ACA, because there are very few wells and mines in Riudecanyes. In many cases, if a farmer has an extra surplus of water he can "give" it (in many cases illegally sell it) to a fellow farmer who needs water. However, the lack of monitoring the amount of water that is extracted may have adverse consequences in the future concerning water tables in aquifers, thus increasing the vulnerability to hydrological droughts.

Farmer 2 stated that Riudecanyes does not use reused water for irrigation because they consider that it is very expensive and they still have not suffered from severe water stress. J. A. Caballe added that there used to be a water treatment plant not far away from Riudecanyes which only produced treated water (not reused water) and then it was deposited in the sea, but nowadays it has been close for unknown reasons.

As mentioned before water that is awarded to farmers by ACA in many cases is wasted, by fear from farmers to loose their concession. In other words, they must make use of all the water awarded to them even if they do not need it. According to J.A. Caballe, farmers can waste water in different ways. One is to simply let the water run on the fields. Another is that ACA has stipulated that dry fruit trees need a maximum of 50 liters/m^2, so this quantity is awarded to farmers, but a dry fruit can also grow with only 30 liters/m^2, therefore farmers may just use extra water for their trees, or simply give it or sell it to another farmer. This usually happens when the levels of water are normal in the water basin.

According to J.A. Caballe, the main drought mitigation measure used by farmers in Riudecanyes is the use of either Rajoli or Drip irrigation systems. The main irrigation system here is Rajoli, in which water is transported in open canals and it is used in small plots of land (Soler 10 March 2007). J.A. Caballe said that drip irrigation, which is used in very few plots of land in Riudecanyes, is used for bigger plots. The advantage of using Drip irrigation is that it is one of the most efficient irrigation systems (efficiency 90-95%) by delivering precise small amounts of water to trees or plants (Miller 2005:324). Farmer 1 explained that in Riudecanyes an olive tree needs 3-4 hours of water/week. The advantage of Rajoli irrigation is that it irrigates water at a faster pace and it is less expensive than Drip irrigation, but it has a lower efficiency due to evapotranspiration. However, both systems use the same amount of water (Caballe 9 March 2007).

According to J.A. Caballe, mitigation plans to decrease socio economic drought impacts do not really exist in Riudecanyes. For example, farmers are not insured in case there is a drought, thus decreasing the amount of dry fruits produced and returning a low economic profit.

J.A. Caballe explained the different preventive measures taken by farmers. One of them is to regulate the amount of water they irrigate. They basically calculate how much water is needed to irrigate. If they begin to experience water stress, they reduce the time of irrigation from 4 hours to 3 and instead of irrigating from 14-12 weeks they reduce it to 10 weeks from June till August. Another preventive measure is the one imposed by ACA to restrict the amount of water farmers can use for irrigation. Evapotranspiration calculations are not a common practice by farmers in Riudecanyes, therefore the amount of water needed is simply a close estimate (Soler 10 March 2007).

Farmer 1 and farmer 2 said that the price of olive (olive oil), almonds and hazelnut in the market is very low. They explained the reasons for this. In the case of olive oil, the committee of Olive Oil Origin of Siurana regulates the price. The price is regulated because if it increases it could not be able to compete with the low price of olive oil from Tunisia and Andalucia (Spain). Even if Catalans would like to support their economy by buying more expensive olive oil, they could not be able to afford it because this product is part of their daily diet which is consumed in large quantities. If the price of almonds or hazelnuts was raised they could also not compete with the low price offered by Turkey. The profit obtained by farmers is very low and it has dramatically reduced the amount of agriculture in this region. Due to this reason, Riudecanyes has lost 40% of the use of cultivated land. Four years ago there were 9,000 farmers and today there are 6,000. Even though farmers do not receive a high profit, socio economic drought rehabilitation for most farmers has fortunately been fast, because severe droughts have yet not been experienced in this region. However, J.A. Caballe stated that in case a farmer has a serious economic loss, he has the possibility to borrow money from banks at a fair interest rate.

Farmer 1 and farmer 2 are concerned with hydrological drought in Riudecanyes. They believe that even though the level of the Riudecanyes water basin together with the transported water from Siurana totals around 40% this year, this is not enough and it is considered as a signal of hydrological drought in this region.

J.A. Caballe, farmer 1 and 2 stated that cooperation with ACA is good. There meetings are mainly about deciding the amount of water that ACA allows farmers to use for irrigation. However, one of the main concerns for farmers is the expensive price for acquiring an extra surplus of water.

The main effort from farmers to take care of the environment is to collect in the fields all their fertilizer and pesticide packages or containers (usually made of plastic or paper) (Caballe 9 March 2007).

8.3.4. Local Citizens from Riudecanyes

The survey conducted to the citizens of Riudecanyes took place on March 9, 2007. All interviewees (a total of 8) have lived in Riudecanyes all their life. Their age ranged from 35-55 and it includes both men and women.

The following is the list of interviewees:
Person 1: Joan Llobreira. Farmer
Person 2: Dolors Teigell. Shop assisstant
Person 3: Pilar Roige. Shop assistant
Person 4: Miguel Seuba. Mechanic
Persons 5-8: Anonymous (They preferred not to give their names). 1 housewives, 1 restaurant waiter, 1 salesmen, 1 farmer

All people interviewed in Riudecanyes agreed that there have been droughts almost every year. They believe so because the level of the water basin has been very low and also because it has not rained. Although government authorities do not think that drought is a result from climate warming, all interviewed citizens from Riudecanyes do. For example, person 1, said that last year in August, there was an unusual thunderstorm never else seen in this town in which hail, the size of an egg, fell from the sky, thus endangering people's

lives, damaging many agricultural products, cars on the street, etc. Person 10 believes that this is an obvious sign that climate is changing and that authorities are not acknowledging.

All citizens except for two farmers (person 1 and 10) that were interviewed, feel that the price of water is low and that in case there were a drought they would not mind to pay a little more for its supply. The two farmers stated that the price of water is cheap because it is subsidized by the government and also indirectly by the high prices that farmers need to pay to ACA when they need to irrigate water for support in months that are not included in the agreement between ACA and farmers. They believe this is not fair to them, since they are not rich. The two farmers said that they would not pay more money for water because it is one of their rights as humans.

Some of the answers given to what they could do to use less water at home were: to use the dishwasher and washing machine less often. Person 2 said that she uses her washing machine almost every day. This action seems excessive since she only lives with her husband and one son. Another answer given by person 3 was to use a shower to bathe instead of a bathtub and also to not leave the kitchen sink open all the time when cleaning the dishes.

All interviewees agreed that to decrease the high consumption of water in Riudecanyes, the price for water for private non priority uses should increase. These non priority activities include water for swimming pools, gardens, cleaning cars and dishwashers. Person 1 said that some people that have gardens in Mont-Roig del Camp (a small and important tourist center near Riudecanyes, water here is supplied by the Ebro River and from wells) have an automatic valve that is turned on even when it is raining. Persons 3, 5 and 7 feel that there should be more programs to make people more conscious on the use of water, targeted both to children and to adults. There was a consensus about golf courses in Mont-Roig del Camp. All interviewees feel that golf courses should not be irrigated with water because of the high volumes required to keep the course in good conditions.

Half of the interviewees feel that water conservation programs, either from TV or radio, have been effective. The other half say that people consume the same amount of water as before. Person 3 believes that people are using even more water today because there are more swimming pools and gardens. A 17 year old boy who suddenly joined the interview said that school in Riudecanyes does not include any program to teach children about water conservation.

According to person 1, the municipality of Riudecanyes on an attempt to reduce household water consumption, set forth a plan in which local citizens were given a discount in the price of water if they would buy a special faucet that expels air bubbles, thus reducing the amount of water coming out. Person 1 said that according to the Municipality of Riudecanyes it was a success story, but in some cases many households already had such device installed at home without even knowing it, like it happened to him. Fortunately the consumption of water in Riudecanyes is low, but it is still very high in many other cities in Catalonia (Soler 10 March 2007).

It is important to mention that even though, M.A. Prats (Riudecanyes water basin) says that after renewing the water pipes to eliminate leaks in their system, person 1 and person 5 said that there are leaks in the city’s water supply system. The percentage of water loss is unknown.

8.4. Worst case scenario: Brunyola

Effects of climate change are already intensifying droughts in some cities of Catalonia. I hereby present a worst case scenario in the town of Brunyola, a town that has not experienced extreme water stress until recent years. The role of this worst case scenario in the study is to present evidence of a town in which extreme water stress is started to become more frequent, even though Brunyola had a higher average of rainfall than Riudecanyes in the past years and its level of rehabilitation is faster in Brunyola due to its level of humidity (Sos Bravo 8 March 2007). This reinforces the idea that cities in Catalonia are also vulnerable to water stress as Brunyola and that a new and improved DMP needs to be adopted to prevent such situation from happening in Riudecanyes or any other city in Catalonia.

On March 8, 2007, I interviewed Vicent Sos Bravo, who is a lawyer working for the Municipality of Brunyola. I hereby present the information provided from the telephone conversation and the written questionnaire (see Appendix B).

The town of Brunyola is located in the north east of the county of Comarca de la Selva, which belongs to the Province of Girona in Catalonia. Its territory is 36,61 km^2 and it has 384 inhabitants[14] (see Fig. 8.4). The water that is provided to this town comes from the river El Conquet and also from a well in Sant Marti Sarpressa. What is special about this town is that it is more humid compared to many other town or cities in Catalonia, thus having no water stress problems (average rainfall is about 800-1100 mm per year), until last year and this year. Vicent Sos Bravo believes that there is a drought in Brunyola due to a lack of precipitation. From August 6-26, 2006, 150.000 m^3 of water was brought to the nucleus Sant Marti Sapresa (that provides water to Brunyola) by trucks. ACA paid 2.110,04 Euros for these expenses. Fortunately, the production of hazelnuts, was not harmed because they are dry fruits and need little water and also because the lack of water in this town lasted for only 12 days.

Unfortunately, this situation repeated itself this year in January. Due to low rainfalls and a warmer winter this year, it was necessary for ACA to bring water to Brunyola (among other 20 municipalities) by trucks (ABC 2007). Vicent Sos Bravo thinks that one of the drawbacks in bringing water to Brunyola is that local citizens need to wait for the water to come and that there is bureaucracy in which there is a long lapse between the municipality of Brunyola asking for a subsidy from ACA and for the latter to provide it.

Vicent Sos Bravo said that there is not a drought contingency plan in Brunyola. However, the municipality of Brunyola has asked ACA for economic aid to write a drought contingency plan. The limitation to writing it depends now on the economic aid. According to Vicent Sos Bravo the mitigation plan that is still in a draft form is the construction of a well in Can Illus to supply water to Sant Mari Sapresa and to Brunyola. This mitigation plan is not sustainable; it will only alleviate the problem for some years while water can still be pumped out from this well.

Having droughts and not even having a contingency plan makes this town even more vulnerable to water stress problems in the future. Therefore, a drought management plan, changes in policies and adding new measures are necessary are an important step in reducing vulnerability to water stress, not only in Brunyola and Riudecanyes but also in the rest of Catalonia.

[14] http://www.ccselva.org/municipis/index.php?id_muni=6

Fig. 8.4 Map of Brunyola

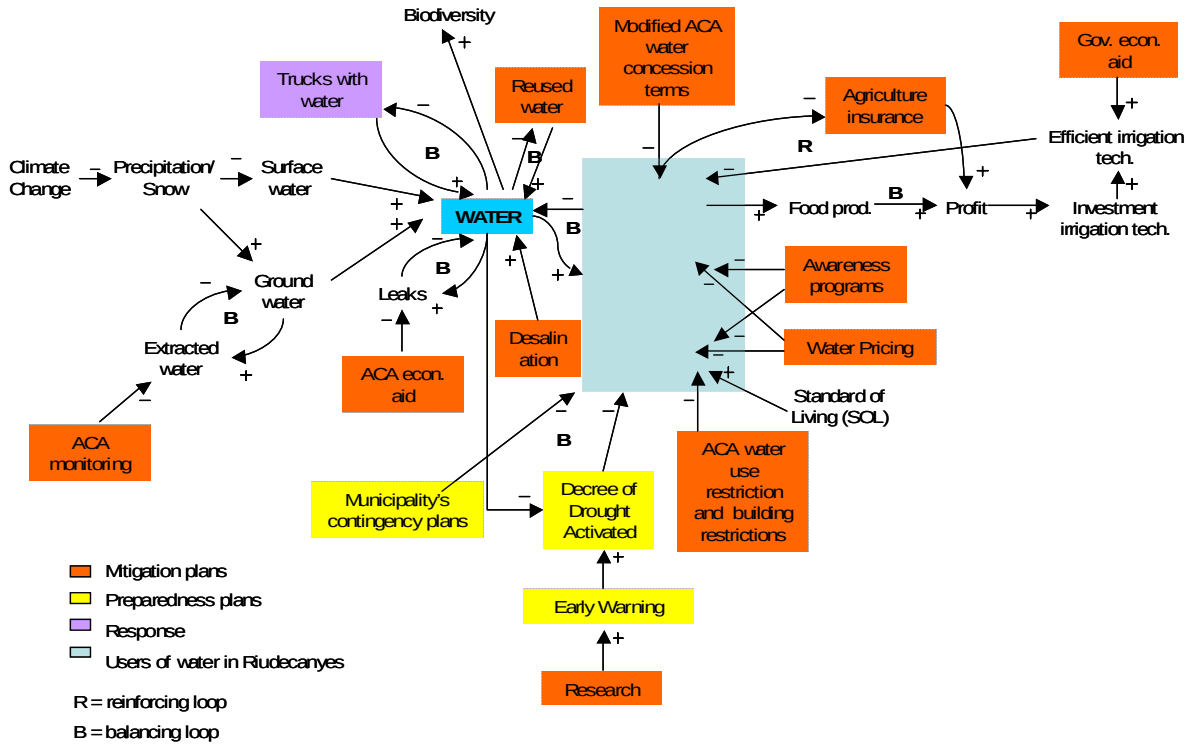
source: www.geocities.com

9. Recommendations

To avoid reaching high levels of water stress, it is imperative to improve and implement different measures and policies for all stakeholders involved in the water management process and water consumption in Riudecanyes. Mitigation measures are the most important to reduce water stress vulnerability in the medium and long term. The cooperation of all stakeholders is very important to reach such goal. The feedbacks in the CLD show possible solutions that will decrease droughts in the future and will reduce the use and consumption of water in Riudecanyes (see Fig.9.1). The positive feedbacks include new measures as well as modifications in the existing measures or policies in Riudecanyes. These feedbacks are shown in colored boxes according to the steps of action in the Cycle of Disaster Management (Wilhite 2000:15). These actions will trigger a positive action that will reduce the vulnerabiltiy to water stress in Riudecanyes. Some of the following recommendations are not shown in the CLD because there is an external or ´invisible hand´ that governs them, such as ´ACA´s acknowledgement of climate change´ and ´ACA´s decentralized management´.

Fig. 9.1 CLD with Feedbacks

Source: V. Smith



9.1. Mitigation

While climate change scientists predict warmer temperatures in the future, preparedness or preventive measures will not be enough to reduce water vulnerability in Riudecanyes in the forecoming years. Therefore, existing mitigation plans must be changed and new ones must be created and implemented.

ACA´s acknowledgement of Climate Change. Most solutions taken by ACA to avoid water stress, such as the Decree of Drought and Municpalities contingency plans are only medium-short term solutions. The idea of transporting water from the Ebro to Riudecanyes and searching for water in wells and mines to reduce water stress have been seen as preventative measures that will fix this problem. However, this is not a long term solution and not a sustainable one. It is very important for ACA authorities to understand that global warming is happening now. If global warming continues than the need of different mitigation plans will have to be taken to reduce water stress and reduce the consumption of water, not only in Riudecanyes but for all Catalonia.

ACA´s decentralized management to fulfill agricultural water needs. The main objective of ACA and all water suppliers is to fulfill household water demand in Catalonia.

This is perhaps the result of a still centralized organization, whose main focus are urban cities like Barcelona where the demand of water for agriculture accounts for only 20%, opposed to rural cities like Riudecanyes and many other cities in Catalonia where it stands at 70%. However, agriculture is affected by this perspective because in many cases the water supplied is not enough for raising crops. This leads to an economic loss that will increase even more in the next years due to increasing temperatures. Riudecanyes main income derives from agriculture, therefore it is important for ACA and the Riudecanyes water basin to take a different approach to protect and develop the technical facilities of agriculture.

Increase the reused and desalinated water. Different alternatives for the supply of water need to be taken into consideration, for example, desalinated water and reused water for agriculture. Desalinated water can be brought from desalination plants located in the Costa Dorada. It is important to make a cost benefit analysis to consider the best option. Although such options are more expensive than the traditional ones (water from the basin, wells and mines), the cost of such options can be met by water pricing and governmental economic aid.

Install a sanitation guarantee for reused water. Even though the new Decree of Drought (still in revision) that will be published this year will force farmers to use reused water at all times, it is necessary that when reused water is provided to farmers this will include a certificate of sanitation to avoid any distrust from buyers. In other words, buyers of dry fruits produced in Riudecanyes will be assured that the reused water used for irrigation follows all sanitary standards.

Introduce proper water pricing and liters/person/day. Even though there was a severe drought in the 80´s and this decreased the amount of water consumed in Reus and in Riudecanyes, unfortunately, it did not become a permanent trend. Today, the price of water in Riudecanyes and in all Catalonia is very low because it is subsidized and the amount of household water consumed is almost double compared to other European countries. Following one of the points of WFD, water prices should not be subsidized. It is necessary to review the option of increasing the price of household water and even more for non priority uses, such as water for swimming pools and gardens, which are become more popular every year. Another advantage of increasing the price of water in households is that the expensive price of reused water and for an extra supply of water for agriculture could be subsidized since it is too high for farmers to afford.

ACA´s water use and building restriction for non priority activities. Since the standard of living in Riudecanyes is increasing due to retired people moving in from Reus and buying a chalet (usually with a swimming pool and a garden), ACA should analyze the possibility of restricting people from using or even having large swimming pools or gardens, which need a lot of water. Although there are no golf courses in Riudecanyes, the construction of such leisure place in the future and the possibility of providing water to golf courses outside Riudecanyes should be prohibited.

ACA create an effective monitoring. It is important for ACA to create constant and effective monitoring services to keep track of all groundwater extracted from wells and mines by farmers, otherwise there is no estimate of how much groundwater there is, thus making early warning less precise.

ACA has to provide economic aid to repair leaks. Although the water basin's supplying system has almost no leaks, there are leaks in the city and in some water pipes supplying water to farmers. Farmers do not have the economic resources to fix the leaks in

their pipes. Therefore, economic aid is needed to avoid loosing water through leaks. ACA seems to be the most appropriate organism that could take responsibility for repairing any leaks in the water supply system.

Introduce assessments for awareness programs. Surveys are needed to assess the effectiveness of ACA´s public awareness programs, since half of the citizens interviewed in Riudecanyes did not feel that they have helped to reduce water consumption. After such assessment, the awareness programs can be modified to become more effective.

Create a system for drought insurance. Farmers will experience greater economic losses in the future. While droughts are happening with more frequency, water in the future will not be enough for agriculture, thus reducing the amount of dry fruits produced. In addition, the market price of their dry fruit is fixed due to globalization and their economic gain is very little. Therefore, it is necessary to create drought insurance plans to protect farmers.

Economic aid to farmers. Since farmers are not making a real profit, it is almost impossible for them to invest on better irrigation systems, such as drip instead of rajoli irrigation. ACA with the help of the municipality must find a mechanism to provide better irrigaition techniques.

Modification of water concessions. The water concession agreement between ACA and farmers needs to urgently be modified. Water is unnecessarily wasted every year by farmers who in fear of loosing their concession with ACA simply let the water run, or make an illegal profit by selling it twice the price to other farmers. The water concession agreement has to be more flexible, if a farmer decides that he does not want to make use of the water awarded to him a certain year, then he will not loose his concession. ACA also needs to set up monitoring bodies to ensure that water is not being sold illegally.

Calculating the right amount of water for irrigation. ACA has calculated a higher amount of water needed to irrigate dry fruits (50 liters/m^2), thus allowing farmers to have more water than necessary when the levels of water in the basin are high. Dry fruits can grow with less water (30 liters/m^2). It is necessary to adjust this figure and to add an evapotranspiration factor (which is not a common practice in Riudecanyes) to calculate the exact amount of water that should be supplied for irrigation.

Drought Impact Assessment. There are no impact assessments (environmental, social or economic) carried out in Riudecanyes. It should be the responsibility of ACA or the Generalitat of Catalonia to assess the economic and social drought impacts, in order to decrease drought vulnerability within their mitigation and preparedness plans and actions in all Catalonia. An example would be to assess the extent to which droughts affects farmers economically and try to find a mechanism or provide aid to help them. An environmental impact assessment report is also necessary to observe how the different mechanisms in a drought management plan or the lack of them will affect biodiversity in Riudecanyes. Thus, creating a holistic view instead of following an anthropogenic approach. To evaluate the effects of a drought it is important to implement such assessment reports at a local scale.

9.2. Preparedness

Contingency plans. These plans are drawn up by the ACA when a municipality consists of less than 20,000 people, however, it should also include the participation of farmers and locals from this area. There is no contingency plan that is tailored made to meet the needs of the town of Riudecanyes. It simply follows the policies and measures

established by ACA. The process of writing and adapting a contingency plan in Riudecanyes must be made in a holistic approach in which all stakeholders are involved.

9.3. Prediction and Early Warning

The flow of information from Riudecanyes to ACA has to be more frequent to avoid bureaucracy and to make the early warning systems more accurate. Also more research in collaboration with international organizations is needed to make a drought prediction more accurate, which is only been made by local Spanish authorities (e.g. ACA) nowadays

9.4. Response and Rehabilitation

Further review of response and rehabilitation measures will be needed in the future in case droughts reach a state of emergency, for example, not having enough water for livestock, or an extremely poor agricultural production of dry fruits that could seriously jeopardize the living of a farmer. However, such emergency state is not expected to happen soon according to climate change scientists.

10. **Conclusion**

The evidence of climate change having an adverse effect in Catalonia in the future is overwhelming. Although many water basins in Catalonia have experienced low levels of water in the past, especially in the Riudecanyes water basin, there is reason to believe that these levels will decrease even more in the future. While ACA maintains that the variability of water is a climatic pattern that has been recorded for more than 200 years and that it will continue this way, meteorological, hydrological, agricultural and socio economic droughts will occur with more frequency in the following years. The effects are already visible in towns such as Brunyola. Therefore, it is necessary for all stakeholders to act upon the precautionary principle to decrease the vulnerability of water stress in the future.

To make change happen it is necessary to adopt a decentralized framework that focuses on the characteristics and needs of each water basin, opposed to ACA´s centralized system that takes a more general view on how to manage water all along Catalonia. Water basins in Catalonia have different sources of water, with different capacities. Depending on the location, water is supplied in different volumes to different sectors (agriculture, industry, and households).

Although ACA, farmers and local citizens have taken important steps forward in reducing water stress in Riudecanyes, a DMP needs to be implemented according to the specific needs of Riudecanyes. This case study should be considered as an example of how each DMP for a certain water basin needs to be approached. Participation from all stakeholders in writing and implementing such plan is necessary to achieve efficiency in water sustainability, thus reducing water stress in each region. The ACA needs to participate more in protecting and helping farmers and local citizens, thus encouraging them to use more efficient techniques and to consume less water. Research and participation with other international organizations will also provide new technologies and sets of measures that might alleviate this problem.

All stakeholders need to realize that water is a natural resource which they will not be able to enjoy at sustainable rates unless they make change happen. Measures, policies, social participation and cooperation among everyone is necessary for achieving such goal.

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Appendix

Appendix 1 Stakeholders Questionnaires

1. Stakeholder: Riudecanyes Water Basin

1. What is the capacity of the water basin?
2. What has been the average percentage of water in the basin and what has it been during the last 10 years?
3. Why is there a drought in this area?
4. How is climate change affecting this region?
5. Why are there droughts in this area?
6. How much water is supplied to agriculture and to public use? (Case: Oliana 100% for public use, due to reforestation)
7. How much water is used and also needed for agriculture and public service per year?
8. What measures are taken when there has been a drought and when the levels in the basin have been low? Can they be improved?
9. If in the future there is not enough water for agriculture and public use, what are the options of bringing water from another place?
10. Is leakage a main concern for the Riudecanyes water basin?
11. Is there enough cooperation between the locals and the ACA? How can it improve?
12. Are there any constraints to make change happen in order to lessen a hydrological drought in the water basin? (e.g. limit supply of water to users, not being able to raise the price of water, etc.)

2. Stakeholder: Agencia Catalana de Agua (ACA)

1. When was the ACA established and why?
2. How does the ACA define the word “drought”? Does the ACA take into account differences in “drought” when it is meteorological, hydrological and agricultural?
3. What kind of specialists work for ACA? (e.g. scientists, policy makers, international organizations)
4. Why is there a drought in Catalonia? (especially in the Riudecanyes area)
5. To what extent is climate change affecting the amount of water available in Catalonia? (especially in the Riudecanyes area)
6. Is there a Risk and Crisis Management Plan for droughts that includes : preparedness, mitigation, prediction and early warning, impact assessment, response, and recovery relief and rehabilitation?
7. If yes, could you explain what is *included* in each step of the above, what are the *constraints* and explain how each step can be *improved*?

Examples of Constraints:
Preparedness: lack or resources, priority attached to, preventive data collection, inadequate training, lack of personnel to analyze large volumes of data in a timely manner, centralized information, bureaucracy or lack of cooperation to take action in time, etc.

Mitigation and relief: research into drought-resistant crops, improvement of marketing networks (insurance), etc.
Prediction and early warning: lack of exact technical methods to predict, insufficient data bases, etc.

8. What are the advantages and disadvantages of the Drought Act in Catalonia? Is there any thing that should be modified or added?
9. What kind of long term and short term solutions are described in the Drought Act of Catalonia?
10. Is there a committee for drought prevention? If yes, what are its responsibilities?
11. Are there any methods used to predict a drought? If not, what is the future for developing such method? (example: Walker´s teleconnection patterns- in which correlations are used, GCMs statistics and probability)
12. Is there are drought monitoring program? If not, why?
13. Are all direct (reduced crop, range land, forest productivity, reduced water levels, increase in livestock and wildlife mortality rates) and indirect (reduced income for farmers, increased prices for food and timber, unemployment, reduced government tax revenues, etc.) drought impacts assessed? and are they classified according to economic, environmental and social impacts, in all regions of Catalonia ?
14. What type of cooperation is there between the government and ACA. What are the constraints?
15. What type of cooperation is there between ACA and local stakeholders (farmers, public, etc.). What are the constraints?
16. Does water have a fixed price for farmers to protect them? Do you think that a rise in price would make farmers use more effective methods for planting and for people to use less water at home, work, etc.?
17. What are the future plans for ACA concerning droughts?
18. Is there a power struggle of interests between stakeholders?
19. Are there any other constraints for ACA to not be able to make change happen?
20. How is ACA involved in public awareness about consuming less water?

3. Stakeholder: Farmers in Riudecanyes

1. What is mainly planted in this area? And how much water is needed for this type of crop compared to seeds that do not need so much water? Why is this crop planted and not another?
2. Is the soil very fertile, fertile or not so fertile? Why?
3. What irrigation method(s) are used? Why?
4. Is fallow or crop rotation a common practice for this area? If not, why?
5. Do you have inventories in case of droughts?
6. What measures or methods are used in the fields to consume less water? Are they effective?
7. What measures are taken when there is a drought? Can they be improved?
8. Preparedness: Do you have any contingency plans?
9. Mitigation:
   Do you have insurance strategies?
   Do you have seed mixes?

Is there cooperation from the rich to help the poor in times of droughts?
10. During the relief period, what are the strategies that are implemented? (eg. borrow money, sell domestic assets, engage in dry season farming, etc.)
11. How fast is the rehabilitation period and why?
12. Is there enough cooperation between the locals and the ACA? How can it improve?
13. Are there any irrigation restrictions when there is a drought? And are any preventive measures taken to use less water in case there will be a drought?
14. Are there any constraints to make change happen in order to lessen an agricultural drought? (e.g. implementing new irrigation techniques, changing crops, etc.)
15. What is the role of agriculture in relation to the economy and society of this area?

Appendix 2

4. Stakeholder: Local citizens in Riudecanyes

1. For what do you use water at home?
2. Have there been droughts in this area? If yes, why do you think so?
3. Do you think the price of water is expensive?
4. Would you be willing to pay more for water, so that this money could be spent on drought management plans?
5. Do you think that ACA´s public awareness campaigns have been effective for people in Riudecanyes to consume less water?
6. Have you had any restrictions to the use of water during droughts or low levels of water in the basin?
7. What do you think needs to be done so people consume less water?
8. For which use do you think it is wrong to use water? (e.g. water for swimming pools, gardens, etc.)
9. What do you do at home to use less water? What else could you do?

Appendix 3

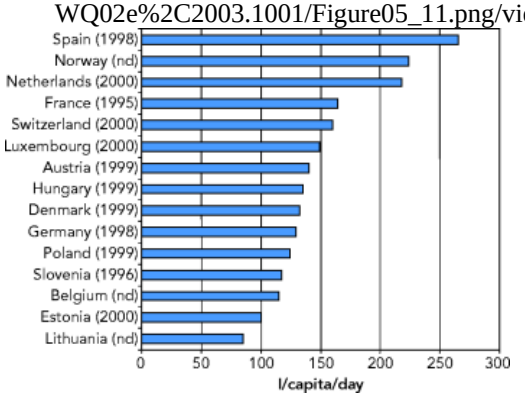
Questionnaire: Worst Case Scenario:Brunyola

1. What is the physical description of Brunyola?
2. What is its population?
3. Why are there droughts in Brunyola?
4. How has climate change affected this town?
5. What measures have been taken to alleviate water stress this year? (e.g. bring water by trucks)
6. What are the drawbacks of transporting water by trucks?
7. What is the percentage of water distribution to households and agriculture?
8. Do you have a drought contingency plan?
9. Who revises such plan?
10. What mitigation plans are been made in Brunyola?
11. How fast is rehabilitation from a drought?
12. Is there enough cooperation between the city of Brunyola and ACA? If not, how could it improve?

Appendix 4

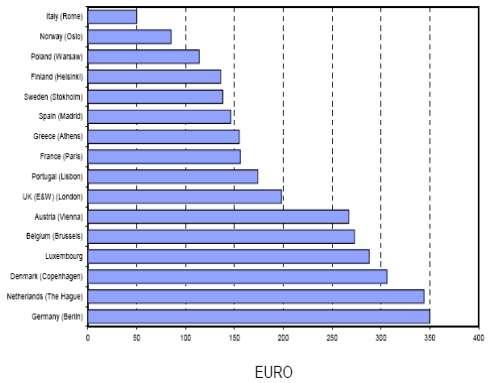
a. Household water consumption in some European countries

source: European Water Association (2002)
http://themes.eea.europa.eu/Specific_media/water/indicators/WQ02e%2C2003.1001/Figure05_11.png/view



b. Typical water prices in some European countries in 1998

source: OECD, 1999



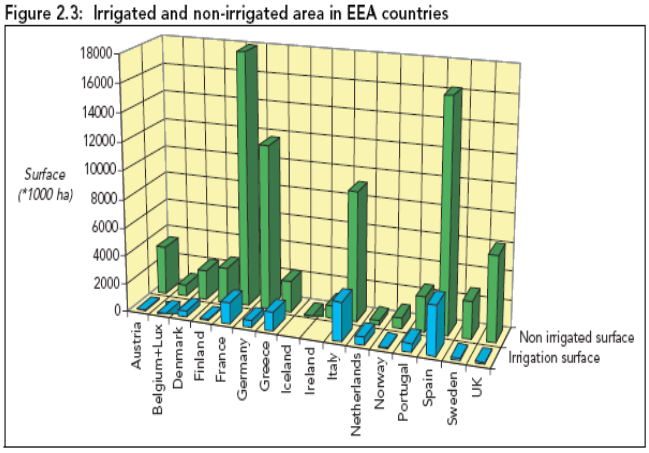
Notes: Prices are shown for a typical household consumption of 200 m3/yr

Appendix 5

a. Irrigated and non-irrigated area in EEA countries

source: FAO, 1995

Figure 2.3: Irrigated and non-irrigated area in EEA countries

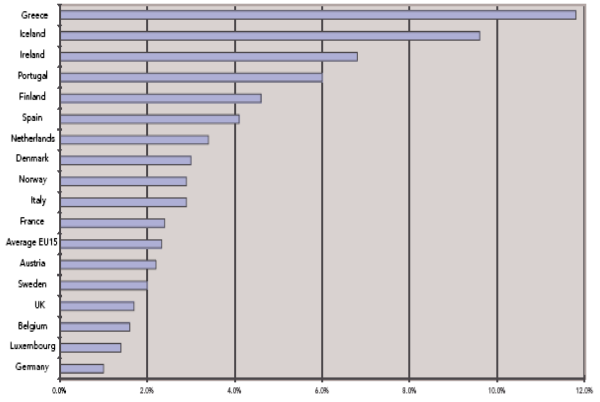


(Source: FAO, 1995; arable land and permanent crops)

b. Share of agriculture in total GDP

source: OECD, 1996

Figure 2.1: Share of agriculture in total GDP

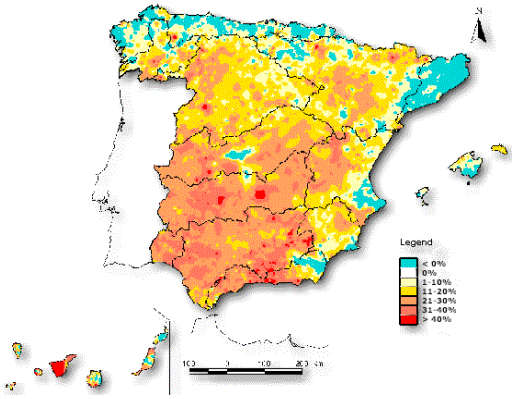


(Source: OECD, 1996)

Appendix 6

Percentile deficit of precipitation in Spain during the 1990-95 drought

source: http://www.eea.europa.eu/documents/ar2001/reports_2001



Appendix 7

Activation Thresholds from the Decree of Drought in the Water system of Siurana – Riudecanyes

source: Decree of Drought, 2005 (ACA)

Each level will be activated when the following figures exceed the threshold levels.

Threshold in hm3	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Exceptional Level 1- Activated	1	1	1	1	2	3	3	2	1	1	1	1
Exceptional Level 1- Deactivated	1,5	1,5	1,5	1,5	2,5	3,5	3,5	2,5	1,5	1,5	1,5	1,5
Emergency decree activated	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5

*The Siurana-Riudecanyes are two different water basins, however, Siurana supplies half of the water needed to Riudecanyes.
**This system does not include the scenario Exceptional 2 because it does not supply great amounts of water compared to other water systems in Catalonia, such as the Ter-Llobregat water system among others.
source: Diari Oficial de la Generalitat de Catalunya, May 2005

Thresholds:

- *Exceptional scenario- level 1.* If the levels of water are lower than the first threshold in the basins, than water restriction measures are set on the supply of each water basin[15] in order to preserve it. The purpose of this scenario is to guarantee the supply of water on a medium term (see Appendix 7).
- *Exceptional scenario- level 2.* If the level keeps decreasing and crosses the second threshold in order to guarantee the supply of water on a short term.
- *Emergency scenario.* If the level of water reaches the third threshold than the Emergency decree is activated, thus further restricting the use of water and providing aid to supply water to regions where basic needs cannot be met.

[15] Each water basin has a different threshold.

Appendix 8

Capacities of Inland Water Basins in Catalonia

source: ACA http://mediambient.gencat.net/aca/en//actuacions/embassaments/caracteristiques.jsp

basin	reservoir	length of coronation (m)	basin area (m)	reservoir area (km^2)	superfície embas. (ha)	capacity (hm^3)	basin capacity (hm^3)
Ter	Sau	84	260	1.564	570	169	407
	Seva (2 preses)	15			2	<1	
	Susqueda	135	360	1.850	466	233	
	Pasteral, el	33	198	1.904	35	2	
	Colomers	15	103	3.000	70	1	
Llobregat	Baells, la	102	433	532	367	115	220
	Sant Ponç	60	311	318	139	24	
	Llosa del Cavall, la	122	326	200	300	80	
	Sant Martí de Tous	32	277	16	15	1	
Muga	Boadella	63	250	182	364	62	62
Gaia	Catllar o Gaià, el	76	385	370	326	60	60
Foix	Foix	38	190	290	71	6	6
Portbou	Portbou	27	87	3	1	<1	1
Riudecanyes	**Riudecanyes**	**51**	**235**	**31**	**30**	**5**	**5**
Tordera	Santa Fe	23	160	5	6	1	1
Besòs	Vallforners	62	160	61	16	2	2