Effects of climate change in Mediterranean water resources and their economic implications

PRIMER PREMIO 2017

Elisa Vargas

2016

UNED/Vrije Universiteit Brussel

AQUAE FUNDACIÓN

Effects of Climate Change in Mediterranean Water Resources and Their Economic Implications

Elisa Vargas Amelin

2016

Clot del Galvany wetland, Elche, Spain. Júcar River Basin

Acknowledgements

The author would like to thank:

I thank above all my husband, Vicente Ramírez Perea, for his unconditional support. Without his care, persistence, enthusiasm and constant support, this thesis would have never been completed. I would also like to thank my daughter Aitana for her patience and love, my parents, Mª Claude and Fernando, my brother Daniel, my mother-in-law Ana Perea, relatives and friends for supporting me emotionally throughout the writing process and in my life in general.

My sincere gratitude goes to my thesis Directors, Gonzalo Escribano, Philippe Quevauviller and Enrique San Martín for their continuous guidance, support, encouragement and commitment. I thank as well the co-authors of all publications for their precious collaboration, friendship and patience: Teodoro Estrela, Miguel Ángel Pérez, Pablo Pindado, Elena López-Gunn, and Gemma Huelva. I would like to thank the dissertation tribunal and jury members for their time, dedication and the interest shown in this work.

Furthermore, I thank Steven Eisenreich for his encouragement and support at a critical stage of the thesis, my friend Hendrika Zemmelink for her language contribution, my colleagues Alberto Parenti, Lucia Bernal, Diego Villalba, and Max Linsen for their valuable time and advice, and all those who directly or indirectly contributed to this work and made possible its completion.

Abstract

The thesis provides an overview of the effects of climate change on water resources at different scales. The research deals with expected impacts in the Mediterranean region, and more specifically in Spanish river basins. It offers an assessment of the European Union (EU) environmental policy, with a special focus on the Water Framework Directive 2000/60/EC (WFD) framework, and includes some specific examples of climate change economic implications.

More precisely, the thesis:

- Provides an introduction to water management in the Mediterranean region.
- Analyses EU policies on water and climate change. Examines the effects of droughts, as a commonly occurring extreme event in Mediterranean areas.
- Shows how water management and planning represent a framework for adaptation to climate change effects, while pointing out to needed improvements.
- Provides examples of policy gaps and recommendations to improve water protection policies in the future.

The study assesses expected climate change impacts on well-studied parameters, such as precipitation, and it builds on the possible implications. For instance, near -5 %, -9 % and -17 % reductions on water availability are predicted for Spain during the periods 2011–2040, 2041–2070 and 2071–2100 respectively. The thesis addresses consequences of these reductions in environmental, social and economic terms. Results point out towards the need to intensify certain measures: saving and demand management measures; using of alternative resources (such as waste water reuse and desalination); ensuring sustainable use of groundwater; promoting green infrastructures; modernising irrigation systems; and using specific plans and measures to address floods and droughts management. Recommendations also include establishing a better and more transparent pricing system that ensures cost-recovery for water services, and phasing out harmful subsidies that favour for instance greater agricultural uptake of water resources.

In view of the forthcoming review of the WFD in 2019, specific guidelines are provided to improve its implementation in Spain and to prioritise management measures given the recent decreases of public budgets. The study points out that one of the main obstacles to achieve a better water protection that incorporates climate change effects is the lack of policy coherence. There is a need to better integrate climate proofed water management measures into relevant sectors such as agriculture, energy or land management.

The work has led to a total of six publications in scientific journals (e.g. Water Resources Management, Hydrological Sciences Journal, Journal of Hydrology), as well as chapters in books edited by leading academic publishers.

Contents

List of Figures

List of Tables

Glossary

Adaptation anticipate to adverse effects of climate change and act to minimise or reduce expected impacts.

Aridity deficiency of moisture. In this thesis, Aridity Index ratio is calculated as precipitation over potential evapotranspiration.

Desertification complex process exacerbated by human action, which includes loss of vegetation cover, soil erosion and loss of arable land.

Diffuse pollution pollution coming from no concrete source derived from widespread activities (e.g. caused by pesticides from agricultural practices).

Drought a hydrological drought refers to abnormal values of precipitation leading to adverse socio-economic and environmental impacts.

Ecosystem services ecosystems benefits and contributions to human well-being (e.g. flood control, cultural and recreational benefits, pollination. . .).

Environmental costs according to the WFD these costs are those representing damage to the environment and ecosystems due to water use..

Financial costs According to the Water Framework Directive (2000) refers to costs of providing water services including operation and maintenance costs of infrastructures.

Mitigation actions that address the main causes of climate change, i.e. reduce greenhouse gasses emissions.

Natural regime refers to unaltered conditions by human actions, focuses on more pristine ecological conditions, and can therefore better reflect climate change impacts.

Point-source pollution pollution coming from a single discrete place, as for instance a pipe discharging into a river.

Resilience ability of a system, society or ecosystem to recover, adapt, or return to the original stage prior to a significant disturbance or impact.

Resource costs according to the Water Framework Directive (2000) these refer to costs linked to opportunity costs (e.g. costs of forgone opportunities due to the depletion of the resource).

Revised Water Exploitation Index (WEI+) total water use (abstraction minus returns) as a percentage over the renewable freshwater resources in a given territory and time scale (definition provided by the EEA).

Water balance or asset account refers to a numerical calculation to account for inputs to, outputs from, and changes in the volume of water in the various components (e.g. reservoir, river, aquifer) of the hydrological cycle, within a specified hydrological unit and during a specified time unit (EC 2015d).

Water demand water requirements of specific quality for different purposes, such as drinking, irrigation, etc., assuming that water availability is not a limiting factor. Water demand is theoretical (calculated or estimated) and can correspond to current situation or to future socio-economic scenarios (EC 2015d).

Water Exploitation Index (WEI) mean annual total abstraction of freshwater divided by the mean annual total renewable freshwater resource at country level, expressed in percentage terms (definition provided by the EEA).

Water governance according to the OECD is the socio-economic, political and administrative systems that exist to manage, develop and use water as a resource within a society. That is the institutions and groups behind all decision making for water use.

Water scarcity Lack of sufficient water for a specific use. Water demand exceeds water availability.

Acronyms

acuaMED Agua de las Cuencas Mediterráneas, S. A. -*Public coorporation Water of Mediterranean Basins*.

AdapteCCa Plataforma de intercambio de información sobre impactos, vulnerabilidad y adaptación al cambio climático -*Platform of information exchange on climate change impacts, vulnerability and adaptation*.

AEMET Agencia Estatal de Meteorología -*Spanish National Meteorological Agency*.

Aquastat Global water information system.

ARIDE Assessment of Regional Impact of Droughts in Europe.

CAP Common Agricultural Policy.

CEDEX Centro de Estudios y Experimentación de Obras Públicas -*Centre for studies and experimentation on public works*.

CEH Centro de Estudios Hidrográficos of the CEDEX -*Centre for Hydrographic studies*.

CHGuadiana Confederación Hidrográfica del Guadiana -*Guadiana River Basin Authority*.

CHJ Confederación Hidrográfica del Júcar -*Júcar River Basin Authority*.

CHS Confederación Hidrográfica del Segura -*Segura River Basin Authority*.

CIRCE Climate Change and impact research: the Mediterranean environment.

CIS Common Implementation Strategy of the WFD.

Climate-ADAPT The European Climate Adaptation Platform.

CSO Civil Society Organisation.

DMG Drought Management Guidelines.

DMP Drought Management Plan.

DPSIR Drivers, Pressures, Status, Impact, Responses.

EC European Commission.

ECCE Evaluación Preliminar de los Impactos en España por Efecto del Cambio Climático -*Assessment report of the preliminary impacts in Spain due to Climate Change*.

ECHAMs Global Climate Model developed by the Max Planck Institute for Meteorology.

EEA European Environment Agency.

EMMCW Euro-Mediterranean Ministerial Conference on Water.

EMWIS Euro-Mediterranean Information System on know-how in the Water sector.

ENP European Neighbourhood Policy.

ENPI European Neighbourhood and Partnership Instrument.

ENSEMBLES Climate change and its impacts at seasonal, decadal and centennial timescales.

EU European Union.

EURO-LIMPACS European project to evaluate impacts of global change on freshwater ecosystem.

EUROSTAT The Statistical Office of the European Union.

FAO Food and Agriculture Organization.

FHIMADES Fundación para el Desarrollo Socioeconómico Hispano-Marroquí -*Spanish-Moroccan Socioeconomic Development Foundation*.

FP Framework Programme.

FRMP Flood Risk Management Plan.

FYROM Former Yugoslav Republic of Macedonia.

GAP Güneydogu Anadolu Project -*Agricultural national Project, Turkey*.

GCM General Circulation Models.

GDP Gross Domestic Product.

GEF Global Environmental Fund.

GHG greenhouse gas.

GMO Genetically Modified Organism.

HadAM3H Hadley Centre Atmospheric Model.

HadCM2 Hadley Centre Coupled Model, version 2 -coupled atmosphere-ocean general circulation model-.

HadCM3 Hadley Centre Coupled Model, version 3 -coupled atmosphere-ocean general circulation model-.

HPR Hydrological Planning Regulation.

IEA International Energy Agency.

IEMED Instituto Europeo del Mediterráneo -*European Institute of the Mediterranean*.

INE Instituto Nacional de Estadística -*National Statistics Institute, Spain*.

INTERREG Interregional cooperation across Europe, Program.

IPCC Intergovernmental Panel on Climate Change.

ITC Instituto Tecnológico de Canarias -*Canary Technological Institute*.

IWMI International Water Management Institute.

MAGRAMA Ministerio de Agricultura, Alimentación y Medio Ambiente -*Ministry of Agriculture, Food and Environment, Spain*.

MARM Ministerio de Medio Ambiente Medio Rural y Marino -*Ministry of Environment, Rural and Marine Affairs, Spain*.

MDG Millennium Development Goal.

MED EUWI Mediterranean Component of the EU Water Initiative.

MEDA MEDA (Mesures d'accompagnement) programme -*Financial Instrument of the Euro-Mediterranean Partnership*.

MEDROPLAN Drought Management Guidelines and Examples of Application.

MENA Middle East and North Africa.

MIRAGE Mediterranean Intermittent River Management Project.

MMA Ministerio de Medio Ambiente -*Ministry of Environment, Spain*.

MS Member States of the European Union.

NGO Non-Governmental Organisation.

OECC Oficina Española de Cambio Climático -*Spanish National Office of Climate Change*.

OECD Organisation for Economic Co-operation and Development.

PAM Parliamentary Assembly of the Mediterranean.

PATRICAL Rainfall-runoff model.

PB Plan Bleu -*Blue Plan*.

PESETA Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis.

PMV Plan Maroc Vert -*Plan Green Morocco*.

PNACC Plan Nacional de Adaptación al Cambio Climático -*Climate Change National Adaptation Plan*.

PoM Programme of Measures.

PRODIM Proactive Management of Water Systems to face drought and water scarcity in islands and coastal areas of the Mediterranean.

PROMES An atmosphere-ocean coupled regional model for climate studies of the Mediterranean region.

PRUDENCE Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects.

RBA River Basin Authority.

RBMP River Basin Management Plan.

RCM Regional Circulation Model.

RDI Reconnaissance Drought Index.

RegCM3 Third generation of the Regional Climate Model.

S-PI Science-Policy Interface.

SEDEMED Dryness and Turning into a desert in the Mediterranean basin project.

SEEA System of Environmental-Economic Accounting (UN).

SEEA-Water System of Environmental-Economic Accounting for Water.

SEMIDE Système Euro-Méditerranéen d'Information sur les Savoir-Faire dans le Domaine de l'Eau -*Euro-Mediterranean Information System on the know-how in the water sector*.

SIA Sistema Integrado de Información del Agua -*Integrated Water Information System*.

SIMPA Simulación Precipitación-Aportación -*Precipitation-Contribution Simulation model*.

SPI Standard Precipitation Index.

SRES Special Report on Emission Scenarios.

SWM Strategy for Water in the Mediterranean.

TIHP Technical Instruction of Hydrological Planning.

UfM Union for the Mediterranean.

UKMO United Kingdom Met Office.

UN United Nations.

UNDP United Nations Development Programme.

UNED Universidad Nacional de Educación a Distancia -*National Distance Education University*.

UNEP United Nations Environment Programme.

UNEP/MAP United Nations Environment Programme - Mediterranean Action Plan.

UNESCO United Nations Educational, Scientific and Cultural Organisation.

USA United States of America.

VUB Vrije Universiteit Brussel -*Free University of Brussels*.

VWWF V World Water Forum.

WAMME West African Monsoon Modeling and Evaluation project.

WATCH Water and Global Change project.

WEI Water Exploitation Index.

WEI+ revised Water Exploitation Index.

WFD Water Framework Directive 2000/60/EC.

WR water resource.

WS&D Water scarcity and droughts.

WSDEN Water Scarcity and Droughts Expert Network.

XEROCHORE Exercise to Assess Research Needs and Policy Choices in Areas of Drought project.

1. Introduction

1.1. Overview

The Mediterranean region presents a strategic location at the crossroads of three continents. Its climate has encouraged the settlement of peoples throughout history and a relevant socio-economic growth. However, pressures produced by the increase in population, tourism and urban development, mainly on the coastal areas, are causing serious environmental problems that affect its development. In addition, climate change effects are likely to increase these pressures, and pose important challenges for natural resources management. While being one of the richest regions in ecosystems, and considered one of the top biodiversity hotspots in the world (Sundseth 2009), the Mediterranean area is at the same time one of the most vulnerable due to these pressures and closely related environmental problems as water scarcity, point-source and diffuse pollution, overexploitation of aquifers, deforestation, soil erosion and desertification.

Water is a catalyst for development, essential for almost all socio-economic activities and it is a vital natural resource for the environment. Yet, it is very unevenly distributed in space and time in the region, and not always managed wisely. Water is very scarce in a way readily accessible for human use, and has limited availability in the quality and quantity required for the different demands[1]. This makes it a limiting factor for economic activities, development and production of food and energy. The main water-related problems are being exacerbated by the effects of climate change, and extreme phenomena such as droughts and floods, increasing social and resource management problems, as well as conflicts among different sectors.

[1] This thesis refers to concepts such as water demand or water scarcity according to their meanings in sectoral European Union (EU) policy and their everyday use in international hydrological planning, which vary substantially from their economic definitions. See glossary for more precise definitions relating to this thesis.

1.2. Climate change

Given the close relationship between water availability and weather phenomena, this thesis focuses on expected climate change impacts in the region and specifically in Spain. According to the Intergovernmental Panel on Climate Change (IPCC) report (IPCC 2013a), in the Mediterranean region the temperature rise linked to climate change will translate into a greater number of extreme events, an increase in their intensity, and a decrease in available water resources. Decreases in rainfall, increasing aridity and extreme droughts in southern Europe and the Middle East are expected (Dai 2011), as well as changes in sea temperature and decreases in river flows. For Spain in particular, the conclusions of one of the first developed comprehensive studies, *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005), regarding water resources highlighted that a general reduction of water resources and increased demand for irrigation systems was expected in the country. The report also predicted a reduction in inputs of up to 50 % in semi-arid regions and an increase in inter-annual variability. It pointed out demand management as a palliative option, the need to improve and expand monitoring networks, the priority of further research and the importance of considering the impacts of these changes in policy and water resources management.

Already in 1995, it was estimated that 1400 million people were living in conditions of water stress mainly in South West Asia, Middle East and in the Mediterranean region (Arnell 1996; Arnell 2004). Thus, it is likely that declines in runoff estimates for the foreseeable future, will cause even higher rates of water stress due to decreasing availability.

Studies have progressed, and while they still present degrees of uncertainty and downscaling techniques are challenging, the predicted impacts continue to be similar. For instance, a more recent study published by CEDEX (2011), has fine-tuned impacts at the national level and predicts a generalised reduction of precipitation and water availability (near -5 %, -9 % and -17 % during the periods 2011–2040, 2041–2070 and 2071–2100 respectively). It also points out that the greatest variability will occur in the Mediterranean coast and in the South-East of the country. In addition, the study predicts increases in temperature, evaporation and evapotranspiration, and decreases in runoff and groundwater recharge.

The effects of climate change will impact the availability and distribution of water resources, and because of this, food production, by affecting crops and livestock. Extreme weather events related to water, droughts and floods, will most likely aggravate, and will be important factors to consider in hydrological planning and water management to prevent shortages or minimise damages to people and goods. Furthermore, specific sectors, such as the agricultural one, will possibly present higher demands caused by the effects of temperature rise and evapotranspiration processes. As water becomes an increasingly scarce resource, coupled with a growing demand, climate change could affect management priorities in the distribution of resources (Estrela Monreal and Vargas Amelin 2008).

As stated, some authors (Magnan et al. 2009) emphasize the uncertainty of climate models and hydrological data or CO_2 emissions, the unpredictability of the natural variability of climate, the lack of consistency in data and the wide margins of estimates on population growth and water consumption. Therefore, it seems necessary to develop more robust studies on climate change and for the predictions of expected impacts, as well as to invest more in adaptation strategies (UNEP/MAP-Plan Bleu 2009). In any case, given the situation present in the region, with fragile water balances, it is expected that any climate variability will generate relevant social and agricultural impacts. Thus, policies and management practices should be adapted considering water availability changes in the near future.

Publications presented in this thesis approach these issues, provide recent references, data assessments, policy studies at the EU and national levels. They determine gaps in adopting climate change considerations in water management, and take specific approaches at the river basin level.

1.3. Policies addressed

There are several environmental policies at the EU level that aim at better protecting natural resources and promoting their sustainable use. The following chapters include just a small selection of these policies. Although there are references to the Nitrates Directive (1991), the Common Agricultural Policy (CAP)[2], the Habitats Directive (1992) and Birds Directive (2009), among others,

[2]Policy born in 1962 to ensure food productivity at affordable prices in the EU and fair living of farmers. It has witnessed reorientation of goals, inclusion of new challenges, and numerous reforms, especially for its economic instruments. See *The common agricultural policy*, Rural Development Regulation (2013), Financing, Management and Monitoring CAP (2013), Direct Payments (2013), and Markets Organisation (2013).

given their inter-linkages, the focus lies on water and climate change policies. More precisely, the thesis takes a close look at those legislative tools that make the backbone of water protection such as the Water Framework Directive (2000).

The implementation of the Water Framework Directive 2000/60/EC (WFD) has made possible that Member States of the European Union (MS) converge towards meeting common quality and protection objectives. The Directive is innovative by setting the river basin as a single system for water management (although Spain has been applying this principle since the beginning of 20th century), aiming at good status of all waters, and establishing River Basin Management Plans (RBMPs) as the main tools with Programme of Measures (PoM) to achieve that status. It is a policy that sets specific deadlines, and it is backed by mechanisms coupled with economic sanctions. Furthermore, the Floods Directive (2007) complements this water protection objective by aiming to improve the management of flood episodes and reduce their risks, especially in watercourses and in coastlines. It requires the mapping of areas with considerable risk and the development of management plans. In addition, the European Commission (EC) has funded several projects and studies to determine the effects of climate change on water resources and has published numerous papers and reports to establish the basis for policy on adaptation, some of which are pointed out in the presented publications.

However, these policies are often developed considering water availability, and territorial characteristics very different from those present in Spain, which can be much more similar to the ones of neighbouring countries in the Mediterranean basin. Moreover, the fulfilment of these policies' objectives seems more than uncertain due to old and emerging challenges. The EC developed a comprehensive assessment on the existing directives, their results, and the causes of not achieving the initially established goals for water quality, management and protection. This initiative, called Blueprint to Safeguard Europe's Water (EC 2012a), which sets the year 2020 as the first horizon, focuses on four major areas: RBMPs developed under the WFD, a review of the European action against water scarcity and drought, the vulnerability assessment of water resources to climate change and other anthropogenic pressures, and a general fitness-check for EU water policy.

Nevertheless, recommendations and tools provided in the Blueprint are to be assessed in the upcoming RBMPs, which should be presented by MS by the end of 2015 and their data reported in March 2016. Furthermore, a revision of the WFD should take place in 2019, when the reasons for non-implementation and a possible review of the Directive's text could take place. Also, in 2017 the EC should report to the European Parliament and the Council on the implementation status of the EU Strategy on adaptation to climate change (EC 2013a). A greater effort of aligning water protection and climate adaptation goals, should, at this point, be considered and assessed.

The fig. 1.1 summarises the introduced problems based on the Drivers, Pressures, Status, Impact, Responses (DPSIR) framework developed by the EEA (1999).

1.4. Spanish river basins

Many Spanish river basins face water shortages, persistent droughts, land degradation and overexploitation of water resources. Moreover, all these problems tend to be exacerbated by the effects of climate change. Mediterranean river basins in Spain, such as for instance the Júcar or the Segura river basins, are typical example of basins suffering the impacts of these phenomena, and having a major surface of semiarid areas (according to the United Nations Educational, Scientific and Cultural Organisation (UNESCO) aridity index). They often suffer different extreme events such as floods and torrential rainfall events (or flash floods), while they present intensive water abstractions primarily for agricultural uses.

The updated RBMPs are still to be reported to the EC, and should provide an interesting opportunity to study the possible effects of climate change on water availability, the proposed technical measures, and to conduct their economic assessment. The publications presented in this thesis provide some insights from the preliminary draft RBMPs, assess the existing policies being implemented and the degree of their coherence.

1.5. Remarks and proposed solutions

The thesis answers different research questions that aim at determining for instance how the overall qualitative and quantitative status of water resources is in Mediterranean countries, in the EU and Spain, what the existing policy and management tools are, which link climate change and water resources protection, or what economic implications climate change impacts might have. The specific research queries are reflected in chapter 2, and discussed in detail

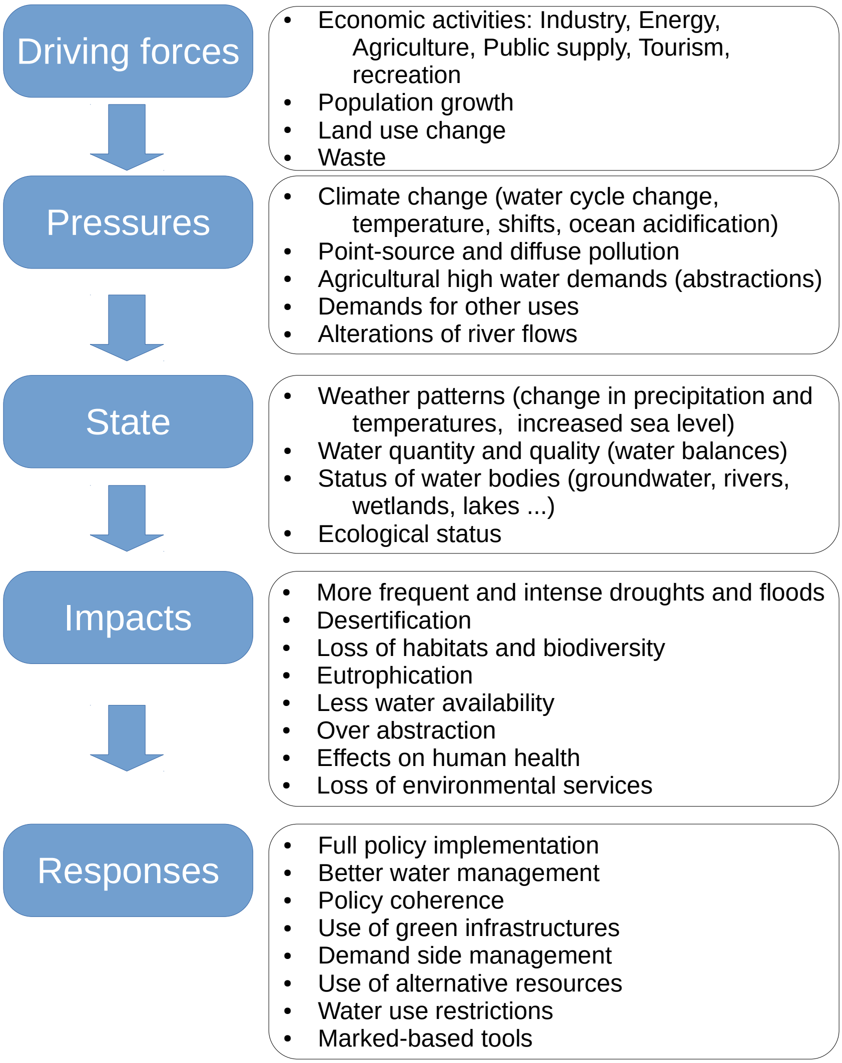

Figure 1.1.: Summary of effects of economic activities and climate change impacts in water resources (DPSIR). Source: own elaboration based on the causal framework developed by the EEA (extended from *Pressure-State-Response* of OECD works from previous *STress Response Environmental Statistical System–STRESS* by Anthony Friend and David Rapport) that links society and the environment.

in chapter 5 based on the conclusions of the presented publications.

The following sections provide an overview of the effects of climate change on water resources, both at regional and national levels and give some examples of economic implications. The effects of climate change indicate the need to intensify certain measures already being implemented: saving and demand management measures, the use of alternative or non-conventional resources (desalination and waste water reuse), a sustainable use of groundwater, greater use of green infrastructures, modernization of irrigation systems, as well as specific plans and measures to address floods and droughts management.

The thesis core part (chapter 3) is the result of assessed information, studies, data series, and main policies development. In addition, some of the most relevant research projects in the sector and their results are presented. The author points out to existing policy, management and research gaps as well as social issues, and proposes solutions and recommendations.

Some of the pending issues in the water sector include the fully incorporation of climate change impacts on water planning, and better uptake of economic considerations in technical measures and adaptation processes. These aspects will be described in more detail in the chapter 7. As mentioned, there are also sectoral tools, such as Drought Management Plans (DMPs) that could be very useful to build on resilience. However, their implementation and integration into broader frameworks such as RBMPs, or their inter-linkage with relevant sectors as for instance land use remains limited (EC 2012c; Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014, section 3.7 of this thesis).

In view of the upcoming review of the WFD, specific recommendation are provided to improve its degree of implementation in Spain or the prioritisation of measures given the recent decreases of available budgets. Yet, one of the main obstacles to achieve better water protection and incorporate climate change effects lies on the lack of policy coherence. This problem has been stressed specifically for water and the CAP, by the European Court of Auditors (2014) and is being addressed in the publications (for instance in sections 3.7 and 3.8).

2. Objectives

The thesis provides an introduction to water resources in the Mediterranean region providing some specific examples (e.g. Morocco and Spain), presents the main witnessed and expected effects of climate change in water resources, providing a specific assessment on drought impacts and management. Furthermore, the impacts of climate change in sectors directly linked to water, such as agriculture or land management, are evaluated at the national level. Finally, the thesis takes a closer look into EU policies, and their implications at the European and national levels.

An evaluation of various studies on the effect of climate change on water and European adaptation policies has been done, providing case studies, specific examples and introducing economic assessments.

More specifically, the established goals are:

a) Provide an introduction to water management in the Mediterranean region.

b) Develop an analysis of EU policies on water and climate change.

c) Analyse the effects of certain extreme events common in Mediterranean basins such as droughts.

d) Determine how previous experience in water management and planning may or may not represent a framework for adaptation to climate change effects.

e) Provide examples of policy gaps and recommendations to improve water protection policies in the future.

Some of the research queries or questions to which the thesis responds to are: What is the situation of Mediterranean countries regarding water resources status, access and policy? How will climate change impacts affect water resources in the EU, in the region and in Spain? What are the existing management tools to address climate change effects in water resources? Are EU policies sufficiently robust to pursue a common strategy, especially given the disparity between the availability of resources from one MS to another? Are countries such as Spain prepared to develop sectoral adaptation plans that address climate change effects? Are economic considerations and impacts linked to water resources sufficiently considered?

The fig. 2.1 shows the relationship between research questions, main contents of publications and the established goals for the thesis.

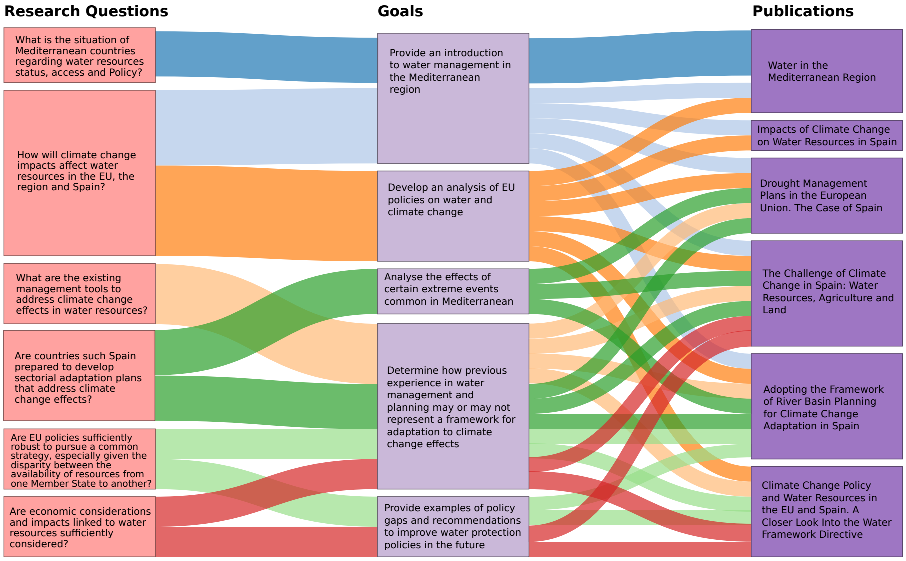

Figure 2.1.: Scheme showing the relationship between research questions, publications presented in chapter 3, and established goals for the thesis.

2.1. Justification

The thesis will present an introduction to the problem of climate change and its effects on water availability and management, responding to the stated questions, based on available studies, hydrological data, and developed publications.

An introduction to the situation of water resources in the Mediterranean basin is provided given the similarities, in hydrological terms, of the riverine countries. This overview is presented to show also disparities in terms of access to water, policy and administrations consolidation, especially between EU and non-EU countries. Given the importance of water for the agricultural sector, and its varying effects in the different national economies, specific examples of agricultural programmes are provided.

Furthermore, a more specific analysis is done on droughts, due to the expected increase in intensity and frequency of drought episodes in the region due to climate change. The reason for this focus is threefold: to address policy, economic and environmental aspects related to droughts. While there is no specific EU Directive to approach drought, an important legislative process was carried out by the EC between 2007 and 2012, which included a specific communication, follow-up reports and studies at the EU and national levels, and an assessment of drought effects in achieving environmental protection objectives. The thesis, considers the specific example of DMPs in Spain, being one of the first existing cases in the EU, and their flexibility in adopting climate change predictions (Estrela Monreal and Vargas Amelin 2012, section 3.4 of this thesis; Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014, section 3.7 of this thesis). As for economic considerations, in section 3.4 some general aspects are provided as the overall valuation of water scarcity and drought costs at the EU level provided by the EC (EC 2007a). As it will be indicated, one of the findings highlights the limited integration of DMPs into RBMPs, and the need for a better harmonisation of these tools at the EU level (see section 3.8).

The environmental acquis[1] at EU level is quite complete and incorporates not only specific sectoral policies, but also horizontal tools that help towards overall environmental protection, and integration of environmental considerations in different sectors and processes. As mentioned, one of the main pillars of water protection is the WFD, which aims to achieve by 2015 good chemical and ecological status for all surface water bodies, and good chemical and quantitative status of all groundwater bodies. The general objective of this Directive is to prevent and reduce water pollution, to promote sustainable water use, environmental protection, and improve aquatic ecosystems. In addition, and through complementary legislation and political initiatives, it also aims to mitigate the effects of floods and droughts.

It requires MS to produce RBMPs as main tools to assess the status of water bodies and the pressures on them, and set the required measures to protect and

[1] The *Community acquis* or *acquis communataire* or *EU acquis* refers to the group of legislation tools, legal acts and court decisions at the EU level.

improve the aquatic environment. However, it has been estimated that about half of EU surface waters are unlikely to reach a good ecological status in 2015 (EC 2012a). Moreover, at the time of entry into force of this Directive, climate change impacts were unclear, and studies presented high uncertainties. It was then recommended and agreed to incorporate climate change considerations in the second cycle of the Directive (RBMPs to be adopted by the end of 2015) and thereafter. Thus, the degree of their implementation is still to be assessed.

Climate change considerations are quite recent compared to policy history, and have not been fully incorporated into water resources management practices. In this sense, recommendations are provided in this thesis on how and where to consider climate change impacts within the WFD cycle, how to liaise with other sectors and policies, while taking also into account economic impacts and tools (see sections 3.7 and 3.8).

2.2. Methodology

The thesis includes a compilation of articles and publications in which the author had a relevant or main contribution, presenting the overall conclusions obtained as well as recommendations for policy makers and managers, and suggesting future lines of work.

To complete works, the author has developed a research process and a comparison of scientific studies, articles and management policies, which includes publications, studies, official governmental and EU sources, as well as results of the application of hydrological models and forecasts on the impacts of climate change. In addition, the thesis considers water balances exercises[2] or water accounts, and other works such as the use of specific water indicators by the European Environment Agency (EEA).

The steps that have been taken for the development of each publication are described below and presented in chronological order. In addition, a summary (see tables 2.1 and 2.2) is presented for the main contents of all publications:

- Water in the Mediterranean Region, section 3.3 page 25.
  - *Main contents*: Assessment of the overall water picture in the Mediterranean basin: quantity, quality and availability aspects, main water consumptions per sector, contribution of agricultural

[2]using the United Nations (UN) System of Environmental-Economic Accounting for Water (SEEA-Water).

practices to Gross Domestic Product (GDP), effects of climate change, extreme phenomena, policies and administrations, economic tools and environmental accounting, water related challenges, regional and neighbouring policies and strategies.

- *Scale*: the focus was established for the whole Mediterranean river basin.
- *Decisions*: 15 countries were selected for the presentation of data assessment.
- *Sources*: Summarised comparable tables were built using data sources from Global water information system (Aquastat) from Food and Agriculture Organization (FAO), The Statistical Office of the European Union (EUROSTAT) and national sources.

• Drought Management Plans in the European Union. The Case of Spain, section 3.4 page 55.

  - *Main contents*: Specific study on drought episodes and their main management tool DMPs. An overall assessment is done on EU policies.
  - *Scale*: it was set at the national level (Spain).
  - *Decisions*: the use of DMPs was assessed more in-depth as management tools as well as the usefulness of the national drought indicator system.
  - *Sources*: mainly national sources were used, such as modelling works from universities, national administration reports, and specific data from the Júcar River Basin Authority (RBA). In addition, some figures at the EU level were provided from the EEA.

• Impacts of Climate Change on Water Resources in Spain, section 3.5 page 77.

  - *Main contents*: Assessment of climate change on water resources in Spain: availability and specificities, hydrological variabilities and trends, studies on modelling hydrological effects of climate change, implications for policy actions.
  - *Scale*: the main scale used in the study is the national one. Specific examples were provided for river basins.

  - *Decisions*: it was decided to highlight natural variability and trends, and the effects of using long and short data series, to show uncertainty in predictions and expected trends.
  - *Sources*: the main data sources consulted were official national data repositories, and specific series for river basins were used (precipitation, runoff, streamflow).

- The Challenge of Climate Change in Spain: Water Resources, Agriculture and Land, section 3.6 page 99.
  - *Main contents*: A study on climate change at the national level is produced, incorporating the effects in water resources, but also in interlinked sectors such as agriculture and land planning.
  - *Scale*: the chosen scale of study was the national one, although it also addressed EU scale by assessing European policy.
  - *Decisions*: the focus on agricultural sector (and land management) was selected for being the one with the highest water demands at the national level. Specific considerations were provided for water accounting (water balances).
  - *Sources*: mainly national official reports on emissions, mean precipitation values, and agricultural practices (water use, emissions).

- Adopting the Framework of River Basin Planning for Climate Change Adaptation in Spain, section 3.7 page 115.
  - *Main contents*: An assessment of river basin planning is developed to assess its suitability and adaptability to climate change
  - *Scale*: the scale was predominately set at the national level (as case study). Specific examples are included at the river basin level, and references to EU policy are provided.
  - *Decisions*: It was decided to encompass the case study into the theoretical framework[3] of the whole book, based on a system approach that addresses local adaptation to climate change. It was decided to highlight the incorporation of climate change aspects

[3] It is based on the assumption that the environment can be degraded by climate change effects, but also regenerated through effective adaptation strategies. It links adaptive capacity with adaptation and mitigation, with loops that provide feedback to the different processes (Stucker and Lopez-Gunn 2014).

in the national policy, and the assessment of sectoral tools (specific management plans).

  - *Sources*: most of the data were obtained from national sources, river basin authorities, and draft RBMPs.

- Climate Change Policy and Water Resources in the EU and Spain. A Closer Look Into the Water Framework Directive, section 3.8 page 139.
  - *Main contents*: The final section of chapter 3 provides a comparison between EU and national policy on water and climate change.
  - *Scale*: The scale of study was set at the EU and the national levels (examples are provided for specific river basins).
  - *Decisions*: it was decided to address, in addition to the assessment of policy implementation and policy coherence, emerging issues (e.g. the water-food-energy nexus).
  - *Sources*: data and information were obtained mainly from official reports of the European institutions (EC, EEA, EUROSTAT, Court of Auditors), and national sources (ministries, agencies, river basin authorities. . .). Also, scientific reports and articles were consulted, as well as recent EU-funded research projects.

The findings of publications determine if past experiences, especially in the development and implementation of management plans (for river basin, as well as droughts and floods), will allow, in a practical and feasible way, to implement policies for adapting to climate change in the water sector, and which economic implications will imply, taking into account the current national economic recession. The link between the stated research questions and the findings is described in chapter 5.

Table 2.1.: Summary of the main topics covered by sector in all presented publications (1/2).

Publication	Scale	Water resources	Climate change
Section 3.3 Water in the Mediterranean Region	Mediterranean basin (15 countries with greater focus in Spain).	Availability and status. Precipitation and renewable resources. Water consumption. Demands per sector (focus on agriculture). Access to water.	Main predicted effects. Direct impacts on water resources. Link to other sectors: food production.
Section 3.4 Drought Management Plans in the European Union. The Case of Spain	EU and national	WS&D. WEI. Water imbalances. Supply/Demand. Non-conventional resources.	Climate change effects (intensification of droughts, decrease of water availability). Vulnerability and water stress. Adaptation.
Section 3.5 Impacts of Climate Change on Water Resources in Spain	Spain (EU to lesser extent)	Water imbalances Scarcity Runoff and precipitation Overall demands	Major projected impacts Vulnerability issues Uncertainty of models and trends Intensification of impacts (droughts)
Section 3.6 The Challenge of Climate Change in Spain: Water Resources, Agriculture and Land	EU, national (some references to regional competences)	Latest management shifts (desalination, demand management, modernisation of irrigation techniques) Imbalances. Over abstraction. Major demands.	Main predicted effects. Direct impacts on water resources. Link to other sectors: agriculture, land, and desertification. Adaptation and mitigation.
Section 3.7 Adopting the Framework of River Basin Planning for Climate Change Adaptation in Spain	EU, national, Spanish river basins (some references to regional and local level)	WS&D. Water planning. Groundwater dependency. Major water demands and abstractions. Water infrastructures.	Vulnerability. (Spontaneous) adaptation. Adaptation capacity. Climate change scenarios.
Section 3.8 Climate Change Policy and Water Resources in the EU and Spain. A Closer Look Into the Water Framework Directive	EU and national	Water pollution. WS&D. Precipitation ranges. Water planning. Water efficiency. Water-food-energy nexus.	Major projected impacts (decrease river flows, saline intrusion, coastal subsidence, modification of habitats) Vulnerability issues Extreme phenomena (floods, heat waves).

Table 2.2.: Summary of the main topics covered by sector in all presented publications (2/2).

Publication	Policy	Economic	Social
Section 3.3	Policy existence and robustness of water administrations. Regional strategies (Neighbourhood policy, N-S instruments, UfM, WFD, MED EUWI).	Water accounts. Water pricing. Cost-benefit of measures. Main economic sectors: agriculture, industry and tourism. EU financial instruments (ENPI).	Regional conflicts (link to Arab Spring). MDGs. Public participation. Information access. Decentralisation of powers.
Section 3.4	WS&D EU communication. WFD. National legislation and DMPs.	Pressures of coastal economic activities. Overall economic impacts of droughts. Compensations to farmers.	Social and political conflicts (WS&D). Consensus process (DMPs). Public participation.
Section 3.5	Challenge: climate change integration at the national level. National water regulation WFD and RBMPs	General socio-economic impacts of climate change	Public awareness
Section 3.6	PNACC (emissions reductions commitments). Sectorial plans and strategies (agriculture and water). CAP. National water regulations. WFD.	Climate change related costs (energy and food production). Ecosystem valuation. CAP cross-compliance.	Political interests and links to water management. Participative processes. Public awareness. Capacity building. Coordination efforts.
Section 3.7	EU water and climate change policy. Multilevel governance. WFD, EU Blueprint Communication. Adaptation planning. Management tools (i.e. RBMPs and DMPs)	Effects on economic sectors (energy, agriculture, tourism). Resources needed for adaptation strategies. Valuation of climate change measures in draft RBMPs.	Role of society in building adoptive capacity. Role of NGOs and CSOs. Participative processes in decision making. Climate health implications. Public awareness.
Section 3.8	WFD EU climate change policy. CAP and Nitrates Directives. Birds, Habitats Directives. Water governance. S-PI.	Market based instruments (block tariffs, pricing policies). Cost-recovery. Valuation of ecosystem services. Water balances. Harmful subsidies	Participative processes. National conflicts. Water security. Social awareness. Capacity building and training.

3. Publications

This chapter of the thesis is a compilation of a series of publications in which the author had a major or relevant contribution. They introduce the issue of climate change and its effects on water availability and management, responding to the stated research questions, and pointing out in particular to economic implications. Publications presented here are mainly based on recent research and technical studies, hydrological data, and policy developments at the EU and national levels.

3.1. Contributions from the author in each publication

The first publication presented, "El agua en la cuenca Mediterránea" (Vargas Amelin 2011), in section 3.3, was fully developed and coordinated by the author, and it is considered as a first research activity within the PhD programme. Data provided and summarised in forms of tables mainly come from FAO, EUROSTAT and national official sources (Ministries, agencies or national statistics institutes). The text was revised by the Universidad Nacional de Educación a Distancia -*National Distance Education University* (UNED) promoters, Dr Gonzalo Escribano and Enrique San Martín, who suggested reorganisation of some contents, and expansion of the conclusions. No major changes were requested by the book's editor.

For the second publication included in this thesis, section 3.4, titled "Drought Management Plans in the European Union. The Case of Spain" (Estrela Monreal and Vargas Amelin 2012), the author contributions were mainly in the EU policy assessment, and on the part that provides examples of research projects (section 3.4.3). In addition, the author contributed to establishing the link between drought episodes and the WFD (section 3.4.4) and co-writing the conclusions. The author also contributed to overall adjustments, revisions and style improvements of the whole text.

The third article included in this thesis is called “Impacts of climate change on water resources in Spain” (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012), in section 3.5. The publication was coordinated and led by the main author, Dr Teodoro Estrela, but it is included in this thesis given some relevant contributions of this thesis’ author. These include: contents on water resources and their use in Spain, especially aspects related to water use in agriculture and expected climate change impacts in that sector (section 3.5.3), summaries and references to major plans such as Plan Nacional de Adaptación al Cambio Climático -*Climate Change National Adaptation Plan* (PNACC) (OECC 2006), and climate change studies, links to the WFD and RBMPs (section 3.5.6), and co-drafting the conclusions. The author also contributed with additional search of references, overall adjustments, revisions and style improvements of the whole text, as well as with the required corrections after receiving feedback from the journal’s peer reviewers.

The fourth article, titled “The challenge of climate change in Spain” (Vargas Amelin and Pindado 2014), in section 3.6, was coordinated and drafted mainly by the thesis’ author. The initial structure was deeply discussed with the co-author, Mr Pablo Pindado, and agreed bilaterally. The main author drafted and completed all major sections of the article (sections 3.6.2 to 3.6.8), providing an introduction to climate change impacts in Spain, expected effects on agriculture, land and desertification, economic aspects, and on-going measures and initiatives at the national level. Major contribution of the co-author were on agricultural aspects (sections 3.6.5 and 3.6.7) and on collecting information on climate change sectoral coordination structures. The co-author also contributed with additional search of references, overall adjustments, revisions and style improvements of the whole text.

The fifth publication, in section 3.7, consist of a chapter titled “Adopting river basin planning as a framework for climate change adaptation in Spain” (Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014), within the book of Stucker and Lopez-Gunn (2014). The author of the thesis wrote and completed the main contents of the chapter, and coordinated inputs from contributing authors. In addition, text boxes C to E and box F were developed by the leading author. Co-authors of the publication are Dr Elena Lopez-Gunn, Ms Gema Huelva, and Dr Teodoro Estrela. They contributed mainly to establishing the link with the book’s theoretical framework (a systems approach), gathering updated information on the Spanish RBMPs, the completion of figures and maps and overall revisions. The author also coordinated final reviews and format updates required by the book’s editors.

Contents of the final publication (section 3.8) titled "Climate change policy and water resources in the EU and Spain" (Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin in review) were mainly drafted and coordinated by the thesis' author, including figures. All authors of the article however, appear in alphabetical order. Co-authors of the article, also promoters of this thesis, are Dr Gonzalo Escribano, Dr Philippe Quevauviller and Dr Enrique San Martín. They have contributed by providing information on EU research projects, recommendations for contents and restructuring of some contents, overall revisions, and co-drafting of the conclusions.

3.2. Common areas of the publications

The presented publications share topics and ideas. Those that are common to two or more of the publications are summarised in this section.

Publications by Vargas Amelin (2011), Estrela Monreal and Vargas Amelin (2012), Vargas Amelin and Pindado (2014), Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal (2014), and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.3, 3.4 and 3.6 to 3.8, all refer to the expected impacts of climate change in the Mediterranean region, in which Spain is located. These are generaly summarised as it follows: Many semi-arid Mediterranean areas will suffer a decrease in water resources due to climate change, and expected impacts include water shortages, more extreme weather, changes in migrations of marine species and economic losses.

The Water Framework Directive (2000) is mentioned in all publications (sections 3.3 to 3.8) given its importance as the most overarching legislative tool at the EU level that aims at protecting and restoring all water bodies in the long-term.

It is a Directive that establishes a legislative framework in the field of water policy, introduces a new and more integrative perspective for water management, and aims at improving the current status of EU waters and protecting them. It establishes specific environmental objectives, and provides some general criteria to consider drought impacts in the status of water bodies.

More precisely on droughts, there are several references to the Communication of 2007, *Addressing the challenge of water scarcity and droughts in the European Union* (EC 2007a). This Communication sets a series of recommendations and points out to the need of developing a European Strategy, which is based on national and EU measures. It points out to the use and reform of existing tools such as the CAP, the WFD, financing mechanisms and emergency funds. This Communication clearly states that water saving should become a priority, and that efficiency should be maximised prior to increasing water supply options. Furthermore, it highlights the need of establishing priorities and a hierarchy for water uses, through participative approaches, and recommends the development of DMPs.

Regarding the characteristics of Spain, all publications (sections 3.3 to 3.8) describe it as a country that presents an acute irregular distribution of water resources in terms of time and space. The Mediterranean Spanish basins are characterised by presenting water scarcity problems, where there is an intensive control of water resources through infrastructures such as dams and irrigation channels. As indicated in publications by Estrela Monreal and Vargas Amelin (2012) and Vargas Amelin and Pindado (2014), sections 3.4 and 3.6, Spain is one of the top countries in the world with the highest number of large dams. The country presents a fragile balance between available water resources and existing demands, and often water bodies, mainly groundwater ones, are exploited over their recharge capacity. Problems in water scarce areas are often aggravated by drought episodes. Water scarcity and recurrent drought episodes explain, in part, the intensive control of water through hydraulic works. The highest demands coming mainly from irrigated agriculture, are concentrated in water scarce areas, and witness higher peaks in summer periods when precipitation levels are lower and evapotranspiration presents higher levels.

Regarding the effects of climate change in Spain, there are different studies, reports and scenarios assessed throughout the thesis. One of the references that is mentioned in various publications is the report *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005). Its main aim was to review and compile the state of the art on climate change impacts and on the preparation of the basis for future climate change adaptation initiatives in Spain. The main conclusions of the report related to water resources pointed out towards a general decrease of water resources; reductions of up to 50 % in water availability in arid and semiarid regions and relevant effects of seasonal patterns of rainfalls and temperatures. The study also recommended improving and extending monitoring networks and simulation models and better considering climate change effects in water policies.

A more recent study that is mentioned in publications by Estrela Monreal, Pérez-Martín, and Vargas Amelin (2012), Vargas Amelin and Pindado (2014), and Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal (2014), sections 3.5 to 3.7, is the one developed by the Centre for Hydrographic Studies of the Centro de Estudios y Experimentación de Obras Públicas -*Centre for studies and experimentation on public works* (CEDEX), which provides detailed projections of water resources reductions for three time horizons, two main emissions scenarios (A2 and B2), and specific variables such as precipitation, runoff or groundwater recharge. The main results of this study are also summarised in the conclusions of the thesis.

Some other specific hydrological aspects that are stressed, mainly in publications by Estrela Monreal, Pérez-Martín, and Vargas Amelin (2012) and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.5 and 3.8, are the lack of river flow data for long historical series, and thus the difficulty in determining climate change impacts in river flows. In addition, water abstractions are not fully controlled in Spanish basins. Hence, the use of hydrological simulation models has been helpful in shedding some light on specific climatic impacts on river flows alterations.

Specific national legislation that links water management and climate change aspects is covered in publications by Estrela Monreal, Pérez-Martín, and Vargas Amelin (2012), Vargas Amelin and Pindado (2014), Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal (2014), and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.5 to 3.8, for which often national decrees and technical guidance documents are mentioned. Also, the PNACC is described in these publications, which reflects the general national reference framework for impact assessment, vulnerability and adaptation activities. In addition, publications by Vargas Amelin and Pindado (2014) and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.6 and 3.8, describe some of the entities at national level that coordinate climate change efforts in a cross-sectoral way and gather participants and technicians from different levels within the Spanish administration (national, regional and local). These two publications also highlight the need of promoting the use of non-structural measures to increase resilience to climate change, and publication by Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), section 3.8, points out more specifically to the numerous benefits of green infrastructures and nature-based solutions.

Furthermore, Vargas Amelin and Pindado (2014) and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.6 and 3.8, call attention to the expected improvements in the Spanish hydrological planning. In Spain, water administrations have progressively achieved greater control and regulation of water resources, improving for instance monitoring networks. It is expected that the next steps will focus on a better management to control different sectors demands, reduce system losses, raise awareness, continue the modernisation of infrastructures and irrigation techniques, prioritise uses and establish socio-economic activities in the areas best suited for each case.

Weak public participative processes and administrations coordination in the Spanish water sector are identified as an important problem by Vargas Amelin and Pindado (2014), Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal (2014), and Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin (in review), sections 3.6 to 3.8. In particular, publications point out towards the lack of a firmer commitment to civic contribution, public participation and active learning, the strong defence of regional interests and the politicization of key resources such as water or energy, as part of the challenges to achieve an effective adaptation to expected climate change impacts.

3.3. Water in the Mediterranean Region

This section reproduces the chapter "El agua en la cuenca Mediterránea" (Vargas Amelin 2011) of the book *El Mediterráneo tras 2011* (Amirah Fernández, Soler i Lecha, et al. 2011). The chapter provides an introduction to the situation of water resources in the Mediterranean basin, given the similarities, in hydrological terms, of the riverine countries. The chapter focuses on 15 Mediterranean countries, gives an overview of water resources major existing pressures, availability, and dependence by different sectors. It provides information on disparities in terms of access to water, policy development and administrations consolidation, especially between EU and non-EU countries. Given the importance of water for the agricultural sector, specific examples of agricultural programmes are provided, as well as figures on contribution to national GDPs.

3.3.1. Summary

This work addresses the importance of water resources in the region, its status and use and the main challenges faced by Mediterranean countries, particularly in the South and East, providing concrete examples. It also outlines some of the most prominent international policies or initiatives concerning the protection of water, seeks to highlight outstanding issues and to provide certain key future lines towards sustainable development, not a development that bases its economic growth on the over-exploitation of natural resources.

3.3.2. Introduction to the Mediterranean region and the importance of water

The Mediterranean region, cradle of civilisations and religions and located at the crossroads of three continents, presents a mild and favourable climate that has encouraged the establishment of peoples throughout history. It has also been a region marked by trade routes, nomadic caravans, and oasis as meeting points for goods exchange and economic activities, but it has been marked as well by armed conflicts. The wealth of rivers, such as the Nile, the Euphrates and the Tigris and the contribution to their floodplain sediments, have led over the centuries to agriculture development and the establishment of civilisations, favouring the increase of population in the areas near rivers and coastlines where, at present, much of the population is concentrated. Rural populations have co-existed and developed through the rotation of parcels using historically techniques for the use of water resources. In fact, ditches, canals and other water infrastructure are common in the Mediterranean landscape and the first to be registered was the 'Aqua Appia' aqueduct, built in 312 B.C. for water supplies in Rome. Despite the name, it was an underground channel (Ruf and Valony 2007; Peña Olivas 2006). Since around 1000 B.C. also the constructions named 'quanats' or draining galleries have been built in South-West Asia, North Africa and the Middle East in order to exploit groundwater resources, and continue to be used, for example in Spain (Hermosilla 2006).

Currently, the pressure caused by population growth, tourism or urban development, mainly along the coastline, is causing serious environmental problems which affect the social and economic development of the region. Despite being one of the richest regions in ecosystems, is at the same time one of the most vulnerable in the world (EEA 2010), due to the above-mentioned socio-economic pressures and to other environmental problems such as deforestation, soil erosion or desertification. Social issues around the use and exploitation of natural resources in the region, namely water, are widely known.

There is a catchment area clearly divided between the North and the South and East[1]. The North, under a political and economic union, the EU, with specific institutions and competences, has a clear legislative framework that promotes competitive markets, protecting their production, reducing external dependency on energy products, and regulates the management and protection of natural resources. Furthermore, the South and East, even with powerful entities such as the Arab League, structures that bring together Ministers from specific sectors or bi and multilateral economic agreements between certain countries, lacks this unifying framework, particularly with regard to legislation. The industrial sector remains limited, and its economic activity depends more on tourism and agriculture.

There have been many policies to promote approaches and collaborations between the North and the South-East, such as the European Neighbourhood Policy (ENP) and the Union for the Mediterranean (UfM), as well as important international initiatives to promote a sustainable economy and environmental protection, on the basis of the Millennium Development Goals (MDGs), as it

[1] The Southern and Eastern Mediterranean region refer to countries bordering the North African and Eastern Mediterranean: Morocco, Algeria, Tunisia, Libya, Egypt, Israel, occupied Palestinian territories, Lebanon, Syria, Turkey, and Jordan.

will be described later in this section.

In this context, and given the recent social unrest in countries in the Middle East and North Africa (MENA), water plays an essential role as an engine for development, being a necessary factor in almost all social and economic activities, as well as for the protection of ecosystems and livelihoods. In agriculture, a sector in which there is an increased emphasis in this section 3.3, as in other strategic ones such as industry or tourism, water is an indispensable element for production. At the same time, agricultural and livestock activities are based on much of the surface soil and water bodies, resulting in substantial impacts on ecosystems. Water, a vital natural resource, is distributed very unevenly in space and time in the region. Is very scarce in a directly usable way and presents limited availability in terms of quality and quantity required for each use, making it a limiting factor for economic activities, development and production of food.

The current economic downturn, price volatility of agricultural products on world markets and the growing disparity between developed and developing countries are global problems which also affect citizens in the Mediterranean region.

3.3.3. General qualitative and quantitative aspects of water

The environmental component, and in particular water protection, has not been a political priority in the region. There are some growing initiatives by governments to raise awareness, ensure the protection of ecosystems, reduce pollution discharges, or improve the quality of water and its management. However, these require greater planning and long-term strategies in order to ensure sound management of the resource and to minimise the impacts of extreme events, such as droughts, or prevent the damage caused by water scarcity. Both the current economic recession, as the wave of upheavals in the southern and eastern basin, probably do not help to move in this direction, given that countries prioritise other issues such as security, political stability, health, or external trade, despite their inter-linkages with water. However, water resources could also provide an opportunity for cooperation, promoting political and technical agreements and exchanges of information.

Availability and state of water resources

A summary of the principal facts relating to the availability of water resources and associated economic aspects are listed in table 3.1. In general, countries in the region, and especially those in the South-East, are characterised by low availability of water resources as well as the irregularity in their distribution. In many cases, rain falls within a short period of time, and infrastructures for the control, management and storage of water are numerous. In spite of significant spatial and temporal irregularity, average annual rainfall in the region is approximately 600 mm, (FAO 2011). In some countries, their moister areas have averages exceeding 2000 mm/year (North of the Iberian Peninsula), while other semi-arid ones and deserts present values of 0 mm/year to 200 mm/year and represent important areas.

In Morocco, the average annual rainfall varies from 750 mm in the North, to less than 150 mm in the South-East and the Sahara Desert represents 84 % of the total area of Algeria and 95 % in Libya (SEMIDE/EMWIS 2005; FAO 2011, with data from year 2005). The quantity of water available per capita also varies greatly, and in many cases is marked by the country's economic development. As the country's economic growth so does water consumption per capita, although its availability may be limited. As examples, while France has over 3.000 m^3/year per capita, availability of renewable resources in the occupied Palestinian territories is only 201 m^3/year per capita.

Historically, rivers such as the Nile, the Euphrates and the Tigris have been of great importance in the region's development, although the last two end up in the Persian Gulf. 69 rivers flow into the Mediterranean Sea, and in terms of flow, the main contributions come from the Rhone, the Po and the Nile contributing with almost half of the water discharged, which is estimated at 8100 m^3/s. Additional relevant contributions come from the river Ebro and rivers of the eastern Adriatic coast. The contribution from rivers of northern and eastern Africa is considerably lower, with the exception of the Nile (Struglia, Mariotti, and Filograsso 2004) and a small proportion of Mediterranean rivers discharging into the Dead Sea. Furthermore, a significant part of the region's rivers and aquifers are shared between neighbouring countries (for example the aquifer Nubia Arsenica shared between Libya, Chad, Egypt and Sudan). In fact, most of the Mediterranean population live in transboundary basins, and 90 % of the South-eastern European area is located in international basins (Ganoulis 2006).

In 2000, the region's population was estimated at 450 million people, out of

Table 3.1.: Summary of availability and use of water resources in Mediterranean countries selected. Source (FAO 2011).

Country	Pop. (millions)	Area (km^2)	Avg. precip. ($\frac{mm}{year}$)	TIR WRs ($\frac{km^3}{year}$)	TR WRs p.cap. ($\frac{m^3}{year}$)	AC (km^2)	WCA (%)	WCI (%)	SCD (hm^3)	CAGDP (%)	CAWF (%)
Algeria	34.3	2 381 740	89	11	340	84 240	65	13	5 676	11	23
Egypt	73.4	1 001 450	51	2	703	34 220	86	65	168 196	17	31
Spain	43.8	504 782	650	112	2 506	173 000	60	21	55 586	3	4
France	62.0	549 190	867	200	3 401	193 310	12	69	9 917	2	4
Greece	11.1	131 960	652	58	6 667	32 250	89	2	11 770	4	12
Israel	6.7	20 770	435	1	254	3 920	58	6	—	2	2
Italia	59.6	301 340	832	183	3 210	97 680	44	36	8 430	2	4
Jordan	5.7	88 780	94	1	161	2 700	65	4	275	3	10
Lebanon	4.1	10 450	661	5	1 074	2 860	59	11	228	6	3
Libya	5.6	1 759 540	56	1	113	21 500	83	3	385	9	5
Morocco	31.0	446 550	346	29	971	92 830	87	3	16 904	18	33
Syria	19.0	185 180	252	7	1 403	57 420	87	4	19 654	20	26
PT	4.1	6 020	402	1	201	2 182	45	7	0	10	10
Tunisia	10.1	163 610	207	4	482	50 410	75	4	2 512	13	23
Turkey	73.2	783 560	593	227	2 800	266 060	74	11	156 298	9	43

Pop.: population.
Avg. precip.: average precipitation.
TIR WRs: total internal renewable water resources.
TR WRs p.cap.: total renewable water resources per capita.
AC: area under cultivation.
WCA: water consumption in agriculture.
WCI: water consumption in industry.
SCD: storage capacity of dams.
CAGDP: contribution of agriculture to Gross Domestic Product (GDP).
CAWF: contribution of agriculture to workforce.
PT: Palestinian territories.

which two thirds were in the southern Mediterranean area which in 1950, only held one third of the population (PAM 2011). Inequalities in birth rates, linked to the levels of development, have marked important differences between the population growth, but it is estimated that the region could reach 600 million inhabitants by the year 2050 (Saverio Civiili 2010). In addition, they would be mostly concentrated in coastal and urban areas, which generally have reduced water availability. This is one of the reasons why the practice of desalination of sea water has increased in the region and is being used as a solution to supply growing urban centres as it will be discussed. Cities such as Istanbul, Cairo or the Paris conurbation already excess 10 million inhabitants, this gives an idea of the demographic pressure experienced by the region.

In the Mediterranean area there are numerous dams, canals, irrigation ponds and transfers, and irrigation infrastructure which have been used for centuries, although in many cases they are not as efficient as they could be, and require improvements and modernisation investments, to reduce losses and leakages. Countries also have different distribution and supply channels, mainly in urban areas, but the situation varies widely from one country to another. Treatment and distribution infrastructures are not fully implemented, especially in rural areas, leading to problems of sanitation and access to drinking water, and therefore social and health issues.

The main problems faced by the region in relation to the quality of water resources are diffuse pollution[2] (farming practices) and point-source pollution[3] (mainly from urban and industrial discharges), as well as the lack of sanitation and purification. Increase in problems of water quality leads to eutrophication (accumulation of organic matter and decrease of dissolved O_2), and decreases the dilution capacity of rivers.

Also the degradation of wetlands, soil erosion, oil spills and the decline of Mediterranean biodiversity, are among the main environmental problems. However, one of the greatest challenges that most countries are facing is water scarcity. The lack of this highly prized resource in strategic enclaves, as coastal towns or agricultural areas, imposes limits on economic and social development.

Major water quality problems in MS are currently being tackled by the Water Framework Directive (2000) and daughters Directives -Groundwater Directive (2006) and Environmental quality standards in the field of water policy (Priority Sustance Directive) (2008)-, in addition to the Urban Waste Water Directive (1991), concerning urban waste water treatment. For example, the WFD requires MS to achieve good status for water bodies by 2015 through the implementation of RBMPs and PoMs to tackle the main water problems, establishing strict environmental targets. Non-compliance with the Directives, entails infringement procedures and financial sanctions to MS. The lack of a common framework on the protection of waters in the South and East of the

[2]Diffuse pollution is caused by different outbreaks and relates to the pollutants which extend over a wide area of the environment which may affect the soil and water. Each outbreak independently assessed may have no large impact, but all of them together may cause significant problems. For example, the excessive use of fertilisers on agricultural areas produce phosphate and nitrogen compounds that not taken up by plants pollute soils and water bodies.

[3]Point-source pollution refers to that one with a clear origin, and its place of origin is readily identifiable (sewer pipe, other pipes). The direct discharge of untreated water into a river bed through a pipe is an example.

Mediterranean is being addressed to some extent within the UfM, as described below.

Extreme phenomena

Extreme events such as floods, heavy rain or droughts are common in the region. Floods are causing loss of lives and losses of millions euros in materials each year. However, similarly to these phenomena, water scarcity and droughts, are also causing less immediate but not less severe impacts. On the one hand, drought is characterised by a slow and difficult to predict climatic process, caused by less water inputs than in a normal state (mainly due to lower rainfall), and often occurs in the Mediterranean region resulting in significant socio-economic and environmental impacts. Water scarcity, on the other hand, is more linked to anthropogenic effects than natural causes and is defined as the imbalance between the available water and the existing demands under sustainable conditions (EC 2007a; Estrela Monreal and Vargas Amelin 2008). It can be said, that this shortage of water is rather characteristic in the region, and is a problem more prevalent in coastal countries, resulting in substantial damage in agriculture production due to the decline in harvests and difficulties in supplying stocks mainly to urban areas. Indeed, the structural shortage means that 180 million people have an availability per capita of 1000 m^3/year, and 80 million people less than 500 m^3/year (UNEP/MAP-Plan Bleu 2009).

In relation to the economic impacts of droughts, only in MS it has been estimated at € 100 billion in the last 30 years. The average annual impact doubled between 1976–1990 and 1991–2006, reaching an average annual peak of € 8.7 billion in 2003 (EC 2007a).

3.3.4. Climate change

Given the close link between availability of water resources and weather, one should not forget the impacts of climate change in the region. According to the IPCC (2007a), in the Mediterranean region the temperature increase linked to climate change have caused a greater number of extreme events, an increase in their intensity, and dwindling water resources availability. It is foreseen a decrease in precipitation, increased aridity and extreme droughts in southern Europe and the Middle East (Dai 2011), changes in sea temperature and decreases in river flows. In particular, an increase of 1.2 °C for the year

2020 could result in reductions of water availability of 15 % in Lebanon and above 10 % in parts of Morocco (UN 2009). Arnell (1999) stated that in 1995, 1400 million poeple lived in conditions of water stress mainly in south-western Asia, Middle East and in the Mediterranean region, the latter two areas presenting the highest rates, estimates of decrease of water runoff, will lead to even greater stress indexes by decreasing water availability.

The effect of climate change, would affect the availability and distribution of water resources, and in turn food production, and thus the production of crops and livestock. Water shortages and drought will be most probably exacerbated, and will be important factors to be taken into account in water planning and management. This will result in increased demands for an increasingly scarce resource, which will affect government priorities (Estrela Monreal and Vargas Amelin 2008). However, different authors (Magnan et al. 2009; Arnell 2004) underline the uncertainty of climate and hydrological models or data of CO_2 emissions, the unpredictability of natural climate variability, the lack of consistency of data for the region, as well as the wide margins of estimations of growing populations and water consumption.

There will need to be more robust studies of climate change and expected impacts, to encourage governments to develop and invest more in mitigation strategies, compared to existing action focussing mainly on adaptation (UNEP/MAP-Plan Bleu 2009). In any event, given the situation which already presents a sensitive region with strong water imbalances, water scarcity and poverty levels, climate change is expected to generate and lead to agricultural and social impacts.

The Mediterranean countries should consider aspects such as prioritisation of water uses, as for instance prioritise public supply or food production over energy security issues (IWMI 2008). Climate change will affect water availability and distribution, as well as crop production, and it must therefore be taken into account in agricultural policies, energy and water, building on horizontal structures to coordinate actions.

3.3.5. Main water management policies

Institutions, skills and management

Water authorities in the region present a certain degree of complexity, since tasks are shared, and sometimes overlap between different entities. However, they remain quite different from one country to another and particularly in comparison to the EU (which countries share a common legislation). In most countries, the central structures have, at the highest administrative level, the goal to develop guidelines and policies to be applied at regional or river basin level. Usually, they also has specific legislation both for the use and protection of waters, although, as mentioned above, in the case of MS with the Water Framework Directive (2000) and the Urban Waste Water Directive (1991), there is also a system of economic infringements if the Member State fails to comply with the objectives and deadlines set. Countries also have worked progressively towards the creation of national plans for water management, and some are plans by catchment area in addition to other sectoral ones (e.g. droughts, floods and coastal management).

For water management, typically there are several ministries with linked competences on waters (agriculture, environment, food, forestry...). In some cases a principal entity exists with exclusive competence for water management and planning and for developing water works as a Ministry of water resources or State agency. For example, Turkey has the Directorate General of Hydraulic Works.

A significant number of countries apply river basin management, fostered from various international forums and backed up by sound policies (such as the WFD), thus respecting natural limits and presenting specific water authorities, water agencies or Confederations. This is the case of Algeria, Morocco, Turkey, Spain, France, and Lebanon, for the Litani basin. This type of management directly addresses the needs and problems of hydrological systems and integrates more easily different stakeholders, such as users, in decision-making processes (Iglesias, Garrote, F. Flores, and Moneo 2006). Governing Boards, irrigation associations, cooperatives and other associations as well as Non-Governmental Organisations (NGOs) or neighbouring communities play also an important role in the management and protection of water.

Although, in most cases, participatory processes, the consideration of claims from social groups or their direct involvement in decision-making to manage water are not sufficiently covered. In fact, in the vast majority of cases centralised management leaves little scope for public participation. Also the coordination with other agencies, ministries and institutions whose powers are directly linked to water (agriculture, climate change, rural development and land management) is mostly inadequate or fragmented, and policy compliance and enforcement is weak (Ferragina 2010).

The countries of the region have in most cases economic tools as described below, and administrations have sought to apply concepts such as cost recovery, especially following major investments in water infrastructure and some kind of system to establish water pricing (although in many cases is well below their real value). Table 3.2 shows a summary of the institutional arrangements in certain Mediterranean countries, administrations involved, type of legislation and other aspects such as the degree of cost recovery (surveys and studies of the Euro-Mediterranean Information System on know-how in the Water sector (EMWIS)).

Table 3.2.: Percentage of population with access to drinking water in selected Mediterranean countries. Source (FAO 2011).

Country	Renewable resources per capita $\left(\frac{m^3}{year}\right)$	Rural pop. served (%)	Urban pop. served (%)
Algeria	473	80	92
Egypt	859	97	100
Spain	2 506	100	100
France	3 439	100	100
Greece	6 667	100	100
Israel	254	100	100
Italy	3 210	100	100
Jordan	161	91	99
Libya	113	68	72
Lebanon	1 074	100	100
Morocco	971	56	99
Syria	1 403	83	95
Palestinian Territ.	201	88	94
Tunisia	482	60	94
Turkey	2 800	95	98

The majority of fresh water resources and groundwater in the Mediterranean region are shared between neighbouring countries. And although progress has been made in international cooperation between countries and there are numerous treaties and agreements, conflicts over the use of their application are well documented. Some examples are identified in the Nile river (shared by 10 countries), the Euphrates and the Jordan River, Sea of Galilee (or Lake Kinneret) in Syria that was annexed by Israel in the 1967 war, the Kebir River between Lebanon and Syria or the Orontes River between Lebanon, Syria and Turkey. In the case of Nile River, Egypt was the first country to control its flow through major infrastructures, both to increase the irrigated areas and to prevent damage from not controlled flooding. Furthermore, Sudan and Uganda have started to construct dams to supply their demands which might come into conflict with the overpopulated and increasingly water demanding Egypt, creating a situation of potential future conflicts (Fairén Le Lay 2008).

The growing population and economic development go hand-in-hand with an increase in water needs to meet the demands. However, the availability is limited, and not in all cases their use is justified, at least taking into account sustainability criteria. To date, policies centred on increasing available resources, but little by little, the countries of the region are changing towards a demand-side management and increasingly considering the importance of ecosystems, waste water treatment or the costs of long-term overexploitation of aquifers. Some initiatives designed to adjust supply to demand include non-structural measures, such as inter-sectoral collaboration, public awareness or economic incentives in order to make rational use of water (VWWF 2009). The water authorities are thus progressively gaining greater control and regulation of resources, improving monitoring networks, control and extraction, treatment and sanitation techniques. Therefore, it is expected that the following steps should focus on better managing and controlling demands from different sectors, reducing losses in the systems, raising public awareness, modernising infrastructure and irrigation techniques, and establishing prioritised uses and socio-economic activities in the most optimal areas for each case.

Some aspects should be reinforced in the coming years that include the development of legislation in the field of water and enforcement, institutional strengthening and participatory processes with stakeholders and coordination among competent authorities both within countries and at cross-border levels.

Economic and environmental accounting tools

Water administrations use different tools in order to cover the costs linked with the construction and maintenance of supply and storage infrastructures. However, the general feeling that water is a public good which therefore should be free, has a significant impact on the pricing decisions and on assigning a value to water. In fact, it remains one of the most serious discussions in international fora (World Water Forums or Ministerial conferences). In most of the Mediterranean countries, charges for water use apply mainly to urban and industrial sectors, subsidising the cost in agriculture to encourage economic activity in rural areas, food production and export. In addition to fees, charges, and taxes on the use of other tools such as water markets have been strengthened in recent years, favouring the exchange of rights and purchases and sales of volumes between users.

On the other hand, there have been insisting voices on the need to incorporate environmental aspects in national accounts since the 60's, and since the 70's the need on how to integrate indicators that would reflect the degradation of the natural environment was raised (UN 1993; Nordhaus and Tobin 1973). Despite the fact that many years have passed, yet few governments have implemented *de facto* environmental accounts, which could be very useful when assessing the real value of natural resources and their services, compare them to other tangible goods largely integrated in the market (such as wood or minerals) and determine human impact on them. In the case of water, the externalities of its exploitation and use, pollution of water bodies, or the valuation of the services they provide (intrinsic value, landscape, environmental services), are rarely integrated into economic accounting systems, although in some cases satellite accounts are used. These are linked to the national accounting systems, supplement the information available, but do not interfere directly in the calculation of macroeconomic indicators such as GDP or overload or distort the central system but provide extended and specific information.

Water poses major problems to be assessed: it flows through the territory without defined borders, which poses problems of property and rights of use and exploitation. There are a large number of administrations which operate on the resource, and sectors that use, alter and pollute it. The precise accounting of abstractions and discharges, or even their availability (groundwater bodies) is complex. As noted above, in many countries, and similarly to air, is perceived as a universal good which should be accessible by everybody free of charge. This poses serious problems for the water authorities facing the costs of extraction, processing and distribution. In Spain, for example, the unit price of water (ratio of revenue from services -supply, sewerage and purification- and the volume of water consumed -homes, services and industry-) for 2005 was 1.02 €/m^3 (0.67 €/m^3 for supply and 0.35 €/m^3 for sewerage and purification) (INE 2008b). However, this price does not include for example the costs of environmental degradation and pollution by its extraction and use, nor does it cover its role as an essential factor in ecosystems.

Population growth, and therefore demand for water in all Mediterranean countries will require more investments in treatment and re-use, saving measures and increasing the use of non-conventional resources, such as desalination, translating into significant economic costs which should be reflected in the value of water. The use of satellite accounts for water in Mediterranean countries could be a statistical tool to determine how economic activities produce impacts which affect the environment. This would help to develop and support policies which slow down the ecological damage and help ensure a sustainable integrated water management address studies and works on cost-benefit measures, environmental impact assessments or cost recovery for water services, in addition to raise awareness of the intrinsic value of a vital resource.

Main economic sectors

Agriculture remains the most water demanding sector, with an average demand of 64 % in the Mediterranean (UNEP/MAP-Plan Bleu 2009). Although there are two main agricultural sectors, cereals (non-irrigated) and irrigated agriculture for fruits and vegetables. It is important to stress that the economy of the region has been growing by relying increasingly in specialised and irrigated agriculture, whose origins rose in the nineteenth and twentieth centuries (Ruf and Valony 2007). Olives, dates, citric, vegetables and cereals, are part of the traditional agricultural landscapes of the Mediterranean, and the export of these products represents an important part of the economy for many countries.

Two specific examples highlighting the importance of the agricultural sector in the region are provided: the Güneydogu Anadolu Project *-Agricultural national Project, Turkey* (GAP) project (box A) and the Plan Maroc Vert *-Plan Green Morocco* (PMV) (box B).

Industry is one of the sectors that makes an important contribution to the economic and social development of the countries. The agri-food sector, metal production, cement or textiles, among other, generate jobs and exports and contribute significantly to the levels of national GDP. It is expected that industry and the production of manufactured products will rise progressively even more with societal changes and the opening of the economies in the Southern and Eastern region. But the sector is also accompanied by environmental impacts on the water environment, and discharges of untreated water cause significant inputs of pollutants, materials in suspension or heavy metals.

Water is also necessary for the cooling of production plants, as well as a source of energy in the region, since the power supply covers non-negligible rates in some countries —in 2009 hydropower generation represented 7.3 % of the Spanish electricity generation (MARM 2009b), while in Turkey it represented 18.5 % (IEA and OECD 2010) and 9.25 % in Egypt (IEA 2011). Abstractions, recurrent droughts and the resulting decrease of flows in rivers, compromise the production in hydro-power plants.

Another sector which plays an important role in the region is tourism, receiving 30 % of the world total tourism. In 2007, for example, there were 275 million tourists, making this the number one region in tourist destinations. The sector generates thousands of jobs, supports the development of less-favoured regions and also promotes social and cultural interchanges. The total contribution of travel and tourism to the Mediterranean countries' GDP is

Box A: GAP project in Turkey

The GAP project in Turkey in the South-East Anatolia Region, is the largest project of the country. Its main project plan was drawn up in 1989 and aims at developing a number of actions in that less-favoured regions to foster rural development and increase agricultural production, create jobs and develop an exporter centre. It covers an area of 75 000 km^2, and focuses mainly on increasing the irrigation area and hydroelectric generation in the basins of the rivers Euphrates and Tigris, but it also includes actions for the improvement of urban and rural infrastructure, education and health.
The programme of water resources includes the construction of 22 dams and 19 plants (7 and 4 built respectively in 2001) and provides for channels and irrigation infrastructure in an area of 1.7×10^6 ha. The main enclave is the Ataturk dam with a capacity of 84.4×10^6 m^3. The total budget for the project is US $32 billion, of which 14.8 have already been invested with significant input from the World Bank, United Nations Environment Programme (UNEP), EU and European governments among others (Olcay Ünver 11-12/oct/2001).
Inappropriate irrigation, the excessive use of fertilisers and the extraction of water have caused serious problems of salinization of soil in the region and diffuse pollution. Thus, both water saving programmes and good farming practices have been launched as well as reforestation projects. Other related problems include the reduction of water flows downstream, which mainly concern Iraq and Syria, with which the Turkish government has developed cooperation agreements and allocation of volumes mainly from the Dicle-Firat basin (OECD 2008).

Box B: Plan Maroc Vert -*Plan Green Morocco*

The PMV, was presented in 2008. Sets the main policy lines for agriculture in Morocco until the year 2020, based on two pillars: the economic and the social sectors. Its main objectives include improving the production and export of goods, modernising the sector, increasing private investment, contributing to GDP and creating jobs, by developing between 1000 and 1500 projects with an investment of 10 to 15 000 million dirhams/year.

The Plan defines a framework of free trade for the export of products, the institutional reform of the Ministry of Agriculture and Fisheries (and creation of an Agency for the launching of a plan), and includes as a priority to improve social conditions in rural areas and reduce poverty rates. Key actions are the conversion, intensification and diversification of crops. For example, the aim is to transform less productive areas of cereal in export crops (tomato or strawberry) generating higher revenues, enhance trade in the EU market and diversify exports by branching out into newer markets, such as those of US or China. In relation to water resources, the plan includes applying tariffs to water, especially in private farms, promoting a better use of it, and delegating progressively the management to the Agricultural regional offices (MAPM 2011).

The EU is increasingly liberalising agricultural trade with Morocco under the Association Agreement in force since 2000 and under the ENP. Its ultimate objective is the establishment of a free-trade area, which, *inter alia*, has been updating its agricultural Protocol. It will represent a further step in the liberalisation of certain products through the expansion of the application of quotas for some fruits and vegetables and a reduction in tariffs, increasing the competitiveness of products of MSs and encouraging economic agreements with the country (EU 2011). This in turn is leading to conflicts of interest and rejection by countries such as Spain, Italy or Portugal, whose agricultural associations complain on the economic impact that this agreement can produce, for example, by the entry of Moroccan tomatoes in the market, which, they claim, do not respect quotas and the agreed entry price system.

estimated at US $895.3 billion in 2011 (10.9 % of total GDP), providing for an increase by 2.5 % by 2021. Furthermore, the sector comprises 4.5 % of total jobs (WTTC 2011). Travel and stays are concentrated in most cases during the summer, so that water demand takes place at the time of the year with the highest shortage in the Mediterranean. Tourism is therefore in many cases the reason why new sources to provide water become necessary, concentrated in space and time. According to the media, social unrest and political instability in the region, are already having impacts on the distribution of tourism, and countries of the North area are being advantaged to the detriment of the reduction seen elsewhere.

Environmental challenges and water

As mentioned, water is necessary for any economic activity, although agriculture remains the main demanding sector and takes a leading role in the region using most of the resource. Other sectors such as industry or tourism, also consume water and cause significant impacts on the natural environment. And although water scarcity could be regarded as one of the main problems, the region faces many other environmental impacts, produced mainly by human activity. Agricultural production and industrial development are inseparable of contamination of water resources, soil erosion or pollution discharges. Agricultural activities, to a large degree, the essence of the economy of the region, require significant input of plant protection and produce serious problems of diffuse pollution in both surface waters and groundwater, the latter being even more fragile due to slow recharging processes. These problems of water pollution, in turn, produce negative economic impacts: increased need for treatment in surface water courses, treatments when using groundwater especially for public supply, or even causes the impossibility of using the water due to high levels of nitrates and phosphates. Where human and economic resources to treat and purify water are insufficient and there are still extractions, pesticides and fertilisers can cause health problems, both from direct consumption of water, and the contamination of raw vegetables.

Over-exploitation of aquifers for public supplies generally produces marine intrusion in coastal aquifers, and some non-renewable fossil aquifers are being exploited without being recharged naturally, as for example in Egypt, in the Nubia sandstone aquifer system in Libya (The Government Office for Science 2011; FAO 2011). The decrease of extensions of wetlands and lakes and the loss of their natural functions, fish deaths, or increase of desertification are also problems common to the countries of the region. Certain highly water demanding crops (cotton, rice, maize or beet) are producing progressively increased demand in areas which already had water imbalances or even suffered from water scarcity. Unfortunately, this situation increases the competition between the various water using sectors. The use of water for irrigating large areas of cultivation has led to lower natural river flows resulting in impacts on aquatic ecosystems (e.g. wetlands) or social conflicts by reducing the availability of water downstream (far from the place of extraction).

Other environmental problems include the introduction of alien invasive and aggressive species in the region, reduction of biodiversity of fields, displacement and affection of animal species, alteration of ecosystems and impoverishment and erosion of soils, and the possible risk of the use of Genetically Modified Organisms (GMOs). For the latter, further assessment is needed to determine profits (resistance to pests and drought for example) versus their potential negative impacts (effects on both wild fauna and flora in contact or biological contamination of fields) where public opinion is having an important influence. In addition, local air pollution is common due to the burning of residues of most traditional crops (although the inflow of nutrients is much lower that if the waste was left to decompose naturally). Also leaving the bare ground after burning accelerates erosion, desertification and favours the decreased production on arable land.

Despite all these externalities, the agriculture and the agri-food sector remain key economic activities in the countries of the region, employing a high proportion of the workforce (table 3.1. Turkey, Tunisia, Syria, Morocco, Egypt and Algeria) and provide environmental and landscape services rarely measured. It is worth noting that some ecosystems used primarily for food production have a high ecological value due to their biodiversity. Furthermore, many Mediterranean agro-ecosystems present high levels of biodiversity and have been adapted to the existing farming practices for thousands of years, making it possible to produce food whilst maintaining biodiversity and ecosystem services (The Government Office for Science 2011). The use of certain agricultural practices, the expansion of organic farming and mechanisation in the most suitable areas, could assure a more rational use of water and soil and plant protection, reducing externalities while retaining the benefits of the sector.

Expectations and improvements in the management of water resources

There are different improvements of water resources use and management that can be applied in order to secure the supply to the main uses, in a sustainable way and improve the competitiveness of agriculture in the region. In this context, water pricing and technological aspects will be key in the years to come. Both the improvement in agricultural techniques, such as the increase of harvest and the modernisation of infrastructure, notably in the irrigated areas may be translated into greater efficiency in production and less use of water, achieving even lower economic and energy costs. These improvements include the modernisation of irrigation systems, water re-use and the use of other non-conventional resources that must be accompanied by an appropriate pricing policy.

In relation to non-conventional resources, some countries already produce significant volumes of desalinated water, that are mainly used in the tourism sector or in supply for urban areas. For agriculture the re-use of waste water is also broadly used. Spain with a production of nearly $700 \times 10^6\,m^3/year$ in 2009, was the fourth country in the world for production of desalinated water behind Saudi Arabia, the United States and the United Arab Emirates (MARM 2009b). Algeria is also currently placed in the Mediterranean as an important producer of desalinated water, with approximately $109.5 \times 10^6\,m^3/year$, after the completion of 11 desalination plants which could be multiplied by eight (UNEP/MAP-Plan Bleu 2009). In Israel is a widespread practice as well and currently the country produces $450 \times 10^6\,m^3/year$ of desalinated water, with the government's objective to produce $750 \times 10^6\,m^3/year$ by 2020 and address water scarcity problems (FAO 2011; MAE, Ambassade de France en Israel 2005). With regard to re-use, countries such as Turkey, Syria or Spain produce significant volumes that are used predominantly for irrigation ($2770 \times 10^6\,m^3/year$, $1364 \times 10^6\,m^3/year$ and $1012 \times 10^6\,m^3/year$ respectively) (FAO 2011; MAGRAMA 2011).

As any treatment associated with water, both reuse and desalination require specialised techniques that present energy use and potential environmental problems linked mainly to the discharge and treatment of waste (sewage sludge and brine) and CO_2 emissions. In recent years, progress has been made in the use of new technologies for reducing required energy inputs. Studies are being developed for assessing potential environmental impacts by means of dissemination and discharges into the sea in the case of desalination, also promoting the use of technologies based on renewable energies such as solar and wind.

On the other hand, it would be necessary to have additional water supply infrastructure and storage systems in some countries (which in the case of dams, could minimise the impacts of floods through their laminating effect). For example, in the case of the occupied Palestinian territories the construction of small dams in wadis (or watercourses) would allow storage of rainwater, which tends to be concentrated in short periods of time with little chance of being exploited.

Also crop rotation and other techniques described above, would minimise impacts made mainly in water, soil and air, and reduce the externalities of agricultural production. In practically all of the Mediterranean countries, waste water treatment is insufficient or non-existent and should therefore be addressed to reduce the quality problems that affect both rivers and the Mediterranean Sea.

Furthermore, enhanced storage, processing and transmission of information and the standardisation of databases on water at regional (through existing structures such as the EMWIS), river basin, and national levels would promote their access by the general public promoting social awareness. Progress and implementation of early warning systems that minimise impacts of extreme events, remote sensing for forecasting drought or accounting for areas of crops, and other technologies will be key to optimise the use of water and to mitigate, as far as possible, the impacts of extreme events. Other important aspects include, institutional strengthening (e.g. through technical training) and improving legal frameworks in water management and protection. Finally, satellite accounts, as mentioned earlier, would allow Mediterranean governments to improve the methodology and the valuation of environmental damage, and to link the indicators of economic performance of agricultural production with rates of pressure on the environment.

3.3.6. International policies and initiatives

In recent years, economic and environmental policies and initiatives have been launched to improve cooperation in the region, promote trade and exchange goods or workers between the two shores, or to protect natural resources, which are of great importance to political and social stability in the region. Both the transfer and sharing of knowledge and technical aspects such as aid and international investment in developing countries have had a significant impact on the construction of infrastructure, modernisation of agricultural practices, and improving access to safe drinking water and basic sanitation.

Water problems have been identified in the policy area primarily under Ministerial Conferences, and discussed extensively during meetings of a more technical nature, such as Water Directors and experts from administrations of Mediterranean countries on a regular basis since 1997. While there has been progress in the search for common solutions to water problems, many practical and environmental aspects still have to be addressed.

Conflicts over water use and the territory

Social and political conflicts around the use and exploitation of water in the region are well known, and tensions remain high particularly in Egypt, Libya, Malta, Syria and Israel (UNEP/MAP-Plan Bleu 2009).

Probably the most striking case in the region is the one of Israel and the occupied Palestinian territories, since in many conflicts the military objectives have focussed on water control, agricultural areas, water treatment plants, bridges, canals and other infrastructures associated to water resources. Most of the water disputed is that of the mountain aquifer of the West Bank and water resources of the Jordan River. Attempts to agree on the use of water in the West Bank have been numerous over the history of the Arab-Israeli conflict, but have rarely been successful. In economic terms, and in comparison with the cost of desalinated water, the value estimated for the 150 m^3/year to 350 m^3/year extracted and distributed from the West Bank aquifer is around US $ 30 million/year to US $ 70 million/year, a figure which is less than 0.1 % of the Israeli or Palestinian GDP (Fisher and Huber-Lee 2005). The minimum water concessions agreement insured by Israel to the occupied Palestinian territories, or the increased use of unconventional resources (desalination and re-use) would easily provide the required resources guaranty and greater political stability in the area.

Contrary to widespread pessimism about the possibility of reaching successful and beneficial agreements, not only in Israel and in the occupied Palestinian territories, but for different stakeholders in the Mediterranean region, some sectors see precisely in water an opportunity and an instrument for cooperation and exchange of information to promote peace and stability in the region. Middle Eastern countries face common problems and a shortage of water increasingly acute, thus water and the environment can be critical for regional development and resilience against climate change impacts. Furthermore, possible short- and medium-term solutions are being proposed, such as the creation of joint technical and political committees to promote integrated water management at river basin scale, cooperation between stakeholders, exchanges of data or research, based on common political principles and protocols for the restoration and protection of waters. This cooperation, with a green and sustainable perspective, would ensure a joint management of resources, reduce the possibility of destroying of infrastructure in times of conflict and attract international investments more easily (Waslekar, Vishwanath, Bakshi, and Motwani 2011).

Furthermore, in relation to land, the Mediterranean region has a mixture of extensive agricultural productions, with other smaller areas, fragmented and managed locally and in co-operatives. In some cases, there are conflicts over the use and ownership of land, as well as the right to water use in arable areas. In this context, the centralised management of water can hinder the development and fight for self-sufficiency of regions or local authorities.

The Millennium Development Goals and access to drinking water

Within the UN framework, the well-known MDGs[4] were approved in the year 2000 to be achieved by 2015, with a view to ensuring human development, combating poverty and create better opportunities to benefit from the global economy. They were revised at the 2010 Summit, adopting an accelerator framework to facilitate compliance (UN 2009). With regard to water, Objective 7 seeks to ensure environmental sustainability, and more specifically Target 10 aims at halving the proportion of people without sustainable access to safe drinking water and basic sanitation. Whereas MS access to sanitation and drinking water is practically ensured at a 100 %, this is not the case in all countries of the region. In the UN report on development in Arab countries (Programme 2009) major efforts were made to supply the population with drinking water, and resulted in a change from 83 % in 1990 to 85 % in 2004, reaching 86 % in the Maghreb and Mashreq areas. Despite this significant progress, there are still differences between access to drinking water in rural and urban areas (see table 3.2), e.g. in countries such as Morocco, Tunisia, Algeria and Syria. Furthermore, in the case of Libya access in urban areas is also limited.

Not only water scarcity and access to clean resources are problems that

[4] In June 2012, UN member states agreed to establish an intergovernmental working group to design Sustainable Development Goals (SDGs) as successors of the MDGs and part of the Post 2015 Development Agenda.

the region faces; also, as explained, mainly water pollution by fertilisers, pesticides, discharges of untreated waste water or emerging pollutants like pharmaceuticals, threaten the access to clean water and human security. It should be noted that the management and treatment of water, as well as the investment capacity in countries in the South and East of the region are rather limited. Water treatment measures are insufficient, and it is estimated that an important share of water supply networks in certain countries exceeds the recommended levels of arsenic, fluorides, nitrates, ammonium and salts, affecting human health.

Horizon 2020

One of the initiatives launched to address these pollution problems is the Horizon 2020, which is reflected in the EC Communication to the Council and the Parliament for establishing an environment strategy for the Mediterranean. This initiative provides assistance to riverine countries for addressing municipal waste, industrial emissions and waste water discharges from urban areas with the aim of reducing pollution in the Mediterranean. Indeed, it is estimated that 80 % of pollution in the Mediterranean comes from these sources (EC 2006). For the de-pollution of the Mediterranean Sea in 2020, the initiative focuses on four main elements:

1) projects to reduce the most significant sources of pollution (industry, spills, municipal waste),

2) institutional strengthening measures (creation of environmental agencies to develop legislation),

3) use of EC research funds to exchange relevant environmental knowledge on the Mediterranean, and

4) development of indicators to monitor the success of Horizon 2020.

The aim of this initiative is to partner countries defined under the ENP and it underlines the use of its financial tool the European Neighbourhood and Partnership Instrument (ENPI), in order to achieve its objective, catalysing additional efforts and investments from international institutions.

The neighbourhood policy and the Union for the Mediterranean.

Outreach efforts from the EU to riverine countries have been substantial in recent years. The Barcelona process, also known as the Euro-Mediterranean Partnership of 1995 with 15 countries of the EU and the 12 Southern Mediterranean countries or ENP (EC 2003b) are proof of this. The objectives of both examples have been rather focused on issues such as democracy and human rights, security and defence, economic and financial issues, as the establishment of a free trade area, or cultural activities, leaving to one side, at least initially, environmental aspects. Although the Barcelona Declaration identified the need to reconcile economic activity with environmental protection and recognised water as a matter of priority, these aspects were only a small portion of the objectives. With the new 'label' UfM the Barcelona process is re-launched and extended at the Paris Summit of July 2008 after more than a decade of existence and with strongly criticism on its success. Various authors think that the Barcelona process did not have the desired results due to, among other factors, the lack of involvement of the civil society, the limited definition of cooperation with the United States, or the need for closer links between the process and the ENP. Additional identified problems were the need of a stronger cooperation between countries, improvement of socio-cultural collaboration or minimisation of existing conflicts (Amirah Fernández and Youngs 2005; Jerch, Lorca, and Escribano 2005). In 2008, the aim is to re-launch the work by focusing on the areas of de-pollution of the Mediterranean Sea, the Mediterranean Solar Plan, the involvement of financial actors, and reinforcement of existing links in the region. It was also decided to set up the Secretariat in the city of Barcelona. That is, the process introduces critical challenges now taking more into account environmental issues, clearly interlinked with the socio-economic aspects.

Additionally, the objective of the ENP, was the setting up of a 'friendly and secure' enlarged area (Europe together with southern and eastern countries), with strong economic ties based precisely on economic integration and exchange of products mainly agricultural and also services. It addresses environmental issues on the surface, including environmental protection mainly linked to economic efficiency, but only makes a specific reference to water, in relation to cross-border cooperation and security.

Moreover, the EU wanted to share with other Mediterranean countries the experience from a common policy framework (such as the one of the WFD) and progress made in MS towards an integrated water management. The

Mediterranean Component of the EU Water Initiative (MED EUWI) and the joint process MED EUWI/WFD (WFD joint process) have been examples that have designed programmes focused on water, to facilitate coordination between projects, make a more efficient use of funding, and improve cooperation to better implement projects.

The UfM relaunched in 2008 as mentioned, (bringing together 43 countries plus the Arab League, the EC and Libya as observer) during the Euro-Mediterranean Ministerial Conference on Water (EMMCW), held in Jordan in December of that year, marked the beginning to create a long-term strategy for water in the region. Countries aimed at adopting it during the first semester of 2010, under the Spanish Presidency of the Council of the EU. As established in the declaration of Jordan, it was important to face problems caused by climate change and environmental needs, using integrated approaches considering all types of water, while ensuring water quality and avoiding its further deterioration or finding a balance between required water quantity and its availability (shortage). The Strategy included objectives that could be measured, with a view to achieve economic growth, social prosperity, access to water and environmental protection among others, as well as to develop technological tools in this field.

Following the establishment of technical groups, supported by the countries of the region, meetings and participative processes on social groups were held between July 2009 and March 2010. It was then when the first draft of the Strategy for Water in the Mediterranean (SWM) was developed. It would have meant a starting point and a basis for funding coordinated actions and optimise water projects in the region with common objectives and criteria focused on governance, sanitation, demand management and extreme events mitigation. However, the conflicts in the Middle East and the associated political deadlock, directly affected relations between countries, in particular between Israel and the Arab League. Therefore, the IV Euro-Mediterranean Ministerial Conference which took place on 13 April 2010 in Barcelona ended without an agreement, despite the widespread support for the content of the SWM. The opposition by Israel and Turkey to two references of political nature (occupied territories and the UN Convention on the Non-Navigational Uses of International Watercourses 1997) triggered the disagreement. In addition, in January 2011, the Secretary-General of the UfM[5], the Jordanian Ahmad Masa'deh resigned, referring to change of conditions under which his position

[5] http://ufmsecretariat.org

was accepted and the lack of economic resources. The Deputy Secretaries of the Secretariat with their different portfolios, including the one on Environment and Water led by the Palestinian Authority, continue with the work (Francis Mateo 2011).

The lack of political support, the consequential stop of technical works, the scarce economic resources set by the EU and the lack of commitment by member countries of the UfM, have meant that many of the international initiatives on waters have not been implemented.

Financial instruments and resources

There have been different economic instruments such as MEDA (Mesures d'accompagnement) programme -*Financial Instrument of the Euro-Mediterranean Partnership* (MEDA) funds (€ 12000 million for the period 1995–2007) and the Interregional cooperation across Europe, Program (INTERREG) programmes which have financed water and environmental actions. From 2007, the MEDA instrument was transformed into the ENPI, with a budget of € 11.1 billion for Eastern Europe, Caucasus and Mediterranean (Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestinian Authority, Syria and Tunisia) (Europe External Policy Advisors 2011). However, the percentage of funds allocated specifically to actions related to water is reduced and difficult to quantify as the funds are used for national or regional plans covering different sectors and not only the environmental one.

Also NGOs, agencies, networks and regional entities have played a key role in promoting integrated water resources management in the Mediterranean area, providing efforts and resources, synergies between projects and initiatives as well as capacity building. These entities have developed projects and organised conferences to exchange experiences, improve water management, catalyse investments to launch research activities and strengthen the cooperation between countries. In many cases, there has been institutional and financial support from the United Nations Environment Programme - Mediterranean Action Plan (UNEP/MAP), UNESCO, the World Bank and the Global Environmental Fund (GEF) among others.

Despite this, efforts and initiatives of administrations and social networks have often been developed in a disaggregated way and even overlapped. There was no common framework establishing rules and common criteria for initiatives and projects focusing on the matter. This would have allowed to launch action plans with clear objectives and concrete help to focus investments and establish targets with time frames. The SWM could have played this role, and may acquire it in the near future[6], taking into account the gradual rapprochement of the Arab countries.

Current subjects

Popular revolts in the Maghreb region and in the Middle East occurred this year 2011 have been marked by poverty, social inequality, opposition to totalitarian regimes and a growing desire for individual freedoms and greater openness to the outside, where the new technologies and exchange of information have been key elements. The riots started in Tunisia and spread to Egypt, Yemen, Jordan, Syria, Saudi Arabia, Algeria, Morocco and Bahrain, and featured the fall of several presidents. Although western countries have focused the discussion on the control of other resources such as oil or gas, in the near future the control over the different economic sectors will be important, and water will remain a key element in the political agenda.

In many cases, lack of commodities or increase prices started the riots. For example, in the case of Morocco, and to appease the protests, the government announced greater support and subsidies for products such as sugar, oil and wheat, and hydrocarbons, as well as buying tons of grain to avoid shortages in the markets using the existing Compensation Fund, which for this year was € 1500 million. The Fund aims mainly to prevent rising prices of staples affect consumers (Cembrero 2011).

Possible transformations resulting from the riots can be numerous, including changes in governments, greater democracy and economic openness to international markets and legislative and political reforms. These social, political and economic changes at medium to long -term can significantly alter the burden of leading sectors such as tourism, industry or agriculture. At this stage, the self-sufficiency in food production and the desire to participate in international markets might enter into conflict.

On the other hand, the possible opening of the economies of the countries could lead to greater collaboration between countries and to the establishment of agreements for the joint use and protection of natural resources and water bodies that would ensure both agricultural development in certain regions, supplying populations, giving responsibilities and rights to the parties in-

[6] By the time this thesis was completed two major milestones occurred in 2015: the endorsement of the Water Strategy under the Western Mediterranean Forum, and the approval of the Regional NGO Master Plan for Sustainable Development in the Jordan Valley.

volved, and supporting new actions within the framework of the UfM and its SWM.

In all these changes, water will continue to be a limiting factor for agriculture or urban and industrial development, so it will play an important role, and its good management and the measures to ensure its rational use and long-term protection will be essential to promote a sustainable development in Mediterranean countries.

3.3.7. Conclusions

The mild Mediterranean climate has favoured over the centuries the settlement and growth of civilizations. Currently, population, tourism, urban and industrial pressures on the coastline are causing severe environmental impacts. Water is a powerful driver for development in the Mediterranean region and supports important economic activities such as agriculture, industry or tourism. The main problems linked to it include its scarcity, irregular distribution, the high point source and diffuse pollution, conflicts between sectors, regions and countries, and overexploitation of aquifers, which also produces marine intrusion in coastal areas. These problems are aggravated by droughts, floods, and climate change, increasing social and management problems. There is a clear difference in terms of economic development, institutional frameworks and the economic importance of agriculture between the North and the South and East of the region.

Water authorities, who in many cases manage water at the catchment scale, have achieved progressively greater control and regulation of resources through infrastructures. However, there is a need of a more rigorous application of existing legislation and economic tools to bear a greater share of the cost of infrastructure development and maintenance, as well as to promote awareness on rational water use and its intrinsic value. Progress has also been made, although insufficiently, on sanitation aspects and access to drinking water or the treatment of waste water. The following steps are tending towards a demand management approach, reducing losses in the systems and raising awareness. The modernization of irrigation infrastructure and techniques, and the use of non-conventional resources and prioritization of uses, fostering socio-economic activities in the most optimal areas adapted to each, will therefore be part of the future of the Mediterranean countries. Without proper water management, and without minimising socio-economic and environmental impacts of water scarcity and droughts, the exchange of agricultural products and sustainable development in the region will be compromised.

Technical coordination is still key between North and South and East to exchange knowledge on the existing positive experiences and to analyse achievements and shortcomings in the implementation of the WFD. Moreover, the technical work, as far as possible, shall be independent from political conflicts that may arise for example in the Middle East peace process, and between Israel and the Arab League.

Hydraulic administrations in the region should be able to enforce existing environmental and water legislation, and monitor both pesticide applications, as well as point-source and diffuse pollution of water bodies to avoid high environmental costs in the long-term. In these processes, decentralization and participatory processes should be strengthened. Moreover, in some countries where the legal framework is weaker, its development and institutional strengthening will be relevant aspects, as well as close collaboration with other sectors and policies (e.g. related to climate change and regional development).

Countries need to promote the conservation of agricultural activities wherever these are more beneficial for their economic, social and environmental effects, and to preserve and create jobs in marginal rural areas to avoid exoduses towards urban areas and agglomerations, where growing population will require further minimum services, food, energy and water. Without the application of good agricultural practices, environmental and social costs of agriculture will counteract its potential economic and social benefits. Agrifood policies should also be developed and coordinated closely with other sectors and activities such as industry, energy, water management, land development, ecosystem services and biodiversity.

The commonly called non-conventional resources, such as water desalination and re-use of waste water use have increased in recent years. Moreover, it is expected that larger volumes of water will be produced from these techniques. The main obstacles, such as environmental externalities, the costs of production, or the high energy consumption are being tackled by new technologies and the use of renewable energies such as solar.

Investment and economic regional initiatives from networks, administrations and social groups in the region have been remarkable, although often low in comparison with other sectors. However, they have been developed in an unbundled way, often with overlaps and without a common objectives.

There have been important close-ups of the EU to the non-EU Mediterranean countries by interests of economic cooperation and security policy and attempts to transfer policies and environmental protection criteria. Ecological aspects and specifically those relating to water have not always been a priority despite their importance to the economy and food production. Yet, these are in part reflected in the MDGs and the ENP, and especially in the Horizon 2020 and the SWM of the UfM. The strategy could have represented the common thread with approved rules and criteria to manage and protect water at the medium and long-term basis with temporary specific milestones. Its importance lies in the fact that without an appropriate approach in the management of water resources countries will not be able to achieve certain regional objectives such as economic growth, social prosperity, equitable access to water use, efficiency, and environmental protection.

The riots experienced in southern countries of the Mediterranean basin and in the Middle East will affect government structures and could easily translate into legislative and economic reforms. In these future changes, water as an essential factor for economic development as well as its management and protection, could have a significant role in the political agenda of the region.

3.4. Drought Management Plans in the European Union. The Case of Spain

This section reproduces the article "Drought Management Plans in the European Union. The Case of Spain" (Estrela Monreal and Vargas Amelin 2012) which provides a specific analysis on droughts, due to the expected increase in intensity and frequency of drought episodes due to climate change. The article addresses policy instruments, economic and environmental aspects related to droughts. While there is no specific EU Directive to approach drought episodes, an important legislative process was carried out by the EC between 2007 and 2012, which included a specific communication, follow-up reports and studies at the EU and national levels, and an assessment of drought effects in achieving environmental protection objectives. The article, considers the specific example of DMPs in Spain and their main repercussions for water management.[7]

3.4.1. Abstract

Water is a strategic resource for the economic, social and environmental development. However, water scarcity and droughts are current challenges to this growth, as it is reflected in EU water policies, and in national and regional growing initiatives. In addition, these water related issues could worsen by climate change effects, adding pressure to already water stressed areas. This paper presents a general overview of drought management in the EU, reviews scientific and technical advances, the status of implementation of policy tools and focuses on drought management plans. It analyses the specific case of Spain, a country characterised by presenting a high irregularity in temporal and spatial distribution of water resources and numerous areas affected by water scarcity and droughts. Details are presented on the National Drought Indicator System and drought management plans approved in 2007 in Spain, which represent strategic tools with positive results in drought warning and impact mitigation respectively.

[7] Acknowledgements: The authors wish to thank the Ministry of Environment, and Rural and Marine Affairs of Spain for providing the opportunity to take part in different national and international projects related to droughts. In addition, they thank Vicente Ramírez Perea for his technical assistance in data analysis and map development.

3.4.2. Introduction

Drought is a natural hazard that results from a deficiency of precipitation from expected or normal rates, which can translate into insufficient amounts to meet the water demands of human activities and the environment. Although by itself is not a disaster, whether it becomes one depends on its impacts on society and environment (Buchanan-Smith and Wilhite 2005).

The impacts produced by droughts are numerous. These phenomena can impede populations receive a minimum water supply, affect crop yields and environmental ecosystems or increase pressures among users, among other problems. They can be exacerbated when occurring in regions already presenting low water resources levels, with imbalances between the available resources and the water demands (Estrela et al. 2001). In addition, it is expected that climate change will produce negative direct impacts on the available water resources in the most vulnerable EU regions (IPCC 2007b).

There are relevant EU policy tools such as the WFD or a specific Communication on water scarcity and droughts titled *Addressing the challenge of water scarcity and droughts in the European Union* (EC 2007a). In addition, a policy review on water scarcity and droughts was carried out to be integrated into the *A Blueprint to Safeguard Europe's Water Resources* (EC 2012a)—an EU policy response to recent water challenges, related to the EU 2020 Strategy and the Resources Efficiency Roadmap.

The WFD establishes a legislative framework for Community action in the field of water policy, introducing a new perspective from a modern view of water policy to all MS of the EU and aiming at improving and protecting the status of water bodies along Europe, with specific environmental objectives for 2015. The WFD also provides general criteria to consider drought impacts in the status of water bodies.

The EC communication responds how to address water scarcity and drought issues and has triggered different technical and political initiatives to mitigate their impacts. This communication highlights that water saving must become the priority, lists possible measures to cope with water scarcity and droughts, and recommends shifting from a risk/emergency to a planned drought management approach, shift that has become evident in other areas such as the United States (Wilhite, Hayes, Knutson, and K. H. Smith 2000). The importance of public participation in the decision making process for an adequate water scarcity and drought management has been stressed, and DMPs have been identified as useful tools to achieve this objective in the EU.

Spain is an EU country characterised by presenting a high irregularity in temporal and spatial distribution of water resources, and numerous areas already affected by water scarcity and frequent droughts (MMA 2000). The gained experience through policies implementation, the new applied tools and technologies as DMPs, and the implication of the users and other interested parties in Spain, are allowing to better predict and manage these situations by applying agreed criteria to minimize the long-term socio-economic and environmental impacts produced by droughts (MMA 2008).

The objective of this work is to revise the scientific and technical advances and the status of implementation of the recent policies and actions on drought management carried out by the MS, focusing on the development of DMPs and analysing the case of Spain, where drought management policies have shifted from risk/management actions to a planned approach in the last years. An innovative aspect to be highlighted is the link between the national drought indicator system and the actions to be taken in the DMPs developed for all the Spanish river basins as well as the experience gained during their application for the severe 2004–2008 drought.

3.4.3. Water Scarcity and Droughts in the European Union

Problem Assessment

Water scarcity and droughts, wrongly used interchangeably, are different concepts linked to permanent and temporary situations respectively. Water scarcity is defined as a situation where insufficient water resources are available to satisfy long-term average requirements (EC 2007a). At least 11 % of the population and 17 % of the European territories are affected by water scarcity (EC 2007b). Cyprus, Belgium, Spain, Former Yugoslav Republic of Macedonia, Malta and Italy show the lowest water availability when comparing their Water Exploitation Index (WEI) (EEA 2005). This index is obtained as the percentage of mean annual total demand for freshwater with respect to the long-term mean annual freshwater resources and shows, in principle, to which extent the total water demand puts pressure on water resources (fig. 3.1). However, it must be taken into account that this index has much more sense when is represented at the river basin scale especially in those countries where there is an irregular spatial distribution of resources and demands. Values of this index corresponding to large European river basins taken from EEA (2005) are shown in fig. 3.2.

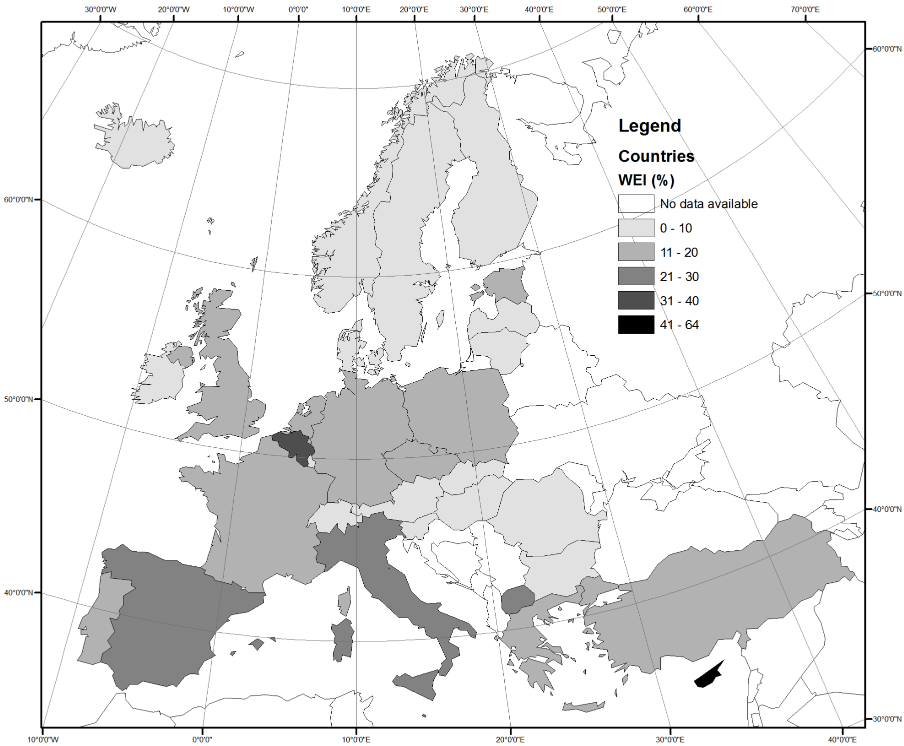

Figure 3.1.: Water exploitation index in the European Union.
Elaborated with data taken from EEA web page.

Droughts, on the other hand, represent relevant temporary decrease of the average water availability and even if it is a concept apparently easy to interpret, the absence of a precise and universally accepted definition of drought adds to the confusion as to whether a drought exists and, if it does, its degree of severity (Buchanan-Smith and Wilhite 2005). According to the EC droughts refer to important deviations from the average levels of natural water availability and are considered natural phenomena (EC 2007b). Drought is thus a climatic cyclic phenomenon, it is difficult to predict and can produce severe socio-economic and environmental impacts, interfering with urban supply, impacting other water uses and affecting vulnerable aquatic ecosystems. However, the duration and related impacts of droughts can greatly

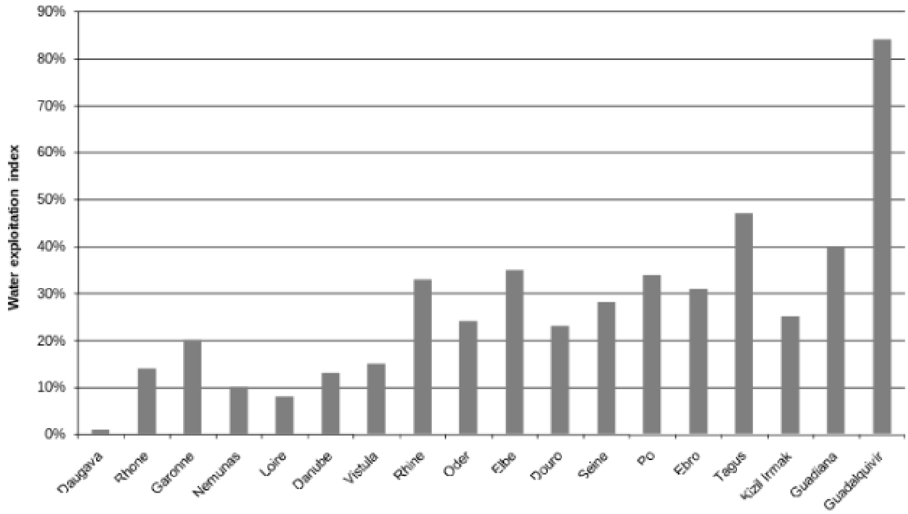

Figure 3.2.: Water exploitation index in large European river basins for the year 2000. Elaborated with data taken from publication by EEA (2005).

vary from region to region and among countries. While in countries lacking water storage infrastructures, directly dependant on rainfall to supply water demands, a decrease in rainfall during some months or weeks can become a drought, in others, droughts can extend for years producing major impacts.

Drought episodes have been occurring repetitively in Europe for the past centuries. Nowadays, these episodes might not be as dramatic as in the past when a strong dependency on localised agriculture translated into devastating famines. During the Middle Ages, Western Europe suffered famines due to harvest failures produced by drought episodes, which in some occasions counted with millions of deaths (UNDP 1994). More recently, and during the past 30 years, drought events have regularly occurred in the EU. The duration, affected population and area, greatly vary throughout this period, but severe events have occurred on annual basis affecting more than 800 000 km^2 of the EU territory (37 %) and 100 million inhabitants (20 %) in 1989, 1990, 1991 and 2003 (EC 2007b).

Furthermore, water scarcity and droughts could worsen by climate change effects increasing the area and population living under water stress. Changes in precipitation and temperature lead to changes in runoff and water availability, affecting water related ecosystems, water requirements for crops, as well as populations' needs. Runoff is projected with high confidence to decrease by 10 to 30 % over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration. There is also high confidence that many semi-arid areas, as the Mediterranean Basin, will suffer a decrease in water resources due to climate change (IPCC 2007b). The EEA (2005) states in *The European environment* that temperatures in Europe could rise by 2 °C to 6 °C this century and that the expected impacts include water shortages, more extreme weather, marine species migrations and economic losses.

Scientific and Technical Advances

Important efforts both in the scientific and technical field in relation with droughts have been or are being carried out by different researchers in Europe. Several research projects funded by the MS show significant and useful results to better manage water scarcity and droughts such as Assessment of Regional Impact of Droughts in Europe (ARIDE), Dryness and Turning into a desert in the Mediterranean basin project (SEDEMED), West African Monsoon Modeling and Evaluation project (WAMME), Proactive Management of Water Systems to face drought and water scarcity in islands and coastal areas of the Mediterranean (PRODIM), Drought Management Guidelines and Examples of Application (MEDROPLAN), Water and Global Change project (WATCH), Mediterranean Intermittent River Management Project (MIRAGE), Exercise to Assess Research Needs and Policy Choices in Areas of Drought project (XEROCHORE) and others. These projects increase the knowledge on droughts in different research areas and regions providing additional tools and experiences for policy makers and water managers. Risk management approaches and DMPs are now being developed in Europe. Thus scientific approaches to risk evaluation including characterization of drought episodes, development of risk indicators, identification, selection and prioritising of measures to alleviate the effects of droughts or analysis of the role of economic instruments for risk mitigation are needed (Iglesias, Cancelliere, et al. 2009). Some relevant methodologies and findings of selected projects are described below.

The severity of droughts is represented by drought indexes, which have been developed during the last century to detect, monitor and assess drought events. Different indexes have been proposed by various researchers in the fields of meteorology, hydrology, agriculture or water exploitation systems. Lloyd-Hughes and Saunders (2002) present a high spatial resolution and multi-temporal climatology for studying the incidence of drought in Europe during the 20th century, based on monthly values of the well known Standard Precipitation Index (SPI) calculated on a 0.5° grid across the whole Europe for the period 1901–99. Álvarez and Estrela (2003) develop a methodology for regionalisation and identification of droughts at a pan European scale in the framework of the ARIDE project, delimiting regions with a homogeneous climatic behaviour and identifying drought events for the 20th century from monthly rainfall data series. Bordi, Fraedrich, and Sutera (2009) provide an analysis of trends in drought and wetness for the whole Europe using monthly precipitation data and applying the SPI. Other new drought indexes, as the Reconnaissance Drought Index (RDI) based on the precipitation to potential evapotranspiration ratio (Tsakiris, Pangalou, and Vangelis 2006; Vangelis, Spiliotis, and Tsakiris 2010) have been applied in Europe. This index was initially proposed in the framework of MEDROPLAN project and was improved during the implementation of PRODIM project. Although in some cases RDI behaves in a similar way as the SPI, it is more sensitive and suitable in cases of a changing environment.

Drought monitoring and forecasting are essential tools for implementing appropriate mitigation measures to reduce negative impacts of droughts. SPI has been extensively used for describing and comparing droughts among different time periods and regions with different climatic conditions, however, limited efforts have been made to analyse the role of the SPI or similar indexes for drought forecasting. In addition, Cancelliere, Mauro, Bonaccorso, and Rossi (2006) provide, under the research activities of MEDROPLAN project, two methodologies for the seasonal forecasting of SPI.

Information on regional drought characteristics can be very helpful for adequate water resource management. Hisdal and Tallaksen (2003) introduce a method to calculate the probability of a specific area to be affected by a drought of a given severity and thereby return periods could be assigned to historical drought events. Tallaksen, Hisdal, and Lanen (2009) examine drought propagation at the catchment scale using spatially aggregated drought characteristics as part of the WATCH project, illustrating the importance of catchment processes in modifying the drought signal in both time and space in the Pang catchment, United Kingdom. Vasiliades, Loukas, and Liberis (2010) assess hydrological droughts by using a water balance derived drought index within an operational context at sub-watershed scale at the Pinios river basin in Greece.

A key aspect of drought management plans is to establish an adequate link between basin drought status and the management actions to be taken. Garrote, Martin-Carrasco, Flores-Montoya, and Iglesias (2006) develop a methodology to link operational drought indicators to policy management actions in regulated water supply systems in the Tagus River Basin DMP in Spain. Basin status is described by a drought indicator system that includes variables like precipitation, streamflow, reservoir inflow, reservoir storage or groundwater piezometric levels and the basin policy consists on a catalogue of management actions, ranging from enforcing demand reduction strategies to establishing priority of uses to allocate scarce water or approving emergency works. Rossi, Cancelliere, and Giuliano (2005) set a conceptual framework for a proactive approach to drought mitigation, by proposing a methodology to assess alternatives that takes into account economic, environmental, and social impacts of different measures. Preferred alternatives are selected based both on the scores of each alternative with respect to the selected criteria and on the capability to reach the consensus among stakeholders. Andreu Álvarez and Solera Solera (2006) propose, in the framework of the WAMME and SEDEMED projects, a methodology for the analysis of water resources systems which aim is the design and planning of operational measures that would avoid or mitigate the negative effects of droughts in the Júcar River Basin District in Spain.

As a relevant policy science action, one of the main objectives of the MEDROPLAN research project must be highlighted, which consists on developing guidelines for drought preparedness plans and setting up a network for drought preparedness in Mediterranean countries. The Drought Management Guidelines (DMG) published by MEDROPLAN (Ameziane et al. 2007) provide Mediterranean countries with a framework to prevent and/or minimize the impacts of droughts, promoting a risk based preparedness and mitigation approach.

Research addressing water scarcity and droughts is covered by the XEROCHORE Support Action of the 7th Framework Programme (FP) that aims at establishing the state of the art of drought related policies and identify research gaps on various drought aspects (climate, hydrology, impacts, management, and policy) and steps to take in order to fill them. Networking is developed with close links to on-going initiatives, e.g. the European Drought Centre and relevant research projects which include drought components such as the WATCH, Climate Change and impact research: the Mediterranean environment (CIRCE) and MIRAGE projects (Quevauviller 2011).

Political and Technical Responses

Due to the obvious and repetitive related problems, the Council of Ministers of the EU launched a policy request to assess the gravity of water scarcity and droughts in Europe in March 2006. The EC responded by an impact assessment developed through MS and the EEA feedback. Furthermore, a specific working group was created in 2007 within the Common Implementation Strategy of the WFD (CIS) of the WFD. This working group which has been led by Italy, Spain, and France (fig. 3.3), assessed technical needs and contributed with technical documents to find common mitigating measures.

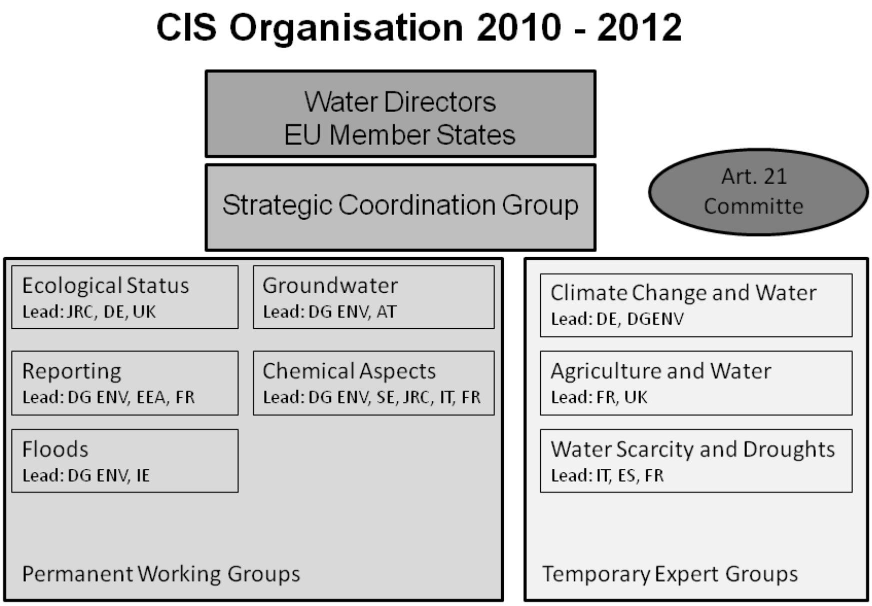

Figure 3.3.: Scheme of the Common Implementation Strategy of the Water Framework Directive, for the period 2010–2012.

After the drafting and discussion process within stakeholder groups, the Communication of the EC (2007b) to the Council and European Parliament was issued on July 2007. As previously commented, this communication sets a series of recommendations and establishes the need for a European Strategy based on national and EU measures. It recognises the importance of both problems, and the need for undertaking European actions to use and reform, whenever necessary, the existing tools: CAP, WFD, financing mechanisms and emergency assistance. The communication underlines that water saving must become the priority, and that all possibilities to improve water efficiency must be explored prior to increasing supply. In addition, it states that policy-making should be based on a clear water uses hierarchy established through participative approaches. The communication lists possible measures to cope with water scarcity and droughts, recommends the development of DMPs, supports establishing a European drought strategy, considers using European funds when suffering prolonged droughts, and proposes establishing a European drought observatory.

The EC (2011c) in the third Follow up Report to the Communication on water scarcity and droughts in the EU gives further details on the extent of water scarcity and droughts in the EU and the measures which are being put in place to address both situations. According to this report most MS have not yet implemented national legislation in terms of water efficiency standards in buildings or water using devices, though some aspects are included in the RBMPs. Also it is highlighted that many MS face non-authorised water abstractions which affect water availability and that a better control is required. On the other hand, activities to integrate water scarcity and droughts into sector policies have been undertaken by several MS, in particular efforts to reduce water consumption and adaptation to climate change. Most MS (except United Kingdom, Spain and Belgium) do not envisage setting up water markets to address water scarcity. Other relevant point highlighted in the report is that the prototype of the European Drought Observatory has been developed providing for the continuous monitoring of drought indicators across Europe. In 2010, the first tests for meteorological drought forecasting were performed with national, regional and local services including the Drought Management Centre for South East Europe and the Observatory for Sustainability in Spain.

Although DMP and risk management approaches have been applied in other regions of the world since years ago, as in United States of America (Martin 1991; Pirie, de Loë, and Kreutzwiser 2004) or Australia and South Africa (O'Meagher, du Pisani, and White 1998), they have not been implemented in EU countries until very recent dates. MS participating in the water scarcity and droughts working group in collaboration with the EC elaborated in 2007 the technical report *Drought Management Plan Report, Including Agricultural, Drought Indicators and Climate Change Aspects* coordinated by Spain (WSDEN 2007). Its main objective is to serve as a useful tool to elaborate DMPs, supplementing RBMPs according to the WFD article 13.5, providing general criteria, structures, and recommended measures. This guidance document can help MS, and other countries, to mitigate and prevent drought effects by minimising socio-economic and environmental impacts. It provides technical recommendations to establish useful indicator systems to declare drought statuses. In addition, it establishes measure types,—revision or strategic, operative, organisational, follow-up and recovery-, in accordance with the indicators status, consistent with RBMPs. Last, it relates direct issues clearly affected by droughts (agriculture and groundwater) and considers possible consequences of climate change.

Recent works within the CIS of the WFD are focusing on further developing water scarcity and droughts indicators that could be commonly used by MS, and on a policy review and assessment of the EU related strategy to be integrated into the 'Blueprint to safeguard European Waters' (an EU policy response to recent water challenges, related to the EU 2020 Strategy and the Resources Efficiency Roadmap).

3.4.4. Droughts in the Water Framework Directive

Droughts are considered in different parts of the WFD, which has among its main purposes to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, which contributes to mitigate the effects of floods and droughts.

The directive is very demanding in the fulfilment of environmental objectives. However, the temporary deterioration of the status of water bodies shall not be in breach of the WFD requirements if this is the result of circumstances of natural cause or 'force majeure', as prolonged droughts, when some conditions are met. Also, the WFD establishes the possibility of supplementing RBMPs with detailed programmes and plans to deal with particular aspects of water management. In this case, DMPs can be considered as relevant additional tools to cope with the effects of prolonged droughts and ensure the WFD's implementation. As it is summarized in Estrela Monreal (2006):

a) droughts constitute an exemption from certain WFD requirements,

b) the declaration of a drought situation must be defined in the RBMPs, adopting adequate indicators,

c) measures to be adopted in drought situation must be incorporated in the PoM of the RBMPs and

d) the plan, once updated, will summarize the effects of droughts and applied measures.

The WFD provides general criteria to consider drought impacts in the status of water bodies. However, MS are facing some challenges in the application of these criteria. For instance, there is no clear detailed common definition of prolonged drought, just a general common understanding, and although there is room for using supplementary tools to the RBMPs, such as DMPs, the relationship between both tools is still unclear and to be defined. Furthermore, climate change effects will very likely affect drought and management approaches, increasing the difficulty of MS for supplying basic demands while protecting water quality and ecosystems.

3.4.5. Water Resources Management in Spain

Spain is characterised by presenting an irregular temporal and spatial distribution of water resources and a fragile balance between water resources and demands. Although national mean values reflect enough available resources for all uses, a regional approach shows water scarce areas aggravated by drought episodes.

Spain presents an average precipitation of approximately 670 mm/year , varying from 2200 mm in northern areas to 120 mm in south-eastern ones, has a population of 44.7 million inhabitants (year 2006), which mainly concentrates in urban (cities of Madrid, Barcelona, Valencia, Sevilla, ...) and coastal areas. The coastal economic and tourist development (mainly in the Mediterranean side), coupled with highly productive agricultural areas, translates into a higher demand of water in areas where this resource is scarce, and often during lower availability periods, e.g. summer time. Approximate distributions of water demand per sectors are 68 % for irrigation, 13 % for urban uses, 14 % for refrigeration and 5 % for industrial purposes (MMA 2000).

There is a clear unbalance of water availability in Spain between northern, central and south-eastern areas (MMA 2000). The high variability, uneven distribution of water and its scarcity throughout the territory, more persistent in the Mediterranean regions, has lead to an intensive control for water to supply the different water demands, especially those coming from the agricultural sector, through hydraulic infrastructures, such as dams or irrigation channels. In fact, Spain is the fifth country in the world with the highest number of large dams, approximately 1200, after China, the United States of America (USA), India and Japan. The capacity of these reservoirs is 56 000 hm^3 (INE 2008b).

Water balance issues can worsen by climate change impacts. These impacts were assessed in 2005 by the Spanish Ministry of Environment in the report *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005). Its main aim was to review and compile the state of the art on climate change impacts and on the preparation of the basis for future climate change adaptation initiatives in Spain. The main conclusions of the report related to water resources were:

a) a general decrease of water resources will occur,

b) reductions until 50 % in arid and semiarid regions could arise,

c) seasonal patterns of rainfalls and temperatures may even have greater effect on water resources than mean values,

d) there is a need to improve and extend the monitoring networks and investigate hydrological processes and simulation models and take into consideration climate change effects in water policies and regulations.

Historically, Spain has suffered important dry periods that have caused severe impacts, and have made it difficult to satisfy basic water needs, such as public water supply and irrigation. Water scarcity and the frequent drought episodes in Spain explain, in part, the ancient tradition of building hydraulic works. The spatial and time variability of water resources has made necessary the construction of numerous hydraulic works, to supply water demands. Furthermore, these demands, mainly coming from irrigation, are mostly concentrated in water scarce areas and especially during seasons when precipitations are lower and evapotranspiration is greater (e.g. summer periods).

The Mediterranean coast and south-eastern part of the country are the most affected areas by water scarcity and droughts with consequent socio-economic and environmental impacts. These problems in turn, have created social and political conflicts, especially in areas with high population pressures. For instance, water demands in the Segura river basin district are greater than available water resources and a 300 km long water transfer from Tajo river basin district was constructed and has been operating since the 80's of the past century.

Most of the natural water resources are already regulated with the constructed large dams and, therefore, a significant increase of conventional water resources in the future is not foreseen. In the most vulnerable areas to water scarcity, non-conventional water resources, such as the treated waste water or desalination of sea and brackish waters, arise as supplementary or alternative sources. These resources have significantly increased in the last years, especially in the Mediterranean basins.

Waste water reuse may provoke quality and health concerns. In consequence, in December of 2007, the use of treated waste water in Spain was regulated through the Water Reuse Regulation (2007). This decree determines the necessary requirements to conduct activities in relation to the use of reclaimed waste water. It establishes the procedures to get the government licenses required by law, and includes the minimum quality criteria required for the use of reclaimed waste water for the different water uses. The obtained reused water volumes are alleviating pressures over natural systems and increasing the guaranty in the most water stressed areas.

Regarding seawater desalination, a process whereby sea and brackish waters are converted to freshwater, is also currently helping to meet water demands along the Spanish Mediterranean coast and on the Balearic and Canary Islands. Desalination can provide additional resources for regions suffering from drought, water shortages and related impacts if energy consumption and environmental impacts are thoroughly assessed (Estrela Monreal and Vargas Amelin 2008). Similarly to waste water reuse, the quality of the desalinated water for public purposes follows strict national regulations.

On the other side, Spain is rich in groundwater, traditionally exploited trough wells from ancient times by private owners, since groundwater was not considered public domain until the 1985 Water Act entered into force. Fortunately, major aquifers are located in regions where water shortages are greater, which allows coping, to some extent, with droughts effects by using groundwater. Unfortunately, and despite the strict abstraction control by RBAs in some aquifers, the intensive use has often produced over-exploitation and saline intrusion problems in coastal areas (MMA 2000).

3.4.6. Legal Framework for Drought Management in Spain

Drought management can be carried out by two main approaches:

a) as an emergency situation, a crisis situation, which can be restored with extraordinary water resources and measures and

b) as a current element of the general water planning and management, which means that a risk analysis must be carried out to assess its probability of occurrence and measures to be applied must be planned ahead.

As regarded by the UNDP (1994), while drought episodes might be regarded as unusual, they are not abnormal phenomena, and should be planned for in all countries. In Spain, as in the majority of EU countries (WSDEN 2007), droughts have been traditionally managed according to the first approach, although since the entry into force of the National Hydrologic Plan Act in 2001 both approaches have been used, and furthermore, the experiences show a shift to the planning approach.

The Water Act (2001) in art. 58, foresees during exceptional drought circumstances, adopting the adequate measures in the public water domain for overcoming these situations through a Royal Decree issued by the Government, agreed by the Council of Ministers, and heard by the RBAs. This approach has shifted towards a planning one in recent years. To minimise environmental, economic and social impacts caused by droughts in Spain, the National Hydrological Plan (2001) established the bases for planned drought management in Article 27. Drought management, which states in Section 1 that the Ministry of Environment, for RBAs will establish a national hydrological indicator system that will allow foreseeing these situations, and will serve as general reference for RBAs for the formal declaration of emergency situations and eventual drought and in Section 2 that RBAs will develop DMP for alert situations and eventual drought, including exploitation rules and measures.

3.4.7. National Drought Indicator System in Spain

The anticipation in the application of mitigation measures becomes an essential tool for the reduction of socio-economic and environmental impacts of droughts; that is why having completed indicator systems that allow calling an early alert of these extreme events and activate in advance the programme of measures established for these emergency situation is crucial. These systems must be considered as key elements in drought events management and in the strategic planning of the actions to be taken. In recent years, regional hydro climatic indicators, which are not necessarily indicative of the impacts of droughts on individual water storage systems, are being replaced by system specific indicators in the context of supply reliability, or likelihood of system failure (Westphal, Laramie, Borgatti, and Stoops 2007).

The Spanish national drought indicator system has been developed in the last years as a response to the article 27 requirements of the National Hydrological Plan Act. This system is formed by basic variables selected in different points throughout the river basins. These variables describe the basin drought status and include: reservoir storages, groundwater piezometric levels, streamflows, reservoir inflows and precipitations. Variables in selected control points are weighted in order to obtain an integrated indicator representative of the hydrological status in each river basin. This indicator is compared to historical series representative of deficits in the basins to ensure its applicability and degree of confidence in the context of supply reliability. The standardised values of the indicators (ranging from 0 to 1) define the basin drought status: normal, pre-alert, alert and emergency. The normal situation is associated with a better hydrological situation than the corresponding to mean values; the rest of levels are established to differentiate situations below the mean one, and are useful to launch the different measures detailed in the drought management plans to mitigate the effects of droughts.

All the data produced by the RBAs are sent periodically to the Directorate General for Water of the Ministry of Environment, and Rural and Marine Affairs, where a common database is kept, and monthly public reports with maps, graphs and statistics are shown in the Ministry's web page. Figure 3.4 has been obtained using data coming from National Indicator System of the Ministry web page (http://www.marm.es).

The evolution of the indicator representative of drought status at Júcar river basin is shown in fig. 3.5 for the period 2000–2010. This Mediterranean river basin has a drainage area of 21 600 km^2, and it is located in the Eastern area of Spain where the negative effects of water scarcity and droughts are more significant. The values of the drought indicator clearly define the drought period occurred from 2004 to 2008.

3.4.8. Drought Management Plans in Spain

The National Hydrological Plan Act established in 2001 that DMPs had to be elaborated by the RBAs. These plans have already been developed for all the Spanish River Basin Districts managed by the State. They were approved by Ministerial Order in March 2007 and are considered, according to the

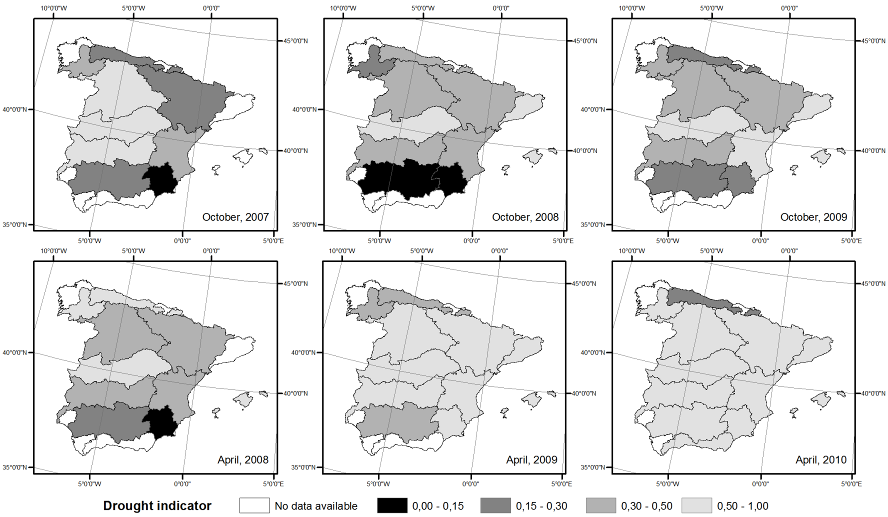

Figure 3.4.: Maps showing the drought status of Spanish river basin districts in October and April of 2007 to 2009.
Legend status: emergency (from 0.00 to 0.15), alert (from 0.15 to 0.30), pre-alert (from 0.30 to 0.50) and normal (from 0.50 to 1.00).

Spanish Hydrological Planning Regulation (2007), as a specific plan of the RBMP (Estrela Monreal 2006).

DMPs have proved to be useful and efficient tools to manage water resources under drought episodes. The specific objectives of the DMP are as follows:

a) Guarantee water availability required to sustain population life and health.

b) Avoid or minimize negative drought effects on the status of water bodies, especially on the environmental water flows, avoiding in any case, any permanent negative effects.

c) Minimize negative effects on public water supply and on economic activities, according to the prioritization of uses established by RBMPs.

To achieve these objectives, DMPs identify the most adequate mitigation measures, adapted to the different established drought thresholds and phases. During a normal phase, the measures derive from the regular management practices. As the drought progresses and a more critical situation takes place,

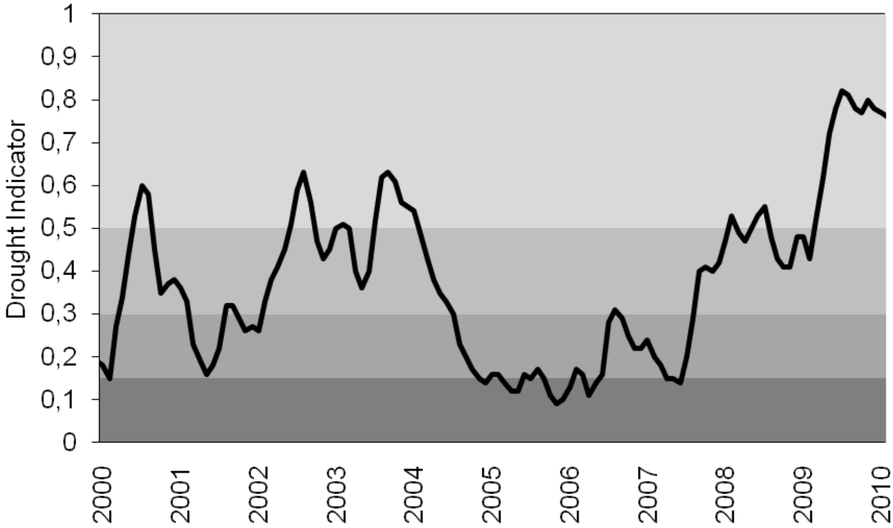

Figure 3.5.: Evolution of drought indicator at Júcar river basin for 2000–2010 period. Elaborated with data taken from Drought Indicator System of Júcar River Basin Authority.

measures go from control and information, to conservation and restriction types, prioritising uses.

The main contents of plans are: drought diagnosis, program of measures and management and follow-up system.

The drought diagnosis includes the identification and characterization of territorial and environmental elements. This part of the DMP analyses and characterizes historical droughts as well as learnt lessons through those episodes, taking into account local and regional acquired knowledge and technical experiences. It incorporates also one of the most relevant elements of the plans, which are the indicators, thresholds and drought phases definitions. A crucial and innovative aspect of DMPs is to establish an adequate link between basin drought status and actions to be taken.

Other key part of the DMP is the programme of measures, which defines the different types of measures that can be applied in each area of the basin, according to the drought status. This programme consists in a catalogue of actions, ranging for enforcing demand reduction strategies to establishing priority of users to allocate scarce water or approving emergency works (Garrote, Martin-Carrasco, Flores-Montoya, and Iglesias 2006). Their action methods and established measures must be applied once the interested parties have previously agreed them: social society, administration, scientific community, NGOs etc. The main mitigation measures included in the DMP can be grouped into different categories: structural measures (new pumping wells, new pipes, use of new desalination plants, etc.) and non-structural measures (changing the priority of the users, water savings and demand reductions, increase in the use of groundwater, etc.). In Spain, the role of conjunctive use of surface and groundwater to mitigate the deficit has been very important, by pumping, in a controlled way, the reserves of aquifers during drought periods (MMA 2000).

Last, DMPs include a management and follow-up system that allows analysing the implementation of measures, using corrective measures in case the established objectives are not met. This part of the plan describes the methodology to develop follow-up reports, and analyses each drought period as it occurs.

DMPs have provided the bases for a more planned drought management in Spain, establishing drought phases and describing measures that should be progressively applied and the needed monitoring and follow-up processes. In the coming years, drought management plans should be an integral part of drought policy in the MS as well as in other regions of the world such as the United States of America (Wilhite, Hayes, Knutson, and K. H. Smith 2000). Ensuring transparent public participation processes, previous agreements among the interested parties, collaboration among the water administrations at the different scales, and the use of adaptive governance, integrating local and rural knowledge as well as active participation, will be essential elements to guarantee the successful application and follow-up of public contingency and management plans (Pirie, de Loë, and Kreutzwiser 2004; Nelson, Howden, and M. S. Smith 2008). This participative and holistic approach will reduce vulnerability of systems, and will increase the flexibility and adaptive capacity of administrations if reference conditions change and evolve, produced, for instance by climate change effects.

3.4.9. The 2004–2008 Drought in Spain

Traditionally, Spain has faced extremely severe droughts, as those occurred at the beginning of the 1980s, during the years 1994 and 1995 or the latest drought, corresponding to the 2004–2008 period. During the occurrence of this latter drought the DMP were approved in 2007 and they have contributed to avoid public supply restrictions.

During past droughts, emergency decrees were mainly issued to regulate performances to minimize drought impacts. They covered a group of emergency performances and measures, which included necessary works, test drilling or researches to be carried out, and addressed temporal land use (e.g. hydraulic works) or forced expropriation of goods and rights.

Since of the beginning of the last drought in 2004, several royal decrees have been developed every year, containing different measures and emergency works to mitigate negative effects on the irrigation sector, guarantee public water supply, or mobilize extraordinary resources (drought wells, desalination or water transfers). For example, Urgent Measures Drought (2006) included regulation fee exemptions or reduction of irrigation fares, depending on the water availability, construction of water supply points for extensive cattle farming and emergency hydraulic works for the improvement and modernization of irrigation systems.

In addition, during the 2004–2008 drought, innovative measures were also put into practice, which supposed considerable water savings in the agricultural sector, allowing to pass an extremely severe drought without applying any significant public water supply restriction (MMA 2008). This was possible though reductions of 50–60 % for irrigation practices in the most critical areas, and water use rights exchange. In this last case, farmers renounced to irrigate their lands during drought periods, receiving an economic compensation by RBAs or exchanged their allotted water use rights among them, which ensured economic efficiency. Analysis of environmental effects during the drought period has been a priority for drought management in River Basin Districts. Among different studies taken into account by RBAs, Boix et al. (2010) analysed the relationships between the biological community structure with the ongoing and preceding hydrological patterns during the drought and recovery periods, determining the effects of water abstraction on Mediterranean river communities.

Once drought management plans came into force, Urgent Measures Drought (2008) regulation was passed, which contained emergency measures regarding mainly fees' payment exemptions and extraordinary measures of land occupation. In addition, water use rights management was approved. The declaration of drought situation in the river basins affected was established in this decree—law (Urgent Measures Drought 2008) taking as a general reference the basin status of the National Drought Indicator System. Furthermore, the evolution of the drought's indicator was useful to put the necessary measures into practice when needed in accordance with the criteria established in the DMP. In the development of the DMP, public participation and the involvement of all interested parties (users, NGOs, administration, private sector, universities etc.) and the consideration of environmental requirements have been essential to minimize social conflicts caused by the lack of sufficient water resources.

3.4.10. Conclusions

The EU has been historically impacted by water scarcity and droughts. In recent years, important efforts, both in the scientific and technical field, have been carried out at the EU to address risk evaluation, characterization of drought episodes, development of risk indicators, identification, selection and prioritising of measures to alleviate effects and establishments of links between basin drought status and actions to be taken. In 2006, political and technical approaches were launched to assess impacts, make recommendations to MS and apply the most effective tools. One of the major results include a Communication issued in 2007 from the European Commission to the European Parliament and Council titled *Addressing the challenge of water scarcity and droughts in the European Union* on how to address water scarcity and drought issues, which has triggered different technical and political initiatives to mitigate their impacts.

Since 2007 until the third Follow up Report of the Communication of the European Commission in 2011, actions to integrate water scarcity and droughts into sector policies have been undertaken by several MS, in particular efforts to reduce water consumption and adaptation to climate change. The European Drought Observatory has been developed providing inputs for the continuous monitoring of drought indicators across Europe being the first tests for meteorological drought forecasting performed in 2010.

Within the EU, Spain is a country characterised by presenting a high variability and uneven water resource distribution, being the Mediterranean coast and South-East region the most affected areas by water scarcity and droughts with consequent socio-economic and environmental impacts. In the past, this situation led to high investments in hydraulic works and infrastructures.

Emergency actions have been traditionally applied in Spain in past drought situations, with a series of actions heading towards increasing water resources by developing hydraulic works, especially for groundwater abstractions. In the last years, Spanish policies, in accordance to the European legislation, have evolved from emergency actions against drought situations with a focus on crisis situation to a planning approach. This translated into designing a national drought indicator system to foresee these situations and elaborating drought management plans for the Spanish river basin districts.

An indicator system that allows foreseeing extreme situations, establishing levels or thresholds depending upon the degree of the drought, and consequently developing actions aiming to delay or impede critical situations has been developed. DMPs approved in March 2007 have contributed to alleviate the negative effects of the last drought occurred in Spain during the years 2004–2008, resulting in water savings, avoiding public water supply restrictions and improving aquatic ecosystem protection. These plans are considered as supplementary plans to the RBMPs and have proven to be valuable management tools.

3.5. Impacts of Climate Change on Water Resources in Spain

This section reproduces the article "Impacts of climate change on water resources in Spain" (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012) which assesses the expected impacts of climate change on water resources at the national level. It highlights availability and national specificities, hydrological variabilities and trends. The article covers studies on modelling hydrological effects of climate change, and addresses implications for policy actions. The text highlights natural variability, and the effects of using long and short data series, to show the existing degree of uncertainty in predictions and expected trends.[8]

3.5.1. Abstract

Impacts on water resources produced by climate change can be exacerbated when occurring in regions already presenting low water resources levels and frequent droughts, and subject to imbalances between water demands and available resources. Within Europe, according to existing climate change scenarios, water resources will be severely affected in Spain. However, the detection of those effects is not simple, because the natural variability of the water cycle and the effects of water abstractions on flow discharges complicate the establishment of clear trends. Therefore, there is a need to improve the assessment of climate change impacts by using hydrological simulation models. This paper reviews water resources and their variability in Spain, the recent modelling studies on hydrological effects of climate change, expected impacts on water resources, the implications in river basins and the current policy actions.

3.5.2. Introduction

Water is a strategic resource for socio-economic development and environmental protection, but water scarcity, insufficient water quality, floods and droughts are current challenges that could get worse due to climate change.

[8] Acknowledgements: The authors wish to thank the Spanish Ministry of Environment, and Rural and Marine Affairs and the Technical University of Valencia for the opportunities provided for taking part in different national and international projects related to climate change impacts.

Changes in precipitation and temperature lead to changes in water resources (IPCC 2007a), thus affecting all sectors involved.

Climate change will increase water stress in some regions of the world, decreasing runoff (mainly in the Mediterranean area, some parts of Europe, Central and Southern America, and Southern Africa). In other water-stressed areas, particularly in South and East Asia, climate change will increase runoff, though these increases may not be very beneficial because they tend to occur during the wet season and so the excess water may not be available during the dry season when it is most needed (Arnell 2004). The EEA (2010) states that the Mediterranean basin has experienced decreased precipitation and increased temperature over past decades, a trend projected to worsen. There is a need to assess uncertainty in climate change assessments due to the incomplete knowledge of, and insufficient data to identify, trends in the past.

A great number of studies and investigations on climate change effects for water resources have been published in different international reports and scientific journals. These studies tend to be mainly focused on Europe, North America and Australia. Most apply hydrological models driven by scenarios based on climate model simulations. Methodological advances in climate change impact studies have focused on exploring the effects of different ways of downscaling from the climate model scale to the catchment scale, the use of regional climate models to create scenarios, the ways of applying scenarios to observed climate data and the effect of hydrological model uncertainty on estimated climate change impacts. In general terms, these studies have shown that different methods of creating scenarios from the same source (a global-scale climate model) can lead to substantial differences in the estimated effect of climate change. Regions with decreasing runoff (by 10 to 30 %), and a rather strong agreement between models, include the Mediterranean, Southern Africa and western USA/northern Mexico (IPCC 2007a).

Climate and water systems are interconnected in very complex ways. For instance, climate change affects water quantity and quality, but water use is also affected by climate change. Water use, in particular irrigation, generally increases with temperature rise and decreases with precipitation rise. However, there is no clear evidence for a climate-related trend in water use in the past. This is due to the fact that water use is mainly driven by non-climatic factors and to the limited availability of water-use data and time series (IPCC 2007a).

The impacts produced by climate change can be exacerbated when occurring in regions that already present low water resources levels and frequent droughts, and, hence, imbalances between water demands and available resources. Within these regions in Europe, Spain is very vulnerable to possible climate changes due to the high spatial and temporal irregularity of water resources, the elevated degree of water use and linked socio-economic impacts, in addition to its location in an area projected to have temperature increases and precipitation decreases (EC 2009a). A large number of regional climate models highlight increases in temperature and decreases in rainfall that will lead to marked decreases in water resources. Studies on impact assessment have been developed in Spain since the mid-1990s and modelling tools are available to assess the effects of different climate change scenarios on water resources with a sufficient level of confidence. Additionally, climate change impact issues are being incorporated into the Spanish water legislation by making compulsory their consideration in RBMPs. This fact presents an opportunity to take into account climate change effects in water decision-making policies.

3.5.3. Water resources in Spain

Water scarcity, which means there is an imbalance between available water demand and existing demands, currently affects many European countries. At least 11 % of the population and 17 % of the European territories are affected by water scarcity (EC 2007a). The number of people living in river basins characterized by water shortages will increase, especially in the Iberian Peninsula, Italy and in relatively large parts of Central Europe (EEA 2010).

Spain, with a territory of 506 000 km^2, has a clear imbalance of water availability between the northern, central and south-eastern areas. The mean annual precipitation is approximately 670 mm/year, varying from 2200 mm/year in the North of the country to 120 mm/year in the South-East (fig. 3.6). The map in fig. 3.6 has been derived using 1 km $\times$ 1 km-resolution data estimated in MMA (2000) using the inverse squared-distance method with data from the nearly 9200 historical meteorological stations in Spain.

Similarly, mean annual runoff is approximately 220 mm/year and ranges from 0 mm/year to 100 mm/year in the south-eastern and central areas, to approximately 1000 mm/year in the northern areas (fig. 3.7). Runoff data were obtained from MMA (2000) by means of the Simulación Precipitación-Aportación -*Precipitation-Contribution Simulation model* (SIMPA) hydrological model described later.

Spain has a population of 47 million people (INE 2011), which is mainly concentrated in urban (the major cities Madrid, Barcelona, Valencia and Seville)

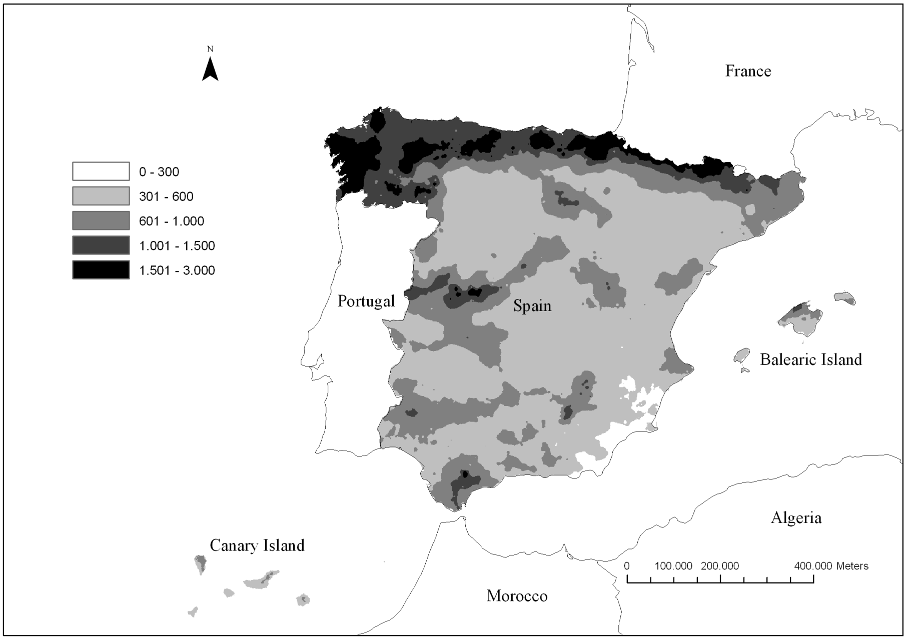

Figure 3.6.: Mean annual precipitation in Spain (mm).
Source: Prepared with data from MAGRAMA (2011).
Note: Canary Islands are represented out of the real location.

and coastal areas. The economic and tourist development (mainly in the Mediterranean area), coupled with highly productive agricultural areas, translate into a higher demand of water in areas where this resource is scarce. The approximate distribution of water demand per sector is 68 % for irrigation, 13 % for urban uses, 14 % for refrigeration and 5 % for industrial purposes (MMA 2000). Spanish agriculture, which has the highest water demand, occupies approximately 50 % of the land area, reflecting its territorial importance and its relevance to management of the environment (EC 2010). Climate change represents one of the main current challenges for agriculture. Impacts are expected to be diverse and heterogeneous where impacts on the quality and quantity of water are foreseen.

The previously mentioned high spatial variability and uneven distribution of water and its scarcity throughout Spain, but especially in the Mediterranean regions, have traditionally produced numerous conflicts related to water use

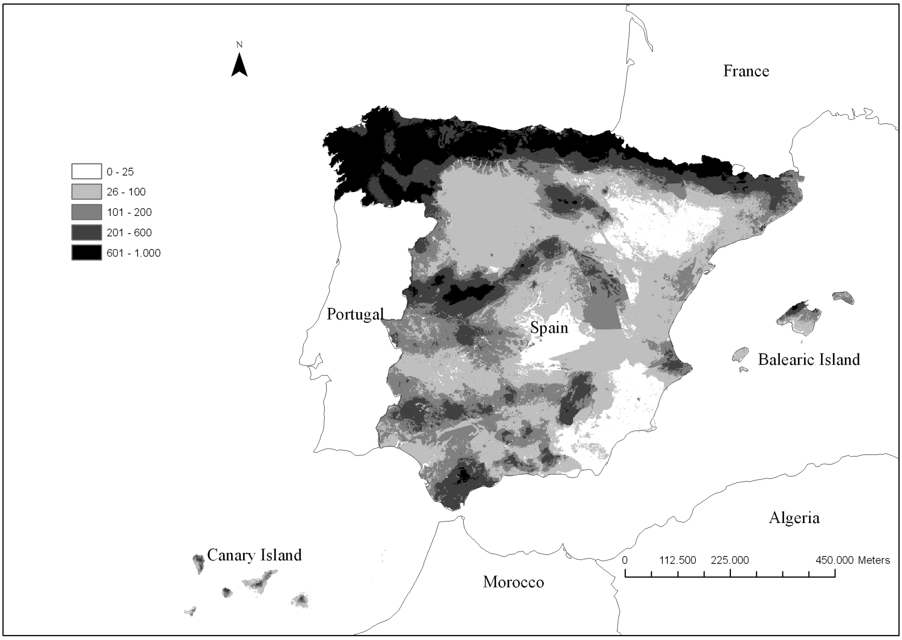

Figure 3.7.: Mean annual runoff in Spain (mm).
Source: Elaborated with data taken from MAGRAMA (2011).
Note: Canary Islands are represented out of the real location.

and have led to the intensive control of water to supply the different water demands (Estrela Monreal and Vargas Amelin 2010). Different measures have traditionally been applied at the national level to decrease water scarcity impacts. For instance, numerous water supply infrastructures have been constructed, or existing ones modernized, to ensure adequate public water supply and meet irrigation demands. In fact, Spain is the fifth country in the world in terms of its number of large dams, 1200, after China, the USA, India and Japan (INE 2008b). Monitoring and metering programmes for both surface and groundwater are being used to control water abstraction. Water savings and water-efficient technologies have been promoted, as well as modernization of infrastructure in the agricultural sector. These measures include public awareness campaigns led by municipalities and supply entities, and investment to implement drip irrigation systems and modern channelization of water in rural areas. In addition, joint management of surface and groundwater is carried out by the RBAs in charge of water management. Last, there has been an important increase in recent years in use of non-conventional water resources, such as waste water re-use and desalination. If climate change scenario projections foreseen for Spain occur in the next years, this set of measures should be applied more strongly to counteract the negative effects on water resources.

3.5.4. Variability and trends in Spain

The detection of climate change effects from streamflow data is not easy; natural hydrological variability and the effects of water abstractions on flow discharges complicate the task of establishing clear trends. Precipitation and streamflows are concentrated over a few months and variations year-to-year are large in semi-arid and arid countries. Annual precipitation data recorded in Spain from 1940 (after the Spanish Civil War) show a high temporal variability, including long runs of dry years followed by humid ones. The dry run that started at the beginning of the 1980s seems to continue, as shown in fig. 3.8. The mean annual precipitation for the period 1980–2009 (634 mm/year) is significantly lower than that for the period 1940–2009 (665 mm/year).

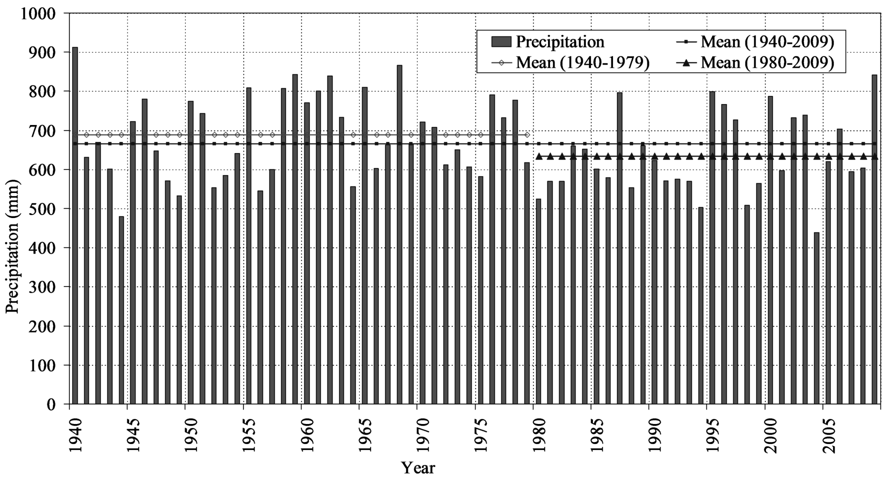

Figure 3.8.: Annual rainfall data in Spain.
Source of data: MAGRAMA (2011).

Although, there is a rainfall record of more than 200 years for the meteorological San Fernando Observatory in Cádiz, from 1805, and there are more than 50 rainfall records of approximately 150 years length, the oldest recorded river flow data in Spain dates back to only the beginning of the 20th century, approximately 100 years. The uncertainty corresponding to the river flow data is greater than that of the rainfall data given that, in the past, it was usual to record only one observation per day, which in rivers with high daily variations could result in an elevated uncertainty.

In spite of the aforementioned data uncertainty issues, the study of some of the longest river flow data series in Spain can reveal valuable results. The main characteristics (location, drainage area, mean annual discharge and degree of hydrological regime alteration) of river gauging stations with some of the longest flow records in Spain are shown in table 3.3; their locations are shown in fig. 3.9.

Table 3.3.: Main characteristics of gauging stations with longest river flow records in Spain. Source of data: Anuarios de aforo 2007–2008 (MARM 2010)

River	Location	Gauging Station	X UTM	Y UTM	Drainage Area (km^2)	Mean annual discharge ($hm^3/year$)	Degree of alteration
Duero	Garray	2002	545 390	4 627 600	1 500	330.1	Low
Tajuña	Orusco	3082	483 590	4 461 810	2 029	162.8	Low
Segura	Fuensanta	7001	569 160	4 250 280	1 218	278.3	Low
Mijares	Villarreal	8005	745 933	4 427 457	2 504	238.0	High
Alfambra	Teruel	8027	659 634	4 469 301	1 396	38.7	Low
Júcar	Los Frailes	8036	608 192	4 333 000	5 403	647.5	High
Cabriel	Cofrentes	8112	664 480	4 347 800	4 694	609.6	Medium
Aragón	Yesa	9101	646 828	4 719 928	2 191	994.8	Low
Ebro	Zaragoza	9011	676 533	4 614 247	40 434	7 359.4	High

The temporal evolution of the annual flow data recorded at these stations is represented in fig. 3.10. Although, at first glance, they seem to show a clear decreasing trend during the 20th century, this appearance is deceptive, as illustrated later.

One of the longest data series in Spain corresponds to the Ebro River at Zaragoza. It has the largest mean annual flow, 16 500 $hm^3/year$, of all Spanish rivers, supplies a water demand of almost 7000 $hm^3/year$ and has been a candidate to make a significant water transfer, 100 $hm^3/year$, to several Mediterranean river basins. Its drainage area in Zaragoza (40 434 km^2) is

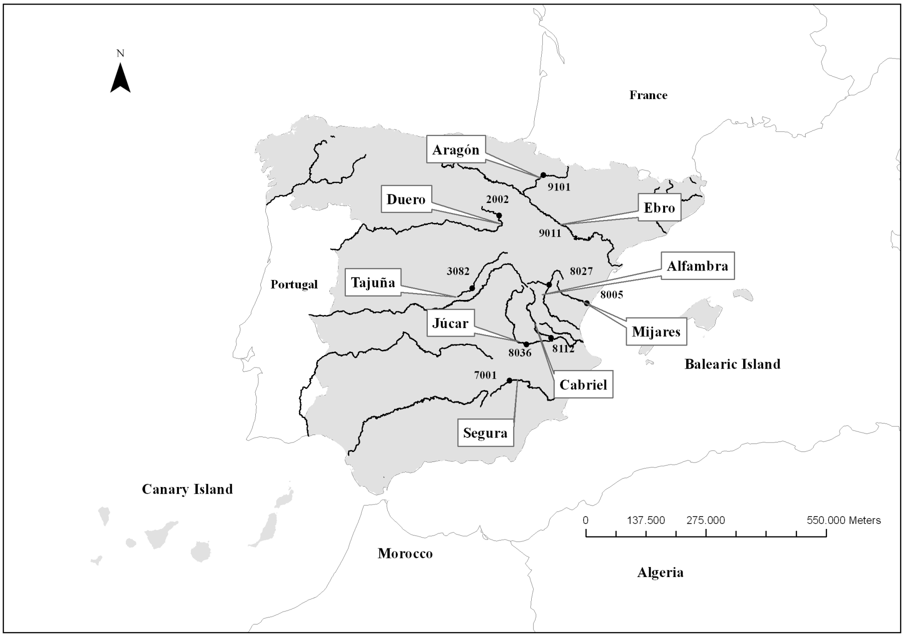

Figure 3.9.: Location of the gauging stations with some of the longest river flow records in Spain.
Source of data: Anuarios de aforo 2007–2008 (MARM 2010).
Note: Canary Islands are represented out of the real location.

much larger than for any other river gauges in table 3.3, and for that reason, the data are not included in fig. 3.10, but represented separately in fig. 3.11. The Ebro flow data at Zaragoza seem to show a clear decreasing trend, if the analysis, based on linear regression, is extended back over the last 50 years fig. 3.11. However, if attention is drawn to the complete data flow series, starting in 1912, the trend is much less clear. Dry and humid periods alternate in this case, and it could be concluded that data seem to follow a stationary pattern. Therefore, caution should be used with this type of analysis, not to establish trends using periods, even with many years, if they do not adequately represent the hydrological variability of flow discharges.

Since 1980, the dry period recorded in the Spanish Mediterranean area has been accompanied by a trend of increasing temperature (Pérez-Martin 2009), as apparent in figs. 3.12 to 3.14, where precipitation, temperature and runoff

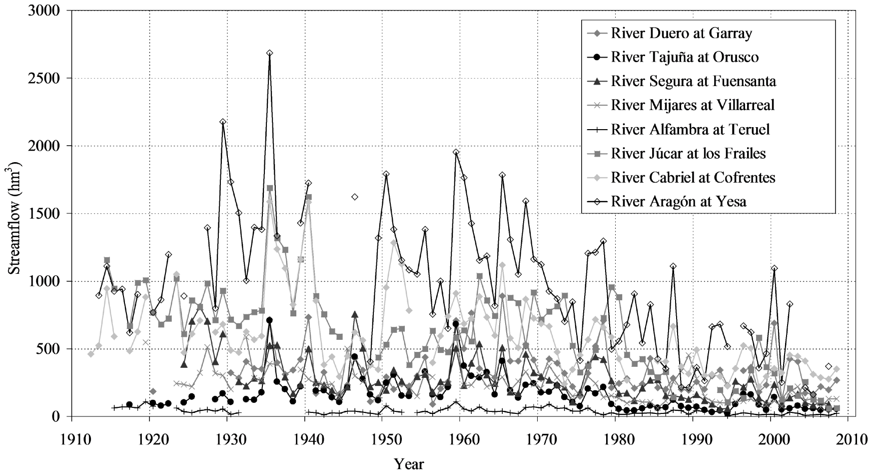

Figure 3.10.: Some of the longest river flow data series in Spain.
Source of data: MAGRAMA (2011).

annual data are shown, respectively, for 1940–2009. These data correspond to the upper basins of the Júcar and Cabriel rivers (8600 km^2) in the East of Spain, draining, respectively, to the Alarcón and Contreras reservoirs, and natural flow regimes can be assumed. This temporal coincidence, together with the short flow series, make it difficult to discern if the cause is due to the occurrence of a dry cycle corresponding to the climate's natural variability, if the runoff reduction is related to the increase of temperature, or if both phenomena occur.

Additionally, some data series shown in fig. 3.10 may also incorporate effects due to human water use. An example is the case of the Júcar River in Los Frailes, where river flow discharges reflect the effect of water abstractions from the Mancha Oriental aquifer (Estrela Monreal, Ferrer Polo, Pérez Martín, and Font 2004), which dramatically increased between the 1980s and early 2000s (fig. 3.15). Regrettably, information on water abstractions it is not always available, or, if available, is not in the appropriate form to reconstruct the natural regime.

The lack of river flow data for longer periods, the effects of river regulation and water abstractions, and the high natural variability of rivers can account for the apparent reduction of river flows. Furthermore, it is not always easy to

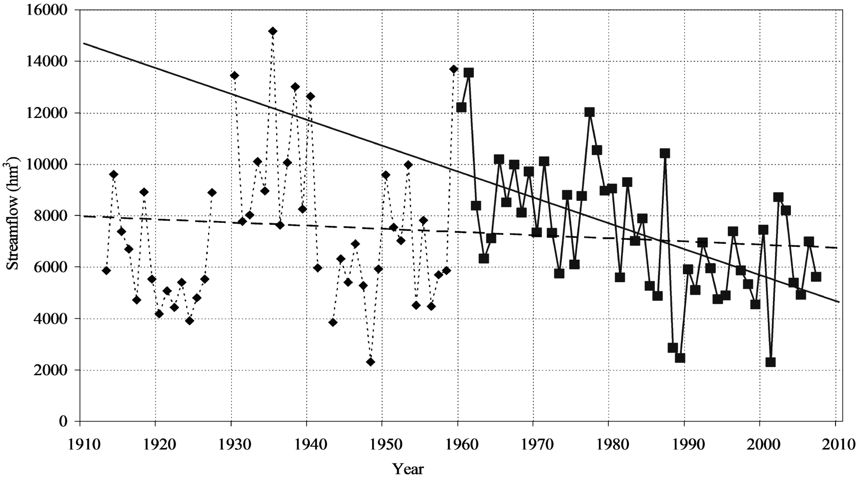

Figure 3.11.: Streamflows of the River Ebro at Zaragoza.
Source of data: MAGRAMA (2011).

obtain data series of water uses. Therefore, it can be concluded that it is not an easy task to study climate change effects on water resources through statistical analyses of observed river flow data, which explains the convenience of using hydrological simulation models.

3.5.5. Studies on modelling hydrological effects of climate change in Spain

One of the first research projects in Spain to study the effects of climate change on water resources was by Ayala Carcedo and Iglesias López (2000) and applied a regional lumped hydrological model for each of the main Spanish river basins. They used a scenario produced by the former National Meteorological Institute of Spain applying the Hadley Centre model for horizon 2060 (2.5 °C increase in mean annual temperature and a decrease of 8 % in mean annual precipitation). The mean global reduction of water resources in Spain obtained was 17 %, the main changes being in the southern areas of the country.

Later, the effects of climate change on water resources was systematically assessed in the White Paper on Water in Spain (MMA 2000) by means of a spatially-distributed hydrological model (1 km × 1 km cells) operating on an

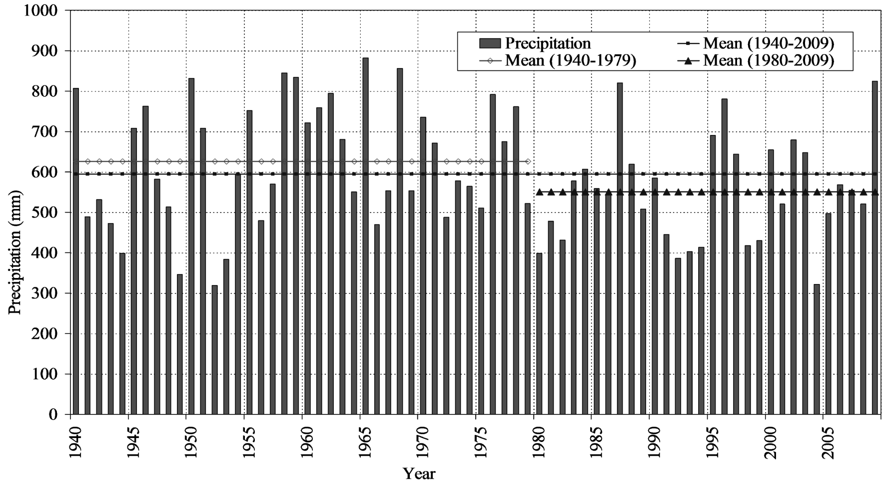

Figure 3.12.: Annual rainfall data for the Upper Jucar and Cabriel river basins. Source of data: Júcar River Basin Authority.

annual basis for the whole Spanish territory and based on the well-known Budyko law (Budyko and Drozdov 1953), which relates, over the long-term, the mean annual runoff with the mean annual precipitation and the mean annual potential evapotranspiration, obtained from temperature. Three scenarios derived from the National Programme on Climate (Ministerio de Obras Públicas, Transportes y Medio Ambiente 1995) were analysed for 2030.

This assessment report shows a clear reduction in total water resources. For a simple scenario corresponding to a decrease of 5 % in mean annual precipitation and an increase of 1 °C in mean annual temperature, a decrease of 9–25 % is expected in runoff for 2030, depending on the river basin district studied. The effect of climate change on water resources varies regionally, mainly following projected changes in rainfall and temperature. The most critical Spanish areas are the arid and semi-arid ones, where water scarcity and drought problems are greater, as in Guadiana, Canary Islands, the Segura, Júcar and Guadalquivir river basins, the southern part of the country and the Balearic Islands (MMA 2000).

The next step in hydrological modelling of climate change impacts was the use of models simulating the main processes that constitute the hydrological

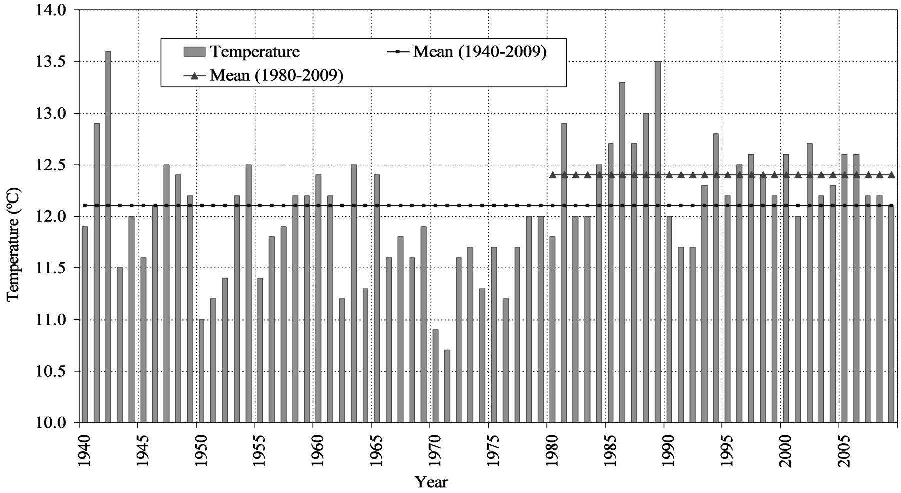

Figure 3.13.: Annual temperature data for the Upper Jucar and Cabriel river basins. Source of data: Júcar River Basin Authority.

cycle. These models estimate variables such as precipitation, snow, actual evapotranspiration, soil moisture, surface and groundwater runoff, aquifer recharge, volume storage in soils, etc. Models may be conceptual or physically-based in type, and different temporal operation intervals can be used.

Fernandez Carrasco (2002) studied climate change effects on water resources in 19 small river basins distributed throughout the Spanish territory using the SIMPA distributed conceptual model (fig. 3.16), developed by Ruiz García (1998) and operating on a monthly scale with a 1 km $\times$ 1 km-resolution grid. The SIMPA model applies conceptual water balance equations in each of the grid cells. It considers the subsurface as divided into two zones: the upper non-saturated or soil moisture zone; and the lower or aquifer zone, which is saturated with water and serves as a groundwater reservoir that may or may not be connected to the surface drainage network. As shown in fig. 3.16, part of the rainfall is stored in the soil moisture zone, providing supplies for the evapotranspiration process. The rest can be regarded as a surplus, and it is divided into a part that flows on the surface, and the remainder that infiltrates into the aquifer. The surface runoff flows out through the basin in the present time, whereas water that has infiltrated forms part of the aquifer and is later

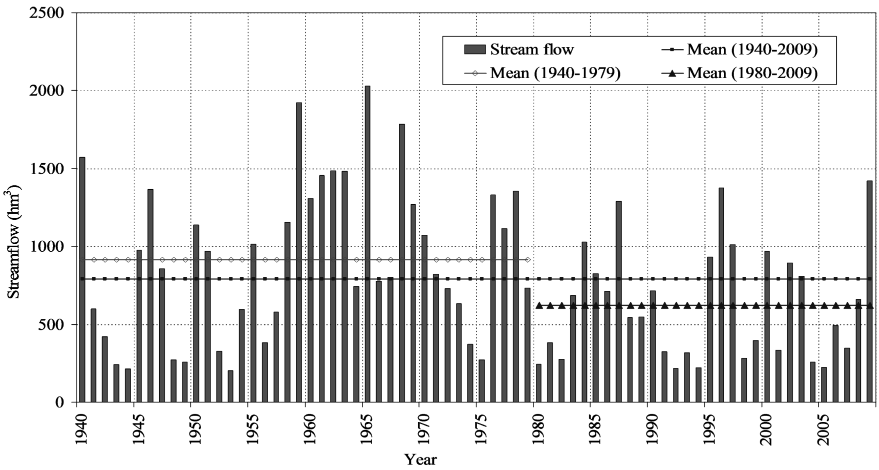

Figure 3.14.: Annual streamflow data for the Upper Jucar and Cabriel river basins. Source of data: Júcar River Basin Authority.

discharged to the drainage network.

The model inputs are monthly rainfall and temperature data from the meteorological stations. The model obtains the different rainfall and temperature maps for each time interval by interpolation. The hydrological model parameters are a function of the physical characteristics of the basins (terrain slopes, geology, land cover, soil types, etc.). The model outputs are the maps of the different storages (soil moisture and aquifer volume) and flows (actual evapotranspiration and total runoff, obtained as the total sum of the surface and groundwater runoff) for each time interval. The model integrates the total runoff at the defined drainage points, calculating the monthly discharges therein. The SIMPA model was used to assess Spanish water resources in the White Paper on Water in Spain (MMA 2000; Estrela Monreal, Cabezas Calvo-Rubio, and Estrada Lorenzo 2001). Monthly maps produced by this model are published periodically in the Sistema Integrado de Información del Agua -*Integrated Water Information System* (SIA) of the web page of the Spanish Ministry of Agriculture, Food and Environment.

Different climatic scenarios, originating from the MMA (2000), General Circulation Models (GCM) (UKMO) and An atmosphere-ocean coupled regional model for climate studies of the Mediterranean region (PROMES) Regional

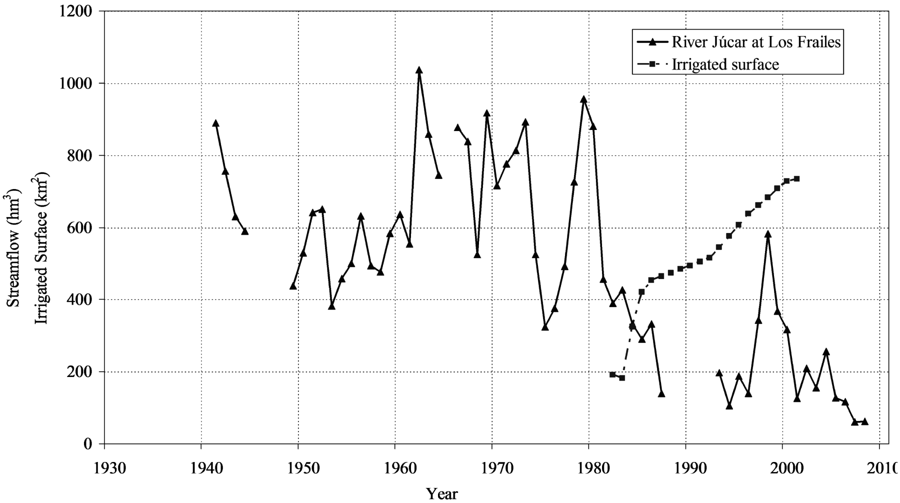

Figure 3.15.: Evolution of flow discharges in the Júcar River and irrigated area in the Mancha Oriental aquifer.
Updated data from Estrela Monreal, Ferrer Polo, Pérez Martín, and Font (2004).

Circulation Model (RCM), were used by Fernandez Carrasco (2002). One of the main conclusions of this work was that there was a need to allow for the seasonal distribution of climatic and hydrological variables in future assessments.

In 2005, the Spanish Ministry of Environment led the ECCE project *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005), in which the main focus was the review and compilation of the state of the art on climate change impacts and preparation of the basis for future climate change adaptation initiatives in Spain. Regional climate scenarios in the ECCE project were taken from the Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects (PRUDENCE) project of the EU 5th FP. The regional model used was PROMES, with the following characteristics: 50 km horizontal resolution; 35 layers, nested in Hadley Centre Atmospheric Model (HadAM3H) with ocean surface temperature provide by Hadley Centre Coupled Model, version 3 -coupled atmosphere-ocean general circulation model- (HadCM3); two time periods, 1960–1990 (control) and 2070–2100; and Special Report on Emission

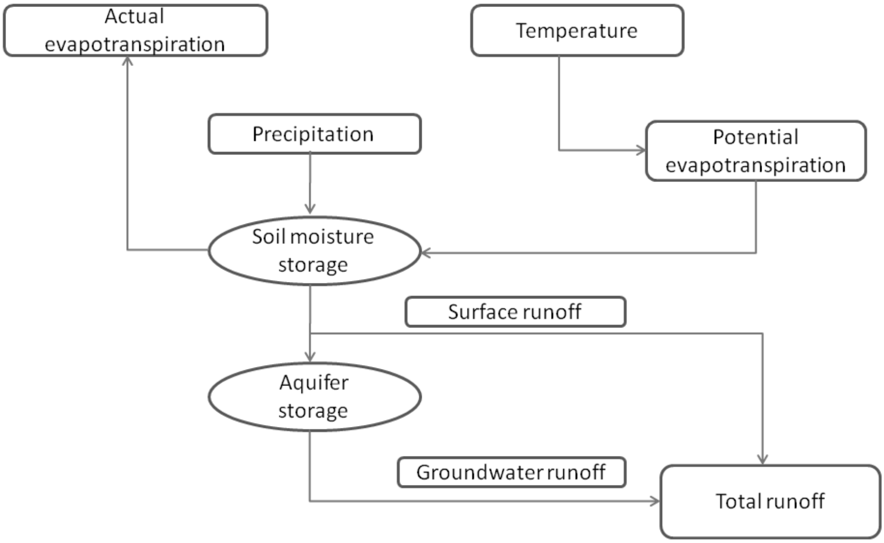

Figure 3.16.: The SIMPA hydrological model scheme.

Scenarios (SRES) A2 and SRES B2 emissions scenarios. This model produced scenarios of climate changes in Spain for the 2071–2100 period compared to 1961–1990. In both scenarios and for all the seasons, a generalized warming was identified all over Spain, but greater in the A2 scenario and in the southern and eastern areas of the Spanish mainland (increases of up to 5 °C to 7 °C in summer). In both scenarios, general annual reductions in rainfall occurred, but with an irregular distribution across the seasons and among the different Spanish regions.

The main conclusions of the report *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005) related to water resources were:

a) a general decrease of water resources and an increase in irrigation systems;

b) input reductions of up to 50 % in arid and semiarid regions;

c) an increase in inter-annual variability;

d) demand management as a palliative option;

e) the need to improve and extend monitoring networks, increase research in hydrological process and simulation models; and

f) climate change effects need to be taken into account in water policies and water resources management.

In general terms, this report highlights the need to develop a more in-depth assessment of the impacts of climate change on water resources.

Available climate change scenarios for the Júcar River basin (42 900 km^2 in the East of Spain) for 2070–2100 were assessed by Hernández Barrios (2007). The climate scenarios corresponded to the results obtained with the HadCM3 model for A2 and B2 SRES (IPCC 2000), regionalised for Spain with the PROMES model (Gallardo et al. 2001). Based on those climatic anomalies, impacts on natural water resources, water needs for crops and water management in hydrological systems in the Júcar River Basin District were assessed. Impact on natural water resources was estimated with the Rainfall-runoff model (PATRICAL) model (Pérez-Martín 2005), with a global runoff reduction of 40 % for the whole Júcar River basin, but significant geographical variations. The most affected areas, with 50 % reductions, are the inner zones of the basin, while the coastal areas show reductions of approximately 25 %. The results obtained also showed increases in water needs of 25–30 % in crops located in inland areas, and 28–38 % in crops located in the coastal areas. The impact on the water resource systems derived from a reduction of natural water resources and from increases in crop water needs were also evaluated. The results show a strong impact on the system with important decreases in the irrigation guarantees and the emergence of environmental problems in river ecosystems. In addition, it was concluded that it is not possible to maintain the current water uses, especially the great water volumes used for irrigation.

Ceballos-Barbancho, Morán-Tejeda, Luengo-Ugidos, and Llorente-Pinto (2008) analysed the temporal trend of water supplies for a network of basins in the south-western sector of the Spanish part of the Duero River basin (78 960 km^2 in North-West Spain), and their relationship with the evolution of temperature, precipitation and the changes that have occurred in plant cover over time. The results show an important decrease in water supply associated with changes in the monthly distribution of water discharge due to alterations in the intra-annual distribution of precipitation and an increase in temperature in spring and summer.

Recently, the Centro de Estudios Hidrográficos of the CEDEX -*Centre for Hydrographic studies* (CEH), a Spanish research and experimentation centre for water issues, has been commissioned by the Ministry of Environment and Rural and Marine Affairs to make an assessment of the climate change impact on natural regime water resources for the whole Spanish territory (CEDEX 2010). The climatic data used include climate scenarios regionalized by the Spanish State Meteorological Agency (AEMET 2008), which combine the results of global circulation models made by various international organizations with techniques of regionalisation at the local level. The chosen emission scenarios (A2 and B2) are part of the set of scenarios of emission of greenhouse gases established by the IPCC (2000). The phases of the hydrological cycle have been simulated using the SIMPA model described above.

The set of projections for scenario A2 suppose decreases of precipitation in Spain over the control period (1961–1990) of approx. 5 %, 9 % and 17 % during 2011–2040, 2041–2070 and 2071–2100, respectively. These reductions are slightly smaller for scenario B1, especially for the period 2071–2100. The projections of the A2 scenario lead to reductions in runoff in Spain of 8 % for the period 2011–2040, 16 % for the period 2041–2070 and 28 % for 2071–2100. The reductions for the B2 scenario are lower, 8 %, 11 % and 14 %, respectively. Runoff reduction also varies regionally as shown in table 3.4 and fig. 3.17, the largest decreases occurring in river basins in southern Spain.

Chirivella Osama (2010) characterizes future climate scenarios in the Júcar River Basin District. According to this work, scenarios collected in AEMET (2008) reproduce well the temperature of the Júcar River Basin District in the control period (1961–1990), but generally underestimate precipitation. Outcomes obtained from the data of the global model Hadley Centre Coupled Model, version 2 -coupled atmosphere-ocean general circulation model- (HadCM2) best reproduce both variables. In addition, the model performs a climatic regionalization obtained with dynamic downscaling. The regional model employed is the Third generation of the Regional Climate Model (RegCM3), with future climate data from the global model Global Climate Model developed by the Max Planck Institute for Meteorology (ECHAMs) and considering the A1B emission scenario, corresponding to the scenarios elaborated for AR4 of IPCC. The Climate change and its impacts at seasonal, decadal and centennial timescales (ENSEMBLES) project established the A1B scenario as the most probable for Europe. The objective of ENSEMBLES is to

Table 3.4.: Variation of runoff (%) for Spanish river basin districts in the periods 2011–2040, 2041–2070 and 2071–2100 with regard to the control period of 1961–1990. Source of data: CEDEX (2010).

	Δ mean annual runoff (control period 1961–1990)					
	Scenary A			Scenary B		
River Basin District	2011–2040	2041–2070	2071–2100	2011–2040	2041–2070	2071–2100
Cantábrico Occidental	-13	-16	-29	-10	-16	-17
Cantábrico Oriental	-12	-16	-30	-10	-16	-20
Cuencas Internas de Andalucia	-12	-30	-41	-16	-15	-27
Cuencas Internas de Cataluña	0	-4	-21	-7	-9	-16
Duero	-8	-17	-31	-7	-9	-13
Ebro	-9	-14	-28	-9	-13	-16
Galicia Costa	-6	-12	-19	-3	-8	-5
Guadalquivir	-22	-28	-43	-13	-12	-24
Guadiana	-12	-27	-42	-9	-11	-20
Islas Baleares	-4	-15	-31	-15	-20	-23
Islas Canarias	-18	-32	-41	-25	-28	-34
Júcar	-5	-18	-32	-12	-13	-24
Miño – Sil	-6	-12	-21	-3	-7	-6
Segura	-10	-21	-33	-13	-14	-21
Tajo	-8	-19	-35	-8	-9	-15
Spain	-8	-16	-28	-8	-11	-14

obtain updated and regionalised results of the probable climate scenario for the 21st century in Europe (socio-economic A1B scenario), including mid-term (2030–2050) and long-term (2080–2100) projections. The results of this project have been recently incorporated into the regionalised climate scenarios for Spain in the web page of the Spanish State Meteorological Agency (AEMET n.d.). The process of downscaling is performed (Chirivella Osama 2010) in two stages: first for all the Iberian Peninsula (nested scope), and second, with the results of the above as boundary conditions for the Júcar River Basin District (coarse scope), and a clear improvement in the characterization of the climate is observed on making this double downscaling. The impact foreseen on the water resources of the Júcar River Basin District for 2010–2040 is a reduction of 19 % over the control period of 1990–2000. This reduction is significantly greater than that obtained in CEDEX (2010) for the same territorial scope for scenarios A2 (5 %) and B2 (12 %), which may be explained by the use of a dynamic downscaling to represent the climate variable, precipitation.

Climate change impacts on natural water resources will affect their use through the water resource system, which contributes to the regulation, trans-

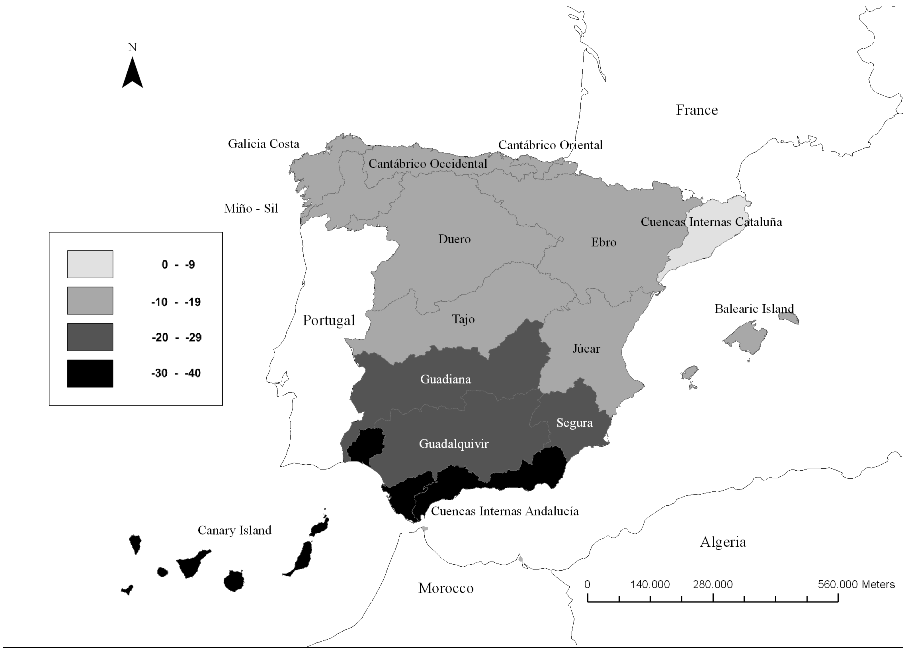

Figure 3.17.: Variation of runoff (%) for Spanish river basin districts corresponding to the A2 scenario in the period 2041–2070 compared to the control period, 1961–1990. Source of data: CEDEX (2010).
Note: Canary Islands are represented out of the real location.

port and distribution of resources to the areas of consumption. The water resource system can absorb or amplify the climate change effects depending on the water management carried out. Therefore, the impact of climate change on water resources also depends on the system's characteristics (reservoirs, channels, etc.) and how the system's management is handled. Unmanaged systems are likely to be the most vulnerable to climate change (IPCC 2007a). Garrote de Marcos, Rodríguez Medina, Estrada Lorenzo, and Muñoz Bravo (1999) estimated the effects on available water resources for the scenarios considered in the White Paper on Water in Spain (MMA 2000). They conclude that a global reduction of 5 % in natural water resources becomes a reduction of 4 % in available water resources. Rodríguez Medina (2004) investigated water resources system sensitivity to water reductions due to climate change, observing the greatest decreases in those systems with less regulation capacity, or with an excess of it. It is clear that the impact of climate change on hydrological design and water resources management could be one of the most important challenges faced by hydrologists and water resources managers, as indicated by Teegavarapu (2010).

3.5.6. Implications of climate change and policy actions

The impacts of climate change on water resources may be exacerbating it occurs in regions already presenting low water resources levels. Table 3.5 shows, for Spanish river basin districts, the mean annual runoff, the runoff reduction for the period 2041–2070, the mean annual total water demand and an indicator of the vulnerability of a territory to water stress, the WEI, as used in this case by CEDEX, was obtained as the quotient between the mean annual water demand and the mean annual runoff. It is observed that the higher reductions in mean annual runoff take place in the river basin districts more vulnerable to water stress, i.e. where the value of the WEI is higher.

If the climate change scenarios foreseen for Spain occur in future years, the measures traditionally used in Spain to fight water scarcity will need to be applied more strongly and in a manner consistent with regional effects on water resources. The challenges for Spanish policy makers include understanding climate change impacts and developing and implementing policies to ensure optimal levels of adaptation to the projected water resources reduction in the most affected territories, especially in those with water scarcity.

During the first cycle of river basin planning of the WFD, a Climate-Check for the PoM has been carried out in Spanish river basin districts, similarly to that which takes place in other MS. Measures that may arise in the RBMP should take into account the effects of climate change in different river basins. The Spanish Spanish Hydrological Planning Regulation (2007) was approved in July 2007, and mandates the consideration of the effects of climate change on water resources in the current RBMP. According to this decree, these plans will assess the effect of climate change on water resources in each Spanish river basin district, estimating the resources corresponding to the climatic scenarios considered by the Spanish Ministry of Agriculture, Food and Environment (AEMET 2008). With the aim of assessing trends and establishing a PoM, each plan will estimate the balance between available water resources for those climate scenarios and the projected water demands for different uses.

A PNACC (OECC 2006) has been under development since 2006 to cope with climate change effects in Spain. Its aim is to integrate adaptation to

Table 3.5.: Comparison between reduction in runoff by climate change and water exploitation index in the Spanish River basin districts.

	Current status			2041–2070. Scenario A2			
River Basin District	WD (hm^3)	Runoff (hm^3)	WEI (%)	Δ Runoff[a] (%)	Runoff (hm^3)	WEI (%)	Δ WEI (%)
Cantábrico Occidental	717	16 143	4	−16	13 560	5	19
Galicia Costa	783	12 077	6	−12	10 628	7	14
Cantábrico oriental	310	1 638	19	−16	1 376	23	19
Miño – Sil	582	11 919	5	−12	10 488	6	14
Duero	3 830	13 179	29	−17	10 939	35	20
Tajo	2 667	10 075	26	−19	8 161	33	23
Guadiana	2 333	4 474	52	−27	3 266	71	37
Guadalquivir	3 368	7 087	48	−28	5 103	66	39
Cuencas Internas de Andalucia	1 908	4 499	42	−30	3 150	61	43
Segura	1 808	762	237	−21	602	300	27
Júcar	2 949	3 358	88	−18	2 753	107	22
Ebro	7 034	16 203	43	−14	13 934	50	16
Cuencas Internas de Cataluña	1 346	2 603	52	−4	2 499	54	4
Islas Baleares	286	639	45	−15	543	53	18
Islas Canarias	414	420	99	−32	286	145	47
Spain	32 243	109 576	29	−16	92 044	35	19

WD: Water Demand. Annual average. $1\,hm^3 \equiv 1 \times 10^6\,m^3$
Runoff: Annual average.
WEI: Water Exploitation Index. $WEI = \frac{Runoff}{WD} \times 100$.
Δ Runoff: Variation at Scenario A2 from current status.
Note: comparison considering water demand without variation.

[a] Source CEDEX (2010)

climate change into the planning strategies of the different socio-economic sectors in the country by establishing a continuous and accumulative process of knowledge generation and strengthening of capacities. For each sector and system, the Plan identifies predicted impacts in accordance with the publication *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005) and establishes measures, activities and lines of work to be developed for impacts assessment, vulnerability and adaptation. A key objective of this Plan for the water resources sector is to develop quantitative scenarios of water resources for the 21st century in Spanish river basins. The Plan includes an assessment of the management and capacity of the Spanish hydrological systems under different water resources scenarios, a second assessment of potential climate change effects on irrigation, and a third one of climate change impacts on the ecological status of water bodies.

3.5.7. Conclusions

Hydrological stress is expected to increase as a consequence of climate change in some regions of the world, including southern Europe, and Spain in particular, increasing the populations affected by living under water-stress conditions.

The detection of climate change effects is not simple because the natural variability of the water cycle and the effects of water abstractions on flow discharges complicate the task of establishing clear trends from river flow data. To assess these effects, major progress in hydrological modelling has occurred in Spain in recent years. Several models have been applied and gradually improved for the Spanish territory. It can be stated that currently there are enough modelling tools to assess impacts on water resources in natural regimes with sufficient detail from climate change scenarios. Results obtained to date show that the negative effects of climate change will mainly affect the semi-arid zones with water shortages and a fragile balance between water resources and demands. Overall, runoff reductions will be between 10 % and 30 % for the whole country through the 21st century, which has important implications for water management in Spain.

Relevant recommendations to policy makers and water managers, which are reflected in recent regulations, have been produced as a result of the scientific work carried out. If the intense use of water resources continues, the environmental requirements increase and the margin to increase available water resources is reduced, then it is most likely that current water uses will not be maintained in the future. In conclusion, it becomes essential to improve assessment of the effects and to adapt water management to the already identified impacts and to the anticipated ones by using future scenarios.

The PNACC is being developed in Spain, which establishes a general reference framework to evaluate climate change impacts, vulnerability and adaptation. In addition, climate change impacts are being taken into account in the water balances of the upcoming RBMP in Spain, which represents an opportunity for taking into account climate change effects in water decision-making policies. According to existing climate change scenarios, reduction of available water resources will gradually occur through the 21st century, and, therefore, the available water resource assessment carried out in the river basin planning framework will play a relevant role.

3.6. The Challenge of Climate Change in Spain: Water Resources, Agriculture and Land

This section reproduces the article "The challenge of climate change in Spain" (Vargas Amelin and Pindado 2014) which addresses the impacts of climate change in sectors directly linked to water, such as agriculture or land management. It provides an assessment of expected impacts at the national level, and offers insights on both mitigation and adaptation strategies within the different sectors, mentioning specific plans and cross-sectoral structures.[9]

3.6.1. Summary

Climate change effects are becoming evident worldwide, but some water scarce regions present higher vulnerability. Spain, located in the Mediterranean region, is expected for instance to be highly vulnerable given its unbalanced distribution between water resources availability and existing demands. This article presents an introduction to the main threats of climate change mainly on water resources, but it also assesses effects in interlinked areas such as agriculture, soil and land management. Contents focus on measures and initiatives promoted by the central government and address efforts to establish multi-sectoral coordinating bodies, specific adaptation plans and measures for the different sectors. The article highlights some political aspects, such as the complexity of involved competent authorities in water and land management, the need to strengthen public participation and the conflicts arising from the defence of regional interests. It also makes a link to current EU policies; summarises foreseeable problems derived from climate change effects, and provides some recommendations in the different areas covered.

3.6.2. Introduction to climate change in Spain

The warming of the global climatic system is a reality, and the human influence has been a dominant cause (IPCC 2013b). It is global, with the most significant local impacts occurring in certain regions, among which the Mediterranean stands out. The Report from the EEA, EC-JRC, and WHO (2008), *Impacts of*

[9] Acknowledgments: The authors would like to thank Dave Brodbelt and Elena López-Gunn for their help in improving the style and grammar of the article, and Vicente Ramírez Perea for his valuable contributions to the text and figures.

Europe's changing climate, noted the high vulnerability of mountain and coastal areas as well as the Arctic and the Mediterranean. This reality was introduced already at the fourth report of the IPCC (2007b), considering that there is a high probability that many semi-arid regions such as the Mediterranean basin, will suffer a significant decline in water availability due to climate change.

Spain is considered one of the most vulnerable countries to climate change within the MS, due to its geographic and socio-economic characteristics. Forecasts obtained from models place it as a region where a further increase in temperature and decrease in precipitation is expected (EC 2009a; EC 2009b; AEMET 2008; Garrote de Marcos 2009; Somot, Sevault, Déqué, and Crépon 2008; Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis) (fig. 3.18 shows average precipitation in the country).

Climate change, on the other hand, is a problem closely related to human development, growth and consumption patterns. One of the difficulties in addressing climate change lies precisely in its overarching and cross-sectoral characteristics. Territorial disconnection between emissions and impacts, systems vulnerability, the difficulty of achieving proper coordination among the various administrations, and the involvement of stakeholders in decisionmaking processes, are additional problems for the adaptive capacity to cope with its effects. Spain experienced, since 1995, an important economic development, higher than the European average, which the current economic recession is now seriously threatening (Pérez García et al. 2011). In addition, the country witnessed a social growth, with a significant increase in population, all of which translated into a growing contribution of greenhouse gases (GHGs) and climate change consequences. For instance, emissions of CO_2-equivalent increased steadily between years 1996 and 2005 (MAGRAMA 2013b).

Another important element when addressing climate change in Spain is its political and jurisdiction organisation, since competences related to climate change (transport, industry, agriculture and environment, among others) are often shared between the Central Administration and the Regional Governments (Autonomous Regions) and, to a lesser extent, the municipalities. Therefore, entities that promote coordination, collaboration and participative approaches are essential. Some current examples include the Climate Change Policy Coordination Commission, which includes the three administrative levels (national, regional and local), and the National Weather Council, adding to the former representatives, experts and the civil society. However, these structures and other advisory bodies do not always have the ability to promote the necessary consensus for complex project implementation. That would be

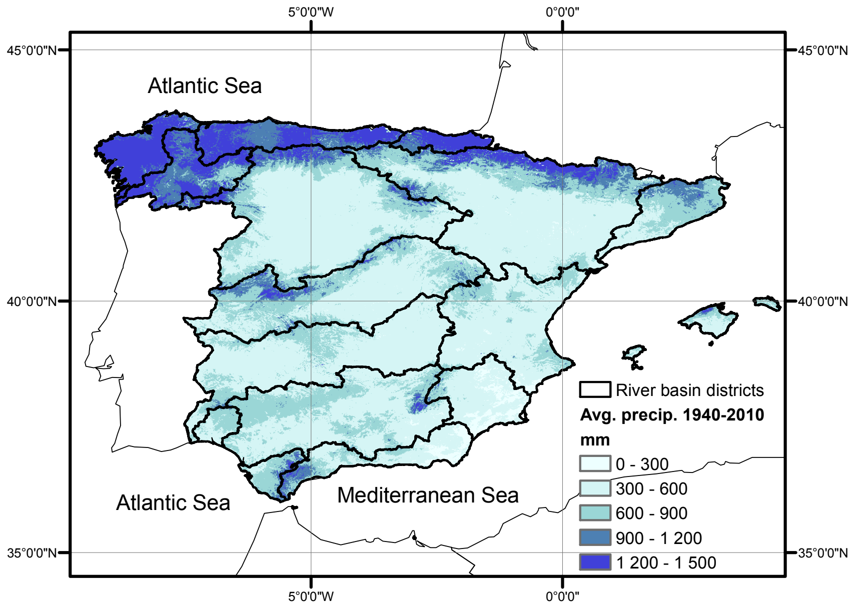

Figure 3.18.: Map of average precipitation for the period 1940–2010. River Basin Districts are shown inside of the boundaries of Spain. Northern Basins Districts (Cantábrico Oriental y Occidental, Miño-Sil and Galicia-Costa) have significantly more precipitation than the rest of Basin Districts. Source: Prepared with data from MAGRAMA (2013c). Precipitation data originated to be used by the SIMPA model of the CEDEX.

the case for some urban[10] projects promoted by local interests, and dependent, among others, on water and energy resources availability. These often lack a regional approach or even national interest, and expected climate change impacts can strongly affect their viability.

It is important to remember that most problems and impacts linked to climate change are not new. In fact, Mediterranean societies, and in particular the

[10]With regard to spatial planning there is certain degree of legal gap, and competences assigned to different administrations are complex and interlinked. Some urban plans promoted by municipalities, despite having completed the formalities required by law, may be approved and developed even though unfavorable opinions are emitted by consulted bodies, which express the lack of water supply guarantee or main road access (these responsibilities are assigned in some parts of the territory to the General Administration).

Spanish one, have always faced floods, water scarcity, heat waves, prolonged droughts, flows variability, temperature rises, and decreased rainfall with related impacts on crops. Although it is difficult to attribute to global warming the occurrence of a particular phenomenon, there are different studies that suggest that climate change will cause a higher frequency and amplification of these problems (IPCC 2008), and their displacement to areas that do not always have sufficient experience to incorporate uncertainty into water planning (Arnell et al. 2001).

3.6.3. Climate change impacts

Given the uncertainty of climate change, the Spanish Administration launched the ECCE project (*Efectos del Cambio Climático en España*—Climate Change Effects in Spain), from which, in 2005, the report *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change* (Moreno Rodríguez et al. 2005) was published. This report represented a solid basis for reviewing and gathering information on the state of the art of climate change impacts and possible initiatives for adaptation. It indicated that climate change impacts could have particularly serious consequences such as water resources decreases, coastal regression, loss of biodiversity and natural ecosystems, increased soil erosion processes and loss of lives and goods resulting from the intensification of extreme weather events like floods, wild fires and heat waves.

3.6.4. Water resources

The findings of the formerly mentioned Preliminary Assessment related to water resources highlighted that a general reduction of water resources and increased demand for irrigation systems was expected in Spain. The report also predicted a reduction in inputs of up to 50 % in semi-arid regions and an increase in inter-annual variability. It highlighted demand management as a palliative option, the need to improve and expand monitoring networks, the priority of further research and the importance of considering the impacts of these changes on policy and water resources management.

Figure 3.19 shows the slight decrease of precipitation over a long series, which climate change impacts could exacerbate. Figure 3.20 reflects the frequency of occurrence of annual precipitation for the different river basins divided in three main areas.

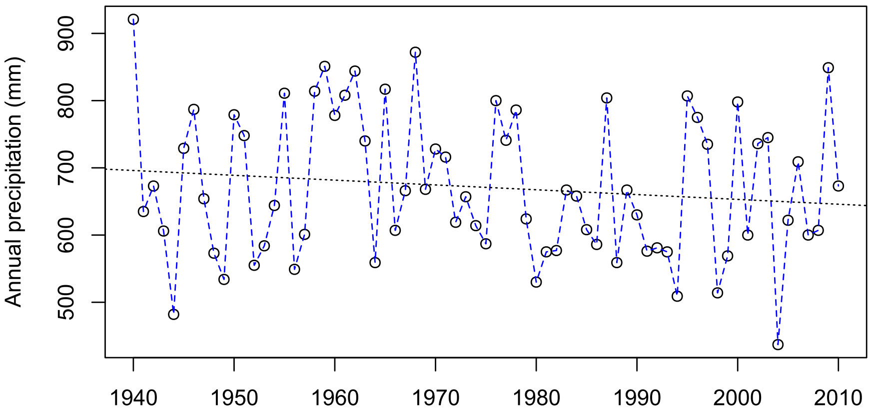

Figure 3.19.: Time evolution of annual precipitation (hydrological years 1940–1941 to 2010–2011). The hydrological year starts on October of year i ending on September of year i+1. The average annual precipitation over the time period for continental Spain and Mediterranean islands was 670 mm (standard deviation 110 mm). The time axis shows the natural year when the hydrological year starts. The trend line shows a linear fit to the data. There has been a decrease of the average annual precipitation of approximately 1 mm per year (roughly 10 % since the begin of the period over the average precipitation). Source: Prepared with data from MAGRAMA (2013c). Precipitation data originated to be used by the SIMPA model of the CEDEX.

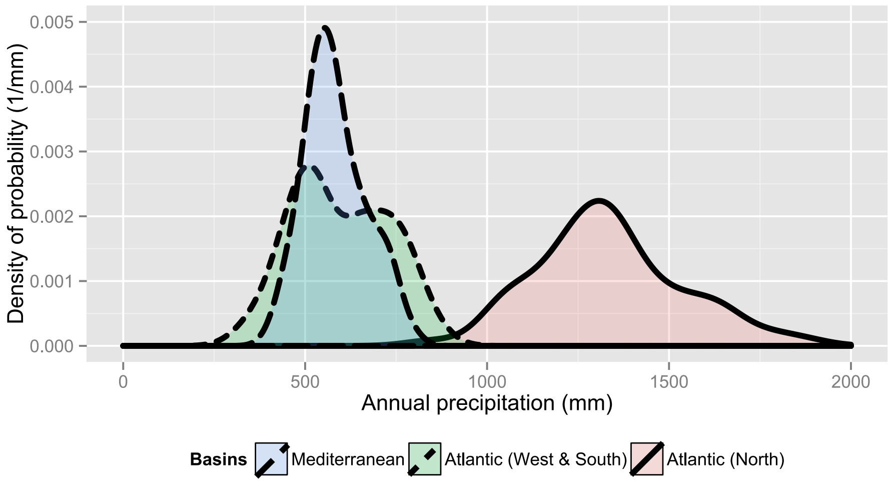

Figure 3.20.: Frequency of occurrence of annual precipitation over the period 1940–2010 for the three main areas. Over the period, the Northern Basins have an average annual precipitation of 1320 mm (standard deviation 200 mm), Western and Southern Atlantic Basins of 600 mm (standard deviation 130 mm), and Eastern Basins of 580 mm (standard deviation 85 mm). Source: Prepared with data from MAGRAMA (2013c). Precipitation data originated to be used by the SIMPA model of the CEDEX.

A more recent study by the CEDEX (2011), has finetuned impacts at the national level and predicts a generalised reduction of precipitation and water availability (near -5 %, -9 % and -17 % during the periods 2011–2040, 2041–2070 and 2071–2100 respectively), with the greatest variability occurring in the Mediterranean coast and in the South-East. In addition, the study predicts increases in temperature, evaporation and evapotranspiration, and decreases in groundwater recharge and runoff.

It is likely that climate change will increase conflicts among the different economic sectors, since it will result in situations with higher demands and reduced availability of water resources.

These conflicts have been present in recent years in Spain (Lopez-Gunn 2009a), although not directly derived from climate change, and not only between sectors, activities or environmental needs, but also among regions, which quite often masked political motives (Estrela Monreal and Vargas Amelin 2008). Experienced conflicts related to water transfers, the role of water in the reforms of the Autonomous Regions' Statutes, the revision of river basin districts delimitation and the transfer of powers to Regional Governments are all aspects that have contributed to the delay in approving the new RBMPs[11] according to Water Framework Directive (2000). These examples highlight the politicization of water in Spain (Lopez-Gunn 2009a). In fact, in the last decade, two trends clearly attached to counter political choices have been consolidated: an uncompromising defence of water transfers from the 'surplus' basins to the 'deficit' ones, and an opposite trend that rejected transfers and focused instead on desalination and other measures that promoted the use of non-conventional resources.

Although, lately these positions have softened, they often have been intermingled with the growing decentralization of power and defence of regional interests. In any case, at present, either option cannot be applied easily or arbitrarily, in Spain, a country so culturally and geo-climatically diverse, where climate change impacts may seriously compromise water resources availability. It is necessary to conduct a case-by-case study, at least both on a large scale and also on projects' impact, ensuring their economic viability, environmental sustainability and social acceptance, accompanied by consultation and public participation processes.

Water is a key element in addressing climate change adaptation in Spain. If

[11] Part of this competence complexity, as well as its possible responsibility for the delays in the current water planning, has been formally reflected in the preamble of the Royal Decree Spanish Hydrological Planning Regulation amended (2010).

in addition, the country presents major water scarcity problems and recurrent droughts, especially in the South, South-East and the Mediterranean coast, the increased scarcity due to climate change will most likely cause higher tensions over water use, interfering even more with the political agenda.

The relationships between users have created conflicts, but they may also translate into greater cooperation. For instance during the last severe drought episode (2006–2008) large volumes of irrigation water were reallocated for human consumption, under the Administration's cost control and supervision.[12] It is important to highlight the strong presence of the irrigation sector in Spain, which presents the largest water consumption (75 %) (INE 2008b), and includes a broad infrastructural network to store and redirect this resource, providing security and also cushioning during long periods of drought. Furthermore, policies to reallocate water rights in Spain will be an important adaptation tool in the near future.

3.6.5. Agriculture, land and desertification

Climate change poses a major current challenge for agriculture in addition to price volatility, increased global food demand and the introduction of biofuels (HLPE 2011). Impacts are expected to be diverse and heterogeneous affecting both water quality and quantity, including significant increase in water demand for irrigation, shortening of vegetative cycles, increase in plagues and exotic species, increased risk of heat waves or floods, direct repercussions on the agricultural production[13], or impacts on products quality (EEA 2012a; Masters, Norgrove, et al. 2010). In addition, environmental and territorial services derived from agriculture and the landscape value of agro-systems could be affected also if significant agricultural land abandonment occurs.

On the other hand, agriculture as an economic sector contributes to an extent to climate change. In 2008, in Spain, this sector was responsible for about 10 % of GHGs, of which livestock (especially pig manure management) was responsible for just over half of the emissions, compared to crop systems, which accounted for the other half (MARM 2009a). The progression of the

[12] The Spanish government approved the Royal Decree-Law 15/2005, of 16 September, on urgent measures to regulate transactions of water use rights (Water rights 2005). It was launched as an urgent temporary policy to address drought impacts, facilitating the voluntary reallocation of water rights. Given the persistence of the drought episode, this measure was later extended through Royal Decree-Law 9/2006, of 15 September (Urgent Measures Drought 2006).

[13] A strong decrease of crop performance is expected, between 10 % and 30 %, in the vast majority of the Spanish surface, which will translate into production decreases (EEA 2007a).

agricultural sector in Spain has been the usual for developed economies[14], having shifted from traditional productive systems to a greater integration with the rest of the economy, especially through the food industry. It is currently showing more modern and intensive characteristics, which in turn have direct effects on the contribution to climate change.

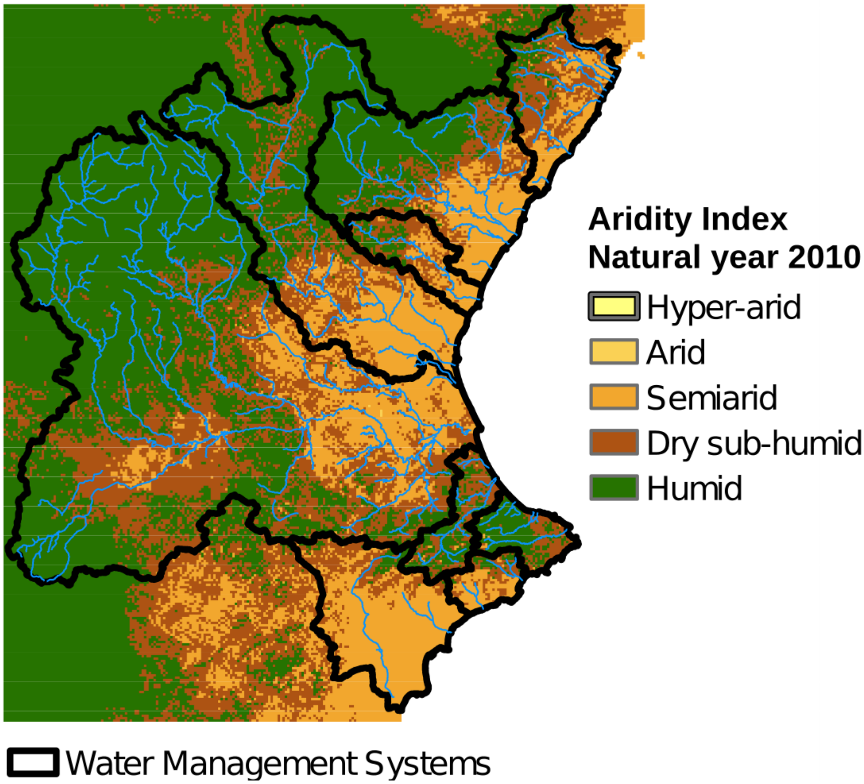

Figure 3.21.: Aridity Index (precipitation over potential evapotranspiration) of year 2010 in the Jucar River Basin District. Roughly 47 % of the territory inside of the Jucar River Basin District is classified as *humid*, 29 % as *dry sub-humid* and 24 % as *semiarid*. Source: Prepared with data from MAGRAMA (2013c). Precipitation and evapotranspiration data originated to be used by the SIMPA model of the CEDEX.

[14]The Spanish agriculture accounted in 2011 for 2.0 % of the GDP at market prices, and employed 4.1 % of the civilian working population, values close to the European averages (1.2 % and 5.3 % respectively in EU-27) (EC 2012b).

Spanish agriculture occupies approximately 50 % of the national area (INE 2008a), reflecting its importance for territorial and environmental management. On one hand, there has been a decrease of cultivated land in the last twenty years (MARM 2008b), with opposite effects occurring in relation to climate change. Part of the land has been afforested based on the CAP aids[15], while other areas have been abandoned due to the decline of vulnerable rural areas, increasing erosion and desertification risks. On the other hand, there has been a slight increase of irrigated surfaces (e.g. from 2004 to 2012) (MAGRAMA 2013a), linked to major irrigation infrastructures of modernisation plans, which were meant to provide important water savings at a time when water scarcity increased.

Moreover, regarding soil resources, the process of desertification might represent one of the greatest impacts related to climate change in Spain, threatening an important part of its territory. According to the National Action Program to Combat Desertification (MARM 2008a), over 30 % of the area is already severely affected by desertification processes, exacerbated by human activity in areas with arid conditions. Desertification causes are diverse and complex, but usually include forest fires, loss of vegetative cover, erosion, the consequent loss of fertile agricultural land and salinization processes (Millennium Ecosystem Assessment 2005). The projections of climate change would exacerbate these problems, especially in areas with a dry and semi-arid Mediterranean climate. Proper handling of cultivation techniques, tillage, irrigation and fertilisation should allow good adaptation to climate change impacts, and their mitigation, for which in Spain the European Strategy for Soil Conservation, the CAP and the Spanish Forest Plan are the main tools.

Recent projects, such as *Halting Desertification in the Júcar River Basin (HALT-JÚCAR-DES)* (Vargas Amelin, Ramírez Perea, et al. 2013) co-financed by the European Commission, have focused on the use of water accounts based on the UN SEEA-Water (UN 2012) to determine the link between water resources management and desertification processes in Spain (see fig. 3.21 for an example). The project has concluded that water accounts can be useful tools. The European Commission is currently promoting this concept at the EU level, to determine the impact of economic uses of water, and to study future impacts of climate change in different elements subject to store water (such as reservoirs, rivers or lakes) (Vargas Amelin, Ramírez Perea, et al. 2013).

[15]Over 600 000 ha of agricultural land were afforested between 1994 and 2006 in Spain with EU funds (V. Flores and Miguel 2007).

3.6.6. Economic aspects

Climate change involves a significant financial effort for Mediterranean countries, which should prioritize investments. However, in the short term the current global economic recession is going to affect this prioritization.

There are many examples of economic costs caused by climate change and related to water resources and agriculture. For instance, in the energy sector, and due to declining flows, a lower hydroelectric production is expected, which in 2009, it accounted for 7.3 % of the Spanish power generation, (MARM 2009a). In the agricultural sector, the likely increase in the cost of water, due to the full implementation of water tarification, as the WFD advocates, will probably influence the abandonment of farming in some areas, mainly the marginal ones, coupled with the loss of agricultural landscape and the associated opportunity cost. In terms of sanitation and waste water treatment aspects, lower flows will result in less dilution capacity for spills, which authorities will need to address through more intensive treatment techniques or efforts to reduce discharges and pollution. In addition, increased investments for adaptation and development of flood protection infrastructure are expected, as well as those needed to minimise water scarcity and droughts impacts or to improve and expand monitoring networks and early warning systems. In relation to environmental issues, declining biodiversity and environmental services of ecosystems will represent a real loss although it might be difficult to assign them a market value. Increased saltwater intrusion into coastal aquifers, loss of wetlands and associated species, in addition to necessary measures for ecosystems restoration, will involve also significant costs.

Investments in non-structural measures should be promoted, such as those related to multidisciplinary education, social awareness, better use of available resources (water savings and efficiency campaigns, use of adapted crops), control, collection and data analysis, research and development of models, capacity building, or coordinated regional planning.

3.6.7. Measures and initiatives

Spain counts on solid administrative and sectoral coordination structures created as climate change policies became important: the National Climate Council (year 2001), the Inter-ministerial Group on Climate Change (year 2004), the Policy Coordination Committee on Climate Change (year 2005), the Secretariat of State for Climate Change (year 2008) and the Government

Commission on Climate Change (year 2008). Moreover, the Spanish Strategy on Climate Change and Clean Energy, approved by the Government in 2007, is the framework that holds together the different climate change policies at the national level and defines basic guidelines for action at the short and medium term (2007–2012–2020) together with the Plan. It also includes measures aimed at reducing GHGs emissions or at adapting to their effects, and promotes various instruments such as the 2005–2010 Renewable Energy Plan or the Plan of Urgent Measures for 2007, among others.

Since 2008, major strategic priorities have been defined with performance targets for reducing emissions that have led to specific actions such as the Integrated National Waste Plan, the Savings and Energy Efficiency Plan in government buildings, or directly linked to agriculture, the Slurry Anaerobic Digestion Plan (*Plan de Biodigestión de Purines*).

Climate Change Adaptation National Plan

The PNACC (OECC 2006) reflects the general reference framework in Spain for impact assessment, vulnerability and adaptation activities. It represents a relevant tool in the planning of different sectors or activities that develops work programs and assists the Administration and other interested organisations, whether public or private. The first Work Programme of the National Adaptation Plan envisaged only three sectors: coasts, water and biodiversity. The second Programme, with a timeframe of four years, incorporated new elements and activities with a holistic approach by considering health, agriculture, tourism, forests, soil and the combat against desertification, and its last follow-up report was published in 2011.

Water resources

The measures adopted in recent years, in contrast to earlier stages of large hydraulic infrastructures (dams and water transfers), have been directed mainly towards demand management (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis). Available and easily accessible water resources are limited. In addition, a growing population and development pressures, especially in coastal areas, as well as high agricultural needs, among other reasons, have resulted in difficulties to supply all demands with sufficient guarantee or to establish priorities. Therefore, authorities increasingly focus on improving the security of water availability to address main uses, while assessing the sustainability of other growing demands. Since water is a limited and precious resource, it is essential to apply the correct prioritization of uses, establishing river basin district needs, taking into account environmental requirements.

In Spain, water administrations have progressively achieved greater control and regulation of water resources, improving monitoring networks, abstractions control, processing and sanitation techniques. It is expected that the next steps will focus on a better management to control different sectors demands, reduce system losses, raise awareness, continue the modernisation of infrastructures and irrigation techniques, prioritise uses and establish socio-economic activities in the areas best suited for each case.

It is also true that other measures could focus on supply, even if such policies, at the expense of those related to demand management, in some cases can provide greater vulnerability to climate change and aggravate pressures and dependence on water resources.

In Spain, where water resources are heavily regulated -it is the fifth country with the highest number of large dams in the world; INE (2008b)-, an increase in supply is expected mainly from non-conventional resources such as desalination or waste water reuse. Thus, in 2004, the AGUA Programme (Actions for the Management and Use of Water) was approved in order to redirect water policy, which comprised different performances including new desalination plants, mainly in the Mediterranean coast. A production of $1.9 \times 10^6\ m^3/day$ (about $700 \times 10^6\ m^3/year$) for 2009, located Spain as the fourth largest producer of desalinated water after Saudi Arabia, the United States and the United Arab Emirates (MARM 2009b). Recent more humid hydrological years, have decreased however the use of this expensive resource. Regarding waste water reuse, several works have been undertaken in recent years, many of them related to irrigation in southern and eastern parts of the country, with the current annual volume close to $430 \times 10^6\ m^3$ (MAGRAMA 2012a). In both cases (desalination and reuse), the energy and infrastructure development costs are considerable, and the potential environmental impacts should be evaluated. However, these additional resources, readily available in places with the greatest water needs, can become a guarantee for supply as well as significant release of pressure on heavily exploited river flows and aquifers. For the case of desalination, studies have been developed on the effects of increasing water salinity, the effects in the Posidonia oceanica meadows and optimisation of the dissemination and dumping devices of brine into the sea. In addition, a major research effort is being developed also to minimise the energy cost of this practice and encourage the use of desalination technologies based on renewable energies.[16]

Furthermore, DMPs in Spain and the new RBMPs have progressively introduced flexible approaches to adapt to changes in water availability and review measures or proposed infrastructures management (Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014, section 3.7 of this thesis).

A progressive improvement in water demand management in Spain will be essential to achieve a lower vulnerability to the impacts of climate change, as the forecasts predict an overall decrease in the availability of water resources.

Agriculture

Historically, agriculture has shown a great ability to adapt in the long term to changing conditions, whether economic, technological or related to resource availability. Nevertheless, the magnitude of the changes ahead will probably exceed the adaptive capacity of many European farmers. Climate change must be integrated within the overall objective of achieving a sustainable agriculture. In this sector, synergies between adaptation and mitigation are particularly important, with no clear separation between them.

Spanish agriculture has taken various measures aimed at reducing emissions and improving knowledge on them. The Government launched a Slurry Anaerobic Digestion Plan, as well as different measures to reduce nitrogen fertilizer use, introduce energy efficiency criteria in the Spanish Modernisation Plan of tractors and farm machinery and to modernise irrigation[17] systems.

On the other hand, the agricultural sector should also count as a temporary carbon sink, mainly in soils with annual crops. Additionally, this feature as carbon sink could be increased by implementing conservation tillage systems (no-till farming, strip-till or others), or by promoting integrated and organic[18] production and lying fallow, among others.

[16] Las Palmas de Gran Canaria University and the Instituto Tecnológico de Canarias -*Canary Technological Institute* (ITC) started in 2009 the project SODAMEE (ITC 2009), which has designed and is testing a seawater desalination system with wind energy, for producing 18 m^3/d of water in isolated areas with limited technological support.

[17] In 2012, drip irrigation techniques (high hydraulic efficiency) covered 47 % of the national irrigated area, when a decade before then, they did not reach 17 % of the surface. Gravity irrigation techniques (low hydraulic efficiency) have experienced a reverse trend (MAGRAMA 2013a).

[18] Approximately 800 000 ha of integrated production and 1 800 000 ha of organic production are grown in Spain, in the latter case being the largest area of the EU (MAGRAMA and Allué Téllez 2013).

Another eminently territorial policy in Spain is forestry, and the Spanish Forest Plan (2002–2032) is its main tool (MMA 2002). This Plan aims at increasing the sustainability of forest systems with direct effects in the fight against climate change. For instance, it promotes increased CO_2 uptake by reforestation, afforestation of unused agricultural and marginal land or forest-hydrological restorations, which in turn reduce soil erosion and desertification processes.

Regarding adaptation, although there is evidence of spontaneous practices among farmers such as the modification of planting and harvesting dates or the introduction of different crops, it is necessary to implement tools within agricultural policies, especially framed under the CAP, to strengthen the sector's adaptation capacity to climate change.

The CAP is progressing towards strengthening synergies between agriculture, land management, water, food security and climate change. Latest reforms of this policy included in 2003, the decoupling of direct payments or cross-compliance and the 2008 Health Check, reinforced earlier reforms and introduced water management and climate change as new challenges. These reforms seem to facilitate adaptation to climate change, by decoupling subsidies from production, and allowing a more flexible and market-oriented agriculture. Within the recently approved CAP reform 2014–2020, climate change is a particularly important element on account of the high margin for manoeuvre that the agricultural policy presents for mitigation, adaptation and its contribution to the emission reduction commitment.

The agricultural insurance system is a particularly appropriate tool in Spain for adaptation of the agricultural sector to climate change, which has a national public–private implementation with significant aids to farmers. While subsidies on insurance premiums could imply a noticeable decrease in the ability (and interest) of the farmers towards adaptation, they show also the important contribution that the farm insurance can have for adaptation to impacts of extreme phenomena linked to climate change.

3.6.8. Conclusions

Negative impacts of climate change in Spain are increasingly seen as evident. The geographical location, its characteristics and predictions from different models and recent studies place it as one of the most vulnerable countries of Europe. If we add to this, that the country has a fragile water balance, with strong contrasts, a powerful and historical agricultural sector that demands water, and an increased decentralisation of competences to the regions, we find a winding path towards mitigation and adaptation.

Climate change poses a threat to the country's sustainable development, so significant efforts have focused on establishing multi-sectoral coordinating bodies and developing specific adaptation plans and measures for the different sectors.

In the case of water resources, studies point towards more frequent and intense droughts and floods, increases in temperature or decrease in river flows and therefore less availability for different uses among other impacts. These, in turn, will intensify existing conflicts that confront Spanish regions and will further place water in a position of a potential strong political tool. Impacts will be significant also in agriculture, ecosystems and biodiversity, will alter the territory's characteristics and accentuate the desertification problems already present in Spain. In addition to the issues of reduced water availability and increased costs for adaptation measures, pests, invasive species, or a decrease in the amount and quality of crop yields will be part of the foreseeable problems. On the other hand, agriculture is responsible at the same time for a significant contribution to GHGs emissions. A problem that is being addressed, as well as its role as carbon sink.

The Spanish Administration has launched a series of specific measures that focus on the management of water demand, the modernisation of irrigation systems or the commitment for using non-conventional resources such as desalination and waste water reuse without excluding other solutions.

However, coordination among competent authorities, the lack of a firmer commitment to civic contribution, public participation and active learning, the strong defence of regional interests and the politicization of key resources such as water or energy, are part of the challenges faced by the country to achieve an effective adaptation to expected climate change impacts.

It is going to be essential to mobilise and secure the necessary funding for both mitigation and adaptation measures in different sectors and maintain horizontal structures to coordinate plans and strategies, which can be a difficult mission in a situation of economic recession and increasing transfer of competences.

3.7. Adopting the Framework of River Basin Planning for Climate Change Adaptation in Spain

This section reproduces the chapter "Adopting river basin planning as a framework for climate change adaptation in Spain" (Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014) of the book *Adaptation to Climate Change Through Water Resources Management. Capacity, Equity and Sustainability* (Stucker and Lopez-Gunn 2014). The chapter provides an assessment of river basin planning, its status and development, and addresses the issue of whether it is suitable and flexible enough to adapt to climate change. It links adaptive capacity, local actions and participative processes with adaptation and mitigation. The chapter highlights the incorporation of climate change aspects in national policy tools, and the assessment of sectoral tools (specific management plans, such as RBMPs and DMPs).

3.7.1. Introduction

Adaptation was, until recently, neglected in climate change research, with the focus centred instead on the global collective action problem of mitigating emissions (Cerdá Tena and Labandeira 2010; Cerdá Tena 2011). In Spain, this is highly relevant because it is expected to be one of the most vulnerable countries to climate change due to its location in the Mediterranean area. The Mediterranean region, given its natural climate variability, has had a long history of coping and adapting to extreme events such as floods and droughts. However, the main differentiating factors arising from climate change are related to the uncertainty, range and magnitude of potential impacts (Grove and Lopez-Gunn 2010).

Water resources in Spain are of relevance for all economic sectors, but especially for agriculture and tourism, public water supply and ecosystems. The irregular distribution of water resources combined with natural scarcity in some regions, have resulted in a long history of water resources management at the basin scale. In addition, the country has taken the lead at the EU level in incorporating drought planning into river basin management (Garrote, Iglesias, and F. Flores 2009; Estrela Monreal and Vargas Amelin 2012, section 3.4 of this thesis). Furthermore, the prevention of flood events have recently been integrated into the river basin planning process to comply with the EU Floods

Directive (2007/60/EC). Section 3.7, after introducing the context and the high vulnerability of the Mediterranean region and Spain, frames the discussion on a multilevel planning framework, looking at the EU and national levels. Then, we discuss initiatives taken at the basin level to prepare for climate change and analyse these using a leverage points framework (Meadows 1999).

3.7.2. The Mediterranean hotspot: climate change impacts and vulnerability

The responsibility for climate change is not equal among countries and neither is the burden of climate change impacts, which is unevenly distributed. The potential impacts of climate change are going to be geographically distributed and particularly concentrated in so-called "hotspots" (i.e. areas of land and population where the impacts are highly condensed, making them particularly vulnerable to climate change).

The Mediterranean region, where Spain is located, is one of these hotspots (Lopez-Gunn 2009b), with a relatively high degree of agreement between the different predictions from global climate models (García-Ruiz et al. 2011; Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012; Milano et al. 2012). Taking into account the analytical framework used in the book by Stucker and Lopez-Gunn (2014, see Ch. 1 of the book, Figure 1.1), global climate changes are reflected on key variables such as temperature, river flows and rainfall and is likely to produce marked impacts on the state of a range of Mediterranean environments. It will also have differentiated distribution of burdens in relation to those water users and sectors most exposed to climate change impacts such as agriculture, with the most productive areas heavily reliant on irrigation. Equally, higher summer temperatures and more frequent and/or longer heatwaves would impact other sectors like tourism.

The Mediterranean region is an area already marked by climate variability, extreme events and water scarcity. Resources are used intensively, in some cases faster than their rate of regeneration. A high percentage of the population is living along the coast and is thus more vulnerable to sea level rise. The region is characterized by a strong rainfall deficit during the growing season and a cool or cold winter that prevents vegetation from benefiting from or making full use of winter rains. The whole geopolitical region is identified as one of the most prominent global climate 'vulnerability hotspots' in global circulation models (Giorgi 2006). For example, in an area with relatively scarce water resources, run-off in southern European rivers is projected to decrease due to increasing temperatures and a decrease in precipitation (EEA 2007b). A study by Diffenbaugh, Pal, Giorgi, and Gao (2007) has estimated that elevated greenhouse gas concentrations dramatically increase heat-stress risk in the Mediterranean region, with the occurrence of hot extremes increasing by 200–500 %. Extreme events, such as the heatwave experienced in 2003, could become more common in the future, coupled with public health implications if CO_2 emissions continue (Costello et al. 2009). The greatest increase in extreme temperatures was predicted to occur in France and the Iberian Peninsula. These predictions coincide with a coupled RCM used by Somot, Sevault, Déqué, and Crépon (2008), which predicts an intensification of the hydrological cycle and a drier climate over Europe and the Mediterranean Basin. See also energy aspects in box C.

Some river basins in the Mediterranean region are already facing water stress and may see marked decreases in water availability. Recent studies based on RCMs aim to downscale the output from large-scale global climate models, produce finer scale regional climate change simulations and determine with greater certainty expected impacts such as sea-level rise; decreases in precipitation, water quantity and quality, agricultural yields (and food security); and effects on ecosystems.

Box C: Climate change in the Mediterranean region and energy aspects

In terms of existing demand, the Mediterranean region has limited water resources and they are variable in nature and unevenly distributed. North African States have 13 % of the total water resources in the Mediterranean and most countries of the MENA are experiencing water scarcity. By 2025, water demand may rise by 25 % in the South and East Mediterranean. Today, 20 million people in the Mediterranean region have no access to safe drinking water and the situation is becoming worse in rural areas, especially in MENA countries (Blue Plan 2008).
Increased climate variability and change will add further pressure on the need to improve water resource governance and to maximize water efficiency and productivity from irrigated agriculture. In this context, for example, shared groundwater aquifers offer huge potential.
The Mediterranean region generates 8 % of global CO_2 emissions and is likely to be at the forefront of adaptation to climate change. Together with the Arab world, the region is in the epicentre of the water/en-

ergy nexus. First, in terms of water resources, the Mediterranean has 60 % of the population of the world's 'water-poor' countries, yet it is an economically important region precisely because of its Mediterranean climate with 30 % of the world's tourism. Second, in terms of energy and emissions, the disparity between the northern and southern Mediterranean is wide: Spain, France, Italy and Greece are responsible for 70 % of the total emissions of CO_2 in the region. Yet the southern Mediterranean has 5 % of the global oil and natural gas reserves between Algeria, Egypt and Libya, with the EU receiving 18 % of its natural gas imports from these same countries. The importance of these imports (not only for the EU but worldwide) was reflected in the 30 % price increase of oil in the markets due to the stop in Libyan production during the 2011 civil war (Escribano Francés and San Martín González 2011) and the Syrian war is likely to have similar effects. Meanwhile, renewable energies (especially wind and solar energy) are under-exploited, representing only 3 % of Mediterranean energy consumption.

In addition, lost energy due to a number of factors like poor infrastructure is estimated to range from 30 to 50 %, depending on the country (Adamo and Garonna 2009). In addition, according to Blue Plan (2008) estimations, energy demand in the Mediterranean region may increase by 65 % before 2025, due to population growth and higher demand linked to economic development. It is very likely that global warming and increased climate variability could amplify the effects of environmental degradation and energy needs with potential social, economic and humanitarian repercussions.

3.7.3. Adaptation in multilevel governance planning frames

Spain has started to take steps towards adaptation planning in a multilevel framework: initiatives taken at the EU level, which provide a continental level framework for Spain as part of a wider geopolitical region and initiatives taken at the national level.

EU, climate change adaptation and water resources

There is a marked interest in the EU in identifying and downscaling potential impacts of climate change at the regional and local catchment level. One of the 'untapped' opportunities is to incorporate adaptation as part of the comprehensive and sophisticated process of river basin planning under the EU WFD (Directive 2000/60/EC). River basin planning includes all the elements, ready-made structures and potential financing channels for adopting the basic aspects of the EU White Paper on Adaptation (EC 2009a) and the EU adaptation strategy (EC 2013a). The Blueprint to Safeguard Europe's Water Resources (EC 2012a) identified as one of its three key pillars the assessment of water resources vulnerability to climate change and anthropogenic pressures in specific catchments, as well as information on how to integrate climate change in the assessment and review of RBMPs under the WFD (box D and fig. 3.22).

Box D: The EU Blueprint on Water

Catchment Adaptation and the Blueprint to Safeguard Europe's Water Resources COM(2012)673

A decade after the adoption of the WFD, the EC made a retrospective assessment and reviewed achievements to ensure the protection and availability of EU waters. The Blueprint was approved in November 2012 in the form of a Communication called 'A Blueprint to Safeguard Europe's Water Resources', with the objective to look into the future by evaluating water resources vulnerability, taking into account climate change impacts and pressures. The Communication aims at determining the sufficiency of existing measures and tools and to consider potential new instruments. The potential to increase water availability will be assessed, as well as savings and systems resilience. In addition, the Blueprint synthesizes policy options from an assessment exercise, accompanied by reports and new initiatives, including legislative options when necessary.

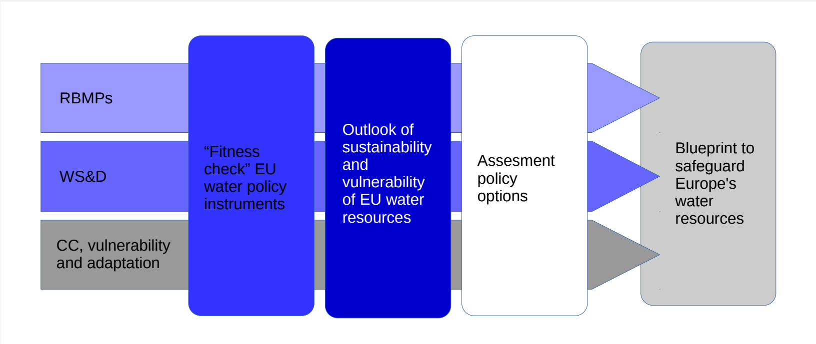

Figure 3.22.: General scheme of the Blueprint. Source: own elaboration based on (EC 2011b).

The three main pillars of the Blueprint are:

1. Assessment of RBMPs (WFD)
2. Review of the policy on Water Scarcity and Droughts
3. Assessment of water resources vulnerability to climate change and anthropogenic pressures

Against this background, the water policy Fitness Check will be a building block of the Blueprint.

In terms of climate change adaptation, some of the proposed actions include improving water efficiency (especially for irrigation practices), decreasing leakage from water distribution networks or promoting green infrastructure and natural water retention measures to minimize floods and droughts impacts. In addition, the Communication promotes better integrating drought risk management and climate change aspects into RBMPs and improving resilience of aquatic ecosystems (e.g. towards invasive alien species). The support of these water measures is proposed through different funds or policies: the Commission's Multiannual Financial Framework 2014–2020, the CAP pillar I, Cohesion and Structural Funds or loans from the European Investment Bank.

National water and climate change adaptation planning

In terms of adaptation to climate change and impact on water resources, it is necessary to look at the intersection of national adaptation planning and national water resources planning. In relation to the former, Spain presented its National Plan on Adaptation to Climate Change PNACC in 2006 (OECC 2006). The Plan provided a framework stating the objectives as well as future climatic scenarios and identified impacts and actions for 15 key sectors, including water. Objectives include:

- Development of coupled climate-hydrology models to obtain reliable scenarios of all aspects of the hydrological cycle, including extreme events.

- Assessment of water management options in terms of the hydrological scenarios generated for the twenty-first century.

- Application of the foreseen hydrological scenarios to other sectors highly dependent on water (energy, agriculture, tourism, etc.).

- Identification of climate change indicators under the implementation scheme of the WFD.

- Development of guidelines and regulations to incorporate the foreseen impacts of climate change into the processes of environmental impact assessment and strategic environmental assessment of plans and programmes within the hydrological sector (OECC 2006).

In relation to adaptation in the water sector, the National Adaptation Plan commissioned a study from the Ministry of Environment, Rural and Marine Affairs to assess climate change impacts with four objectives (OECC 2006): (1) water resources under a natural regime (i.e. considering no infrastructure or flow modifications; (2) water demands (irrigation, public and industrial supply), including adaptation strategy proposals; (3) water resources available by management units (sub-basins division); and (4) to look at the ecological status of water bodies. The first objective was undertaken for the whole of Spain, with results that include updated reports with the latest models and hydrological data (OECC 2006). The climatic data used include climatic scenarios regionalized by the Spanish State Meteorological Agency (AEMET 2008), combining the results of global circulation models made by various international organizations, with techniques of regionalization at the local level.

In relation to national water planning that develops adaptive capacity, measures taken to cope with extreme events are important. In what could be considered spontaneous adaptation and part of the National Hydrological Plan (2001), the Directorate General for Water (Ministry of Agriculture, Food and the Environment) took the lead in coordinating DMPs (CHGuadiana 2007; CHJ 2007; CHS 2007). Section 2 of National Hydrological Plan (2001) considers these plans as an essential tool to reduce the socio-economic and environmental impacts of droughts. DMPs included the development of a national drought indicator system, a strategic environmental assessment, a consultation process and submission to the river basin water councils. The latter approved DMPs in 2007 for all river basins (box E).

Box E: Drought management plans and climate change considerations

The specific objectives of the DMPs are to guarantee water availability required for the population and avoid or minimize any negative drought effects (for example on the status of water bodies, environmental flows or economic activities). The DMPs identify the most adequate mitigation measures, adapted to the different established drought thresholds and phases. During a normal phase, the measures derive from regular management practices. As the drought progresses and a more critical situation arises, measures go from control and information, to conservation, restriction and prioritization of uses.

Precipitation regimes of Spanish basins are highly variable, which has fostered the use of non-conventional resources and numerous retention and storing infrastructures (dams, weirs, channels, etc.). These characteristics and infrastructure are considered in the DMPs. The first supply priority established in the DMP is for the population, the second for the environment. Environmental minimum flows are decreased during a drought episode only under the circumstances that urban supply is compromised. Irrigation and other uses under a water scarce situation come in third and fourth places respectively.

Surface and groundwater resources are characterized and described in the plan, as well as additional inputs, e.g. from water transfers, waste water reuse and desalinated water. Climate change could alter this

characterization, but the plan already considers estimation revisions according to the PNACC and research study results.
The DMPs are not reviewed according to a specific schedule, but any of the following circumstances can trigger a revision:

- Modification of minimum environmental water levels established by the RBMPs.
- Substantial alteration of the information related to aquifer abstractions.
- Relevant improvement of the knowledge on water resources dependence mechanisms of habitats and species.
- Relevant improvement of the knowledge of the hydrological relation between areas of environmental protection, surface water or groundwater bodies.
- High magnitude variances, which require introducing important changes to indicators, forecasts or the programme of measures of the DMP.

To ensure that there is a continuous follow-up of the DMP's implementation, river basin authorities have to set up Technical Drought Offices since the beginning of the water scarce period (pre-alert status according to the plan). There is also a Permanent Commission for Drought Follow-up made up of representatives from the RBA, users and interested parties or stakeholders. The plan takes into account possible increases in urban and industrial consumptions (percentages per month) due to extreme climate conditions.
For example, in the case of the Segura Basin (CHS 2007) these increases vary between 10 % and 15 % for urban areas, 7.5 % for industry and 18 % for irrigation. The plan presents elasticity towards actions: each consumption type can be reduced to some point depending on the involved factors (for instance economic impacts or drought duration). Measures are presented assessing average reductions in each case and per demand activity (indicating the time horizon in which reductions are expected and their duration).

The indicator system used in these plans is based on drought risk (table 3.6 and fig. 3.23), from very low to very high, which is then translated into water planning assigned to sub-basins depending on different status levels (normal, pre-alert, alert and emergency). With the gathered information and indicator status, drought risk maps are generated on a monthly basis and made publically available.

Table 3.6.: Typology of drought risk for water planning

Drought risk indicator	1.0 – 0.5	0.5 – 0.3	0.3 – 0.15	0.15 – 0
Status	Normal (green)	Pre-alert (yellow)	Alert (orange)	Emergency (red)
Objective	Planning	Information - control	Conservation	Restrictions
Type of measure	Strategic	Tactical	Tactical	Emergency

Source: CHJ (2007).

Droughts were considered a crisis until the development of DMPs. The approval of these new Plans meant that these were fully integrated into the general planning framework (see table 3.7), through a risk analysis and development of a strategy (Antolín 2008). One of the main reasons for the emergence of DMPs as a proactive planning approach was the response to the severe drought of 1993–1995. The drought affected more than 11 million people in eastern and southern Spain, which suffered water restrictions and associated water-quality problems in their public water supply. Estimates of agricultural losses ranged between US $ 4.7 billion and US $ 10 billion at 1995 value. Since the 1990s, drought has been the natural hazard that has affected the most people in Spain (Garrote, Moneo, Iglesias, and F. Flores 2009). These drought plans are a positive example of proactive policy-making related to climate variability and they represent strategic tools with concrete results in terms of drought warning, impact mitigation and aquatic ecosystem protection (Estrela Monreal and Vargas Amelin 2010; Estrela Monreal and Vargas Amelin 2012, section 3.4 of this thesis). DMPs define the different actions to be taken, which include enforcing water demand reduction strategies, establishing priority between uses and developing specific water infrastructure works.

Table 3.7.: Integration of climate change impacts into water planning

Level	Year	Initiative	Details
EU WFD and its implementation in Spain	2000	EU WFD	RBMPs should include information on whether planned measures are climate change proofed according to the agreements made under the WFD Common Implementation Strategy.
	2007 and 2008	HPR[a] and TIHP[b]	Art 11.4 of HPR: Inventory of Natural Water Resources, establishing the balance between available resources and foreseeable demand for different uses and their allocation. Concept of available resources to include a reserve for environmental demand requested under the WFD in terms of water resources. Due consideration should be given in water planning to climate change.
National	From 2005	National and DMPs[c]	e.g. CHGuadiana (2007)
Regional	Various	Regional strategies addressing climate change	e.g. Castilla-La Mancha, Extremadura and Andalusia
Local	Various	e.g. Cities (Ciudades contra el clima) companies e.g. Public water supply	e.g. Canal de Isabel II (public water supply company of Madrid)

[a] Spanish Hydrological Planning Regulation (2007).
[b] Technical Instruction on Hydrological Planning (2008).
[c] Foreseen in (National Hydrological Plan 2001) under section 2.

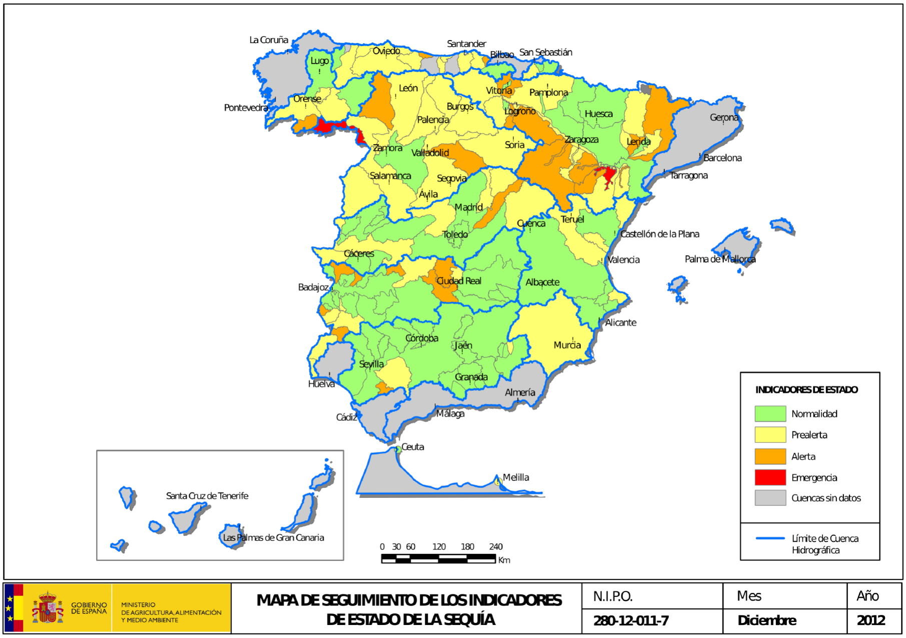

Figure 3.23.: Map of drought status in Spain, December 2012. Source: MAGRAMA (2012b).

3.7.4. Downscaling adaptation to the river basin

It is at the level of the river basin that the intersection between EU and national planning is grounded. For the case of Spain, the development of adaptation in relation to water resources had two clear phases. The initial phase, from 2000 to 2010, was marked by initiatives taken at the national level through the incorporation of adaptation into river basin planning as a result of the national adaptation plan and the development of DMPs. The second phase, from 2010 onward, is incorporating EU regulation in the form of the WFD, the Floods Directive and voluntary adaptation measures for river basin planning, which in Spain coincides with the adaptation developed under national adaptation and water planning policies.

First phase: spontaneous adaptation of river basin planning at national level

Climate change impacts were considered for the first time in the preparation of the White Paper on Water in Spain, as part of the Technical Documents prepared for the 2001 National Water Plan. This White Paper (CHJ 2007) undertook a study on how two scenarios (1 and 2) would impact river flows up to 2030. This in turn helped to generate water scarcity risk maps showing temporary scarcity and structural scarcity as well as percentages per river basin of the drop in rainfall for these scenarios (table 3.8 and fig. 3.24).

Each RBMPs is expected to estimate the balance between available water resources and projected water demands for different uses, taking into account climate scenarios, like those produced by the AEMET (2008) study. The Spanish Hydrological Planning Regulation (2007) determines that this balance should be done for the 2027 time horizon taking into account climate change impacts on water resources. RBMPs and their PoMs should check that medium and long-term planned measures are coherent with foreseeable climate change impacts. The latest cycle of Spanish hydrological planning indicates some evidence of a drop in rainfall when using the 'short series' (i.e. from 1980/1981–2005/2006), compared to the 'long series' (1940/1941–2005/2006). Precipitation from 1961 to 1990 often reached a 30 % decrease in the summers (CEDEX 2011; Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis). It is predicted that there will be an average drop in river flows (for example, 19 % in the Guadiana basin), a shift towards more rain in autumn and a higher frequency and intensity of droughts periods. This corresponds with estimates in Estrela Monreal, Gallart, and Iglesias López (2005) of an average reduction in precipitation of 35 % for the horizon 2070–2100 (up to 48 % for the city of Madrid) and increases in temperature.

However, there could be other important factors that affect river flow data, for instance water abstractions (not always fully controlled), river regulation, natural variability, land use changes (García-Ruiz et al. 2011; Willaarts 2012) and water use volumes. It is not always easy to clearly differentiate or establish the effects of climate change on water resources through statistical data analyses. Thus, river basin authorities are increasingly using hydrological simulation models to improve the understanding of potential impacts and causes (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis).

As discussed earlier, DMPs were developed in 2007 for all Spanish River

Table 3.8.: Climate scenarios from different authors

Scenario 1 by 2030.[a]	Scenario 2 by 2030.[b]	Scenario 3 by 2030.[c]	Scenario 4 by 2060.[d]
1 °C increase no change in rainfall	1 °C increase 5 % decrease in rainfall	no change in rainfall	2.5 °C increase 8 % decrease in rainfall

[a] CEDEX 1998.
[b] MMA 2000.
[c] Fernandez Carrasco 2002.
[d] Ayala Carcedo 1996.

Basin Districts and have been implemented and used since then. From the point of view of developing adaptive capacity for climate change and extreme events, these provide a very important stepping-stone in reducing vulnerability to droughts. DMPs already consider climatic variations and flexibility in adaptation planning and implementation of measures according to water availability reduction scenarios. The experience in producing and applying DMPs could provide a 'template' or precursor, paving the way to elaborate climate change adaptation plans by incorporating a range of additional risks (like, e.g. floods and heatwaves).

Second phase: adaptation planning at basin scale under the EU

In the first cycle of river basin planning there was no obligation to consider or include planning for climate change. However, as established by the WFD CIS, RBMPs must include a Climate Check on their PoMs. Undertaking this in a coordinated way for the different river basins is still to be worked out. Nevertheless, most plans in Spain—in an example of spontaneous adaptation—have included a section that considers climate change. By September 2013, most of the updated RBMPs in accordance to the WFD were approved, with the exception of Júcar, Tagus, Segura and Ebro. These plans were developed for watersheds within the corresponding autonomous regions (Galicia and Andalusia).

Flood management plans are being developed according to the EU Floods Directive and should be approved by 2015. These also mean, in effect, an increased capacity for planning for extreme events at the basin level. However, as discussed below, it is the coming phase that will provide the real test, since the 'philosophy' underpinning EU river basin adaptation planning and the adaptation frame for Spain have some important differences. Box F captures the experience in the Júcar basin.

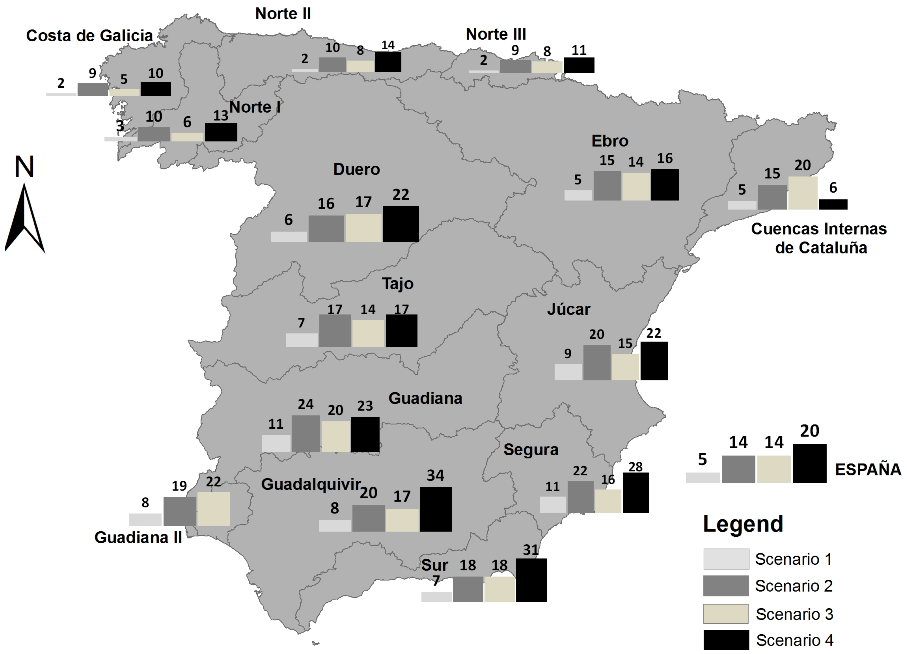

Figure 3.24.: Scenarios of potential reduction in water resources by river basin. Source: own elaboration based on data from OECC (2006).

3.7.5. One step forward two steps back: opportunities for adaptation through river basin planning

In terms of barriers and bridges to adaptation in water resources management at the basin level, this section discusses the 2015 planning cycle, when revised RBMPs should be ready.

Box F: Júcar River Basin Management Plan: Predicted impacts and adaptation

For the case of the Júcar RBMP, a reduction in water resources of 12 % is being considered (which is higher than the 9 % indicated in the Spanish Hydrological Planning Regulation (2007)) and takes into account recent studies and those developed by Chirivella Osama, Capilla Romá, and Pérez-Martín (2011) for the Júcar Basin. The draft RBMPs for the Júcar Basin (CHJ 2009) considered the official predictions of the Spanish White Paper on Water (MMA 2000) and two possible scenarios under the prospect of a doubling of CO_2 emissions: Scenario 1 with a potential increase of 1°C in annual mean temperature and Scenario 2 with the same temperature increase, but a decrease of 5 % in annual mean precipitation. For the Júcar River Basin District, the reduction of total renewable water resources have been calculated for the time horizon 2027 obtaining the following: for Scenario 1 a mean 9 % reduction and under Scenario 2 a 20 % reduction. What is most important for basin planning and adaptive capacity is that, according to the Technical Instruction on Hydrological Planning (2008), these reductions have to be reflected in the water balance between available resources and demands, in the progressive updates of the plan and in the implementation of the river basin plan measures.

The draft RBMP considers that climate change effects will more likely translate into an increase of floods and droughts and sea level rise with coupled coastal erosion. To cope with these impacts, a range of different measures is included in the PoMs in order to: reduce flood risk in the most vulnerable areas, plan and manage drought episodes, minimize extreme climatic phenomena and sea level rise impacts on the environment, assess beach erosion impacts and costs of regeneration measures (which is linked to the National Strategy for Sustainable Coastal Areas) and promote aquifer protection to avoid saline intrusion.

The managing authority envisions applying measures consistent with foreseen climate change impacts to increase the resilience of the system, for example recovering riverine woodlands. The Júcar draft RBMP considers measures that are linked directly to the protection of aquatic ecosystems, taking into account a possible decrease in water inputs. These measures include, for instance, ensuring ecological flows in rivers and decreasing urban and industrial waste water discharges.

One step forward. . .

One of the main bridges in Spain is the well-established tradition in river basin planning which has made it possible to spontaneously integrate adaptation into the existing national frames, even ahead of the EU. According to the theoretical framework of the book (Stucker and Lopez-Gunn 2014), this indicates a level of robustness in terms of local adaptive capacity. Compliance with the national Hydrological Planning Regulation (Spanish Hydrological Planning Regulation 2007) goes one step ahead on the WFD, since updated plans already incorporate climate change aspects. This Regulation requires the calculation of balances between demand and available resources to 2015 using available series (1940–2005 and 1980–2005). More specifically, with regard to the evaluation of the effect of climate change on water resources, the Regulation states that:

> To assess long-term trends, for the 2027 time horizon the plan should estimate water balances between predictably available resources and the foreseeable demands expected for the different uses. To achieve these balances, the potential impact of climate change on natural water resources should be taken into account. (Spanish Hydrological Planning Regulation 2007, art. 21.4)

The Regulation establishes that 'these estimates should be done using hydrological simulation models that would determine resources corresponding to climatic scenarios provided by the Ministry of Environment and Rural and Marine Affairs'. Furthermore, it indicates that – if the scenario assessments are not available – reference reduction percentages should be applied. In many basins, the results from the recent study by CEDEX (2011) have been incorporated. Most of the updated RBMPs have used these reference reductions, ranging from 2 % in the Cantábrico to 11 % in the Segura, one of the basins most at risk for the year 2027 (table 3.9). This leaves the simulations suggested in the Regulation for the next planning cycle, set for 2015. In a strict sense, now that more updated studies are available these reduction coefficients should be updated.

The pre-established reference reductions in the Decree have been used in other cases, such as in the recently approved RBMPs for Galicia Coast. In the Cantábrico basin it is interesting to note that, while it expects the lowest reduction of water resources (2 %), it has allocated the greatest percentage of its budget for adaptation measures (fig. 3.25). For the nine basins (out of 27),

Table 3.9.: Estimated reduction due to climate change in natural water resources availability by river basin

River basin	Percentage reduction
Guadiana	11
Segura	11
Júcar	9
Guadalquivir	8
Tajo (Tagus)	7
Duero	6
Ebro	5
Miño-Sil	3
Cantábrico	2

that cover most of Spain and span over more than one region, there are only four plans that define climate change adaptation measures as such, as for the Cantábrico or the Ebro. In basins managed by regional governments, there are two plans: Galician Coast and the Basque Basins. However, estimated investments for these measures peak at only 0.15 % of the respective RBMP budget. It could seem paradoxical that the basins that are expecting to experience the lowest level impacts (e.g. Cantábrico) are the ones dedicating most financing efforts to adaptation measures. On the other hand, these basins are located in more humid climates with attendant limitations in river regulation capacity, making them more vulnerable, for instance, to short drought events.

However, this analysis on adaptation measures is preliminary. In many cases it is difficult to clearly distinguish climate change adaptation measures from those focused on demand management (e.g. to improve efficiency) or supply increase (e.g. waste water reuse). These types of measures are in many cases triggered by climate change effects as resources decrease and water scarcity increases. Figure 3.25 shows measures embedded in RBMPs that explicitly refer to climate change adaptation. The per cent of the total budget allocated to the plans' programmes of measures is also indicated, although these figures could be low for the reasons just explained. Horizontal adaptation measures should also be considered, as well as other measures that, while related to climate change adaptation, are classified under other categories within the plan. An important issue in the current Spanish economic context is that, under the first cycle of the WFD water planning (2009–2015), it is not compulsory to consider climate change. Therefore, it is difficult to justify new investments to compensate for potential climate change impacts. The second best option has been to ensure that measures adopted are coherent or aligned with the foreseen climate change scenarios.

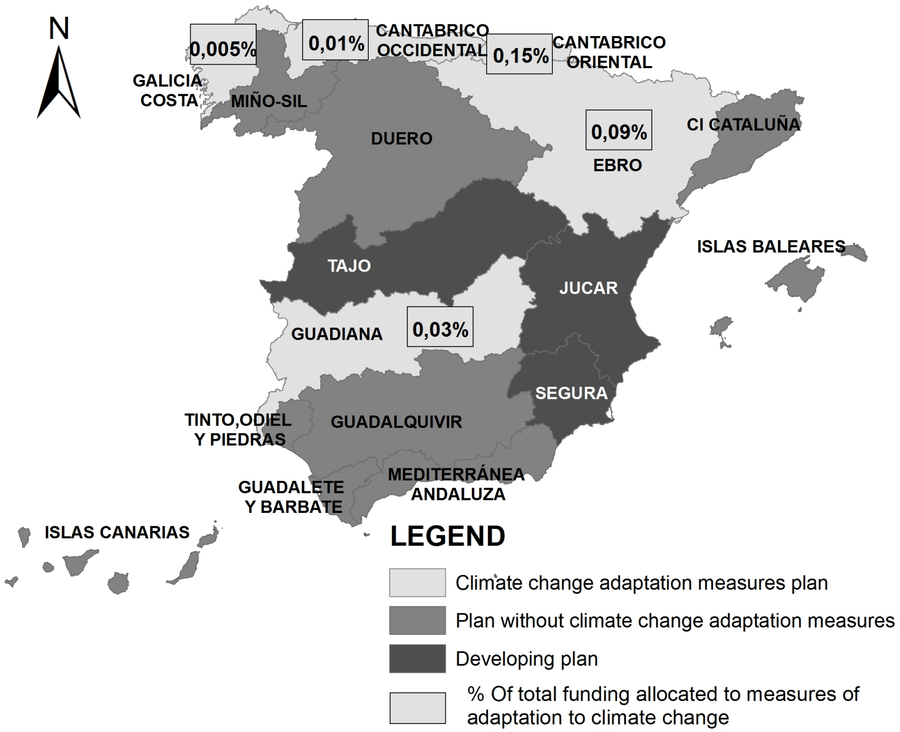

Figure 3.25.: Inclusion of climate change adaptation measures in RBMPs and percentage of budget, February 2013. Source: own elaboration.

... and two steps back

One of the main barriers when addressing adaptation is a heavily techno-centric and top-down approach to river basin planning. Adaptation will require a more networked approach to governance where there is less familiarity in Spanish water planning cycles. In this sense, it is clear that the supply aspects in adaptation are much more developed than the demand side ones. Thus, it is desirable to incorporate climate change expected impacts on demands. The current law does not address this issue and technical and scientific studies are more limited in this area where effects present higher uncertainty. Additionally, an area not fully explored so far due to the disconnection between land use and water planning is the potential offered by green infrastructures. This could be due to a number of reasons ranging from the fact that water agencies have no competences on land use planning to a traditional preference for 'hard' infrastructures.

Overall, water management and planning practices are the river basin authorities' competence, while land planning and agricultural aspects lie under the regional governments' responsibilities. Public water supply and local transport facilities are managed by municipalities. This pool of different management levels and maze of organizational responsibilities has made it more difficult to approach the horizontality of climate change impacts on water in a coordinated way. Particularly noticeable has been the limited engagement with local stakeholders and the identification of the different roles for different players.

In fact, the role of NGOs and Civil Society Organisations (CSOs) at the local, regional (i.e. Autonomous region) and river basin scale has consisted mainly in critically assessing national strategies, scientific studies and initiatives related to climate change and water. There is limited evidence of specific local actions beyond those taken by municipalities that could increase the adaptive capacity or raise public awareness on climate change impacts in the water sector. Among other reasons, this could be due to the slow-onset nature of these risks combined with a legacy of lack of funding for NGOs and CSOs to launch participative actions.

Some of the areas that still need to be assessed are the effectiveness in the application of the water reduction percentages and implementation of measures in RBMPs in terms of adaptive capacity, environment impacts, water equity and people's livelihoods. For instance, more analysis is needed on whether the administrative and technical processes will be adaptable, flexible and responsive to further adaptation measures and water infrastructures if water reductions vary considerably from the estimated percentages. It is also important in the medium and long term to assess the conditions that impede and facilitate these adaptation strategies (e.g. political will, technical and economic resources and local stakeholder involvement and engagement). In addition, there is a need to evaluate the capacity of the population and sectors most vulnerable to severe climate change related extreme events such as prolonged droughts (i.e. to increase the resilience to risks). In reference to the theoretical framework of the book (Stucker and Lopez-Gunn 2014), the evidence indicates that certain factors increase local adaptive capacity (flexibility on updating plans) and others decrease it (limited public involvement).

Finally, RBMPs are developed for quite large geographical scales; the Júcar basin, for example, is 42 900 km^2. In many cases, technical measures apply to large problems that affect several municipalities and even regions. The latest discussions focus on applying more case-specific adaptation strategies that actively involve CSOs and even develop plans for larger cities that might have very specific characteristics and face concrete challenges like the case of Madrid (Lázaro-Touza and López-Gunn 2012). Competent authorities in these cases vary and have different technical and political approaches (e.g. RBA and the City Hall). Thus, it will be important to determine synergies for working in parallel, ensuring strategies that make adaptation plans at different scales compatible.

3.7.6. Conclusions

The precision of climate change scenarios is limited and downscaling techniques to determine effects at local levels can be challenging. Thus, managers and scientists sometimes question the efficiency of measures developed at the local and/or regional levels. On the other hand, if authorities do not support these adaptation efforts, the gap between the desired and current local state could widen. Where there is an engaged civil society, however, public concern and spontaneous local adaptive capacity building and adaptation measures could emerge. The effects of climate change are increasingly being monitored and documented and the direct influence of human activities is indisputable. Changes in climate are directly impacting the water cycle and water resources availability, which are particularly noticeable in the Mediterranean region and, as shown, in Spain.

Due to its geographic location, Mediterranean climate and socio-economic factors, the use of water resources in Spain has been traditionally maximized through water infrastructures. Progressively, a shift has been incorporated from water supply to demand management by including planning and adaptation strategies. Thus, the inclusion of climate change aspects in water planning processes has become a reality. Although climate change effects have a slow onset and are hard to predict due to different factors (data robustness, natural variability, water abstractions control, etc.), the use of models for different climatic scenarios and downscaling techniques are indicating non-negligible effects: e.g. lower precipitation levels, decrease of river flows and increase of number and intensity of droughts.

All of these impacts affect water availability for different socio-economic sectors and the environment. There have been influential initiatives and studies at the EU, national and river basin levels to better understand expected impacts. For instance, the first RBMPs in accordance with the EU water policy WFD have considered water balances in the medium term being consistent with the PoMs. Meanwhile, adaptation measures and initiatives at the autonomous region or local levels are more patchy and emergent and they usually run without a common thread, due to some extent to the complex administrative context and levels of competence. Moreover, local actions that could increase adaptive capacity or raise public awareness on climate change impacts in the water sector are limited (like in the case of the Júcar basin), as well as bottom-up initiatives and participative actions.

Important barriers for strengthening adaptive capacity include adequate coordination between different economic sectors and across administrative boundaries. This could prove difficult considering, for example, the complexity of aligning water and energy policies, or agricultural and water demands, or in terms of administration coordination between regional governments and river basin authorities, which would need to strengthen integrated land and water use planning.

In spite of these barriers, there are relevant bridges for building on capacity and adapting to climate change impacts. These can be found in technical management plans that consider flexible measures to cope with water issues directly linked to climate change effects. For instance, Spanish DMPs and RBMPs include programmes of measures that already anticipate climate change effects and variability in water resources availability and set actions accordingly. These also present a basis to build upon, together with future flood plans, with clear flexibility in terms of applying changes in water availability percentages, revision of plans and consideration of newer climate change studies. The policy and technical experiences derived from these plans could eventually provide a robust base and be highly valuable to produce future climate change adaptation plans.

Spanish RBMPs will need to consider newer and more sophisticated studies that engage with uncertainty in terms of climate change effects on water resources. Moreover, these plans will need to incorporate possible updates in

EU legislation, such as the Water Framework Directive (2000), or in specific policies such as the CAP, which could require further climate change considerations. Furthermore, progress is still needed in assessing specific areas such as impacts on ecosystems, on demands and on water balances that could limit water use in the future.

Some additional aspects to be considered include coordination mechanisms, including sectorial climate change adaptation plans, assessing the conditions that impede and facilitate adaptation strategies and finding methods to integrate adaptation plans that apply to different scales (e.g. river basin vs city plans) while actively involving stakeholders. Furthermore, technical experience should be transferred to society in ways that develop adaptive capacity and can be easily interpreted, fostering resilience to extreme events such as heatwaves and droughts.

Adaptive capacity in the second round of RBMPs should be strengthened with the development of best practice guidelines on e.g. eco-adaptation, catchment planning and societal involvement at the local level. Adaptation plans could then be assessed (or developed where these do not yet exist) and embedded into existing planning frameworks, in particular those related to land use, Local Agenda 21 and RBMPs in compliance with the Water Framework Directive (2000). Thus, the main bridge for adaptation at the river basin scale in Spain will be the successful integration of technical planning measures with societal demands and capacities.

3.8. Climate Change Policy and Water Resources in the EU and Spain. A Closer Look Into the Water Framework Directive

This section reproduces the article "Climate change policy and water resources in the EU and Spain" (Escribano Francés, Quevauviller, San Martín González, and Vargas Amelin in review) which provides a comparison between EU and national policies on water and climate change, with a greater focus on the WFD as main overarching water protection legislative piece. It addresses policy implementation and coherence, economic tools and needs, and the interface with research programmes and projects. The article also approaches emerging issues, such as the water-food-energy nexus, the use of green infrastructures, or the usefulness of ecosystems services valuation.[19]

3.8.1. Abstract

Climate change effects are becoming evident worldwide, with serious regional and local impacts. The EU has launched and developed initiatives and policies that scratch the surface of water resources impacts. This article presents an introduction of the existing environmental policy and more concisely in the areas of climate change and the interactions with water resources. It also addresses main management tools, and plans linked to policies, recent updates on the Science-Policy Interface (S-PI), highlighting major results from research and development projects. The importance of establishing appropriate policies to tackle climate change impacts on water is essential given the cross-sectorial and flowing nature and the importance of water in all environmental, social and economic sectors. There are still some pending reviews and updates in the current EU policy and its implementation, as well as at the national level in Spain. This article identifies existing gaps, and provides recommendations on how and where reforms could take place and be applied by decision makers in the water policy sector.

[19] Acknowledgments: Authors would like to thank Vicente Ramírez Perea for his contributions to improve the style and formatting of the article.

3.8.2. Introduction to climate change and EU policy

The evidence that climate change is producing effects at the global, regional and local scales is growing, as well as the recognition that human action has had a clear impact on its development and on the worsening of natural climatic variations (EEA, EC-JRC, and WHO 2008; IPCC 2013b).

Impacts in Europe include increases in temperatures, changes in precipitation and decreases in ice and snow, with high vulnerability of mountain and coastal areas as well as the Arctic and the Mediterranean region (EEA 2012a; EEA, EC-JRC, and WHO 2008). Decrease in precipitation and runoff in Mediterranean areas, could in addition aggravate other existing problems such as saline intrusion in aquifers, coastal subsidence, water pollution problems and agricultural pressures due to high water demands (EC 2009a; EC 2009b; EEA 2012a; IPCC 2008; Somot, Sevault, Déqué, and Crépon 2008). Furthermore, these impacts could translate into modifications in habitats, reduced crop yields, impacts on human health, and increasing conflicts over water uses or have effects on security issues (Estrela Monreal and Vargas Amelin 2008; EC 2011a).

Many of the problems and impacts on water resources derived from climate change are not new. In fact, MS have often faced floods, water scarcity, heat waves, prolonged droughts, flows variability, temperature rises, and decreased rainfall. However, studies suggest that climate change will cause a higher frequency and amplification of these problems (IPCC 2008), as well as a shift to countries that may lack sufficient experience to incorporate uncertainty into water planning (Arnell et al. 2001). Furthermore, impacts will affect water treatment, system reliability and operating costs as many forms of pollution are expected to be exacerbated (EC 2011a).

In recent years, European institutions have launched numerous actions, strategies and policy instruments related to climate change in the EU although knowledge and policy gaps still exist. While the specific impacts on water resources vary considerably among European regions, Spain is considered to be in a 'hot spot' where a greater increase in temperature and decreased precipitation, evapotranspiration and runoff are anticipated (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis; Lázaro-Touza and López-Gunn 2014; Morata Gasca 2014).

In addition, the variability of temperatures and the spatial and temporal distribution of water resources are very high within the country, with annual mean precipitation values ranging from 2000 mm in the North-West to less than 300 mm per year in the South-East. This variability, coped with the uncertainty of regionalised models and downscaling techniques adds difficulties to estimating the direct effects of climate change in water resources. However, one of the most recent and comprehensive studies developed at national level (CEDEX 2011), provides some important insights of impacts expected in the short-medium term. It predicts a generalised reduction of precipitation and water availability (near -5 %, -9 % and -17 % during the periods 2011–2040, 2041–2070 and 2071–2100 respectively), with the greatest variability occurring in the Mediterranean coast and in the South-East. In addition, the study predicts increases in temperature, evaporation and evapotranspiration, and decreases in groundwater recharge and runoff.

Spain is in the process of complying with EU policies and respond to the recommendations made on climate change mitigation and adaptation.

3.8.3. EU climate change policies

Over the past years, one of the most important documents on climate change adaptation published by the EU was the White Paper *Adapting to climate change: Towards a European framework for action* (EC 2009a). This paper established a framework to reduce the EU's vulnerability to the impacts of climate change, and marked the starting point for implementing a strategic approach to ensure that adaptation measures were consistent across different sectors and levels of management. That is, it started to strengthen the concept of policy coherence. The White Paper also recommended the integration of climate change adaptation in the implementation of EU policies on water. More recently, the EC published the Green Paper, 'A framework for climate and energy policy in 2030' (EC 2013c). This document launched a public participation process to gather ideas that would allow establishing goals up to 2030 on energy and climate policy (carbon sequestration, reduction of greenhouse gases, fund raising and support of a competitive economy while energy security would be promoted).

Furthermore, and with greater relevance, the Commission adopted and EU strategy on adaptation to climate change on April 2013 (EC 2013a). The aim of this strategy is to make Europe more climate-resilient, complement on-going efforts within MS, promote information-sharing, coordination of efforts, and sector and policy coherence. It builds on the demand to develop conceptual and practical systems for monitoring impacts of, and adaptation to, climate change and to inform the adaptation policies. It is important to highlight that the Strategy provides funding tools to strengthen adaptation capacities, and addresses specific vulnerable areas such as water resources.

Moreover, while substantial progresses have been made on mitigation to achieve the established '20-20-20' targets (20 % reduction of greenhouse gas emissions, 20 % share of renewable energy consumption, 20 % improvement of energy efficiency), the 2030 framework for climate and energy policies goes further and establishes stronger commitments. As stated by the EU Council conclusions of October 2014 (European Council 2014), new targets are set to reduce greenhouse gas by 40 % (compared to 1990 levels), and achieve a share of renewable energy and energy savings of at least 27 %. EU documents that have linked even more closely climate change and water are mainly the Water Framework Directive 2000/60/EC (Water Framework Directive 2000), the Guidance Document No. 24 *River basin management in a changing climate* (EC 2009c) within the CIS or the communication of the *A Blueprint to Safeguard Europe's Water Resources* (EC 2012a).

The WFD[20] does not explicitly address the relationship between climate change and RBMPs, although all qualitative and quantitative water aspects referred in the directive may be affected by climatic changes. Annex II of the Directive however, refers to the need to identify 'significant pressures' affecting water bodies, it provides a framework to incorporate the impacts of climate change in the water planning process. In addition, the cyclical approach of the Directive, with specific steps and envisioned periodic revisions, which allow incorporating scientific and technical progresses, and the integration of other Directives domains within the text (habitats, agricultural development) make this policy suited to adapt to and manage climate change impacts (Quevauviller 2014). Given that climate change could aggravate future anthropogenic pressures, expected impacts should therefore be considered within the framework of the Directive (Quevauviller 2011; Wilby et al. 2006). The Guidance document No. 24, previously mentioned, provides more direct support to river basin organisations for incorporating climate change projections into the second and third planning cycles and more specifically in the assessment of pressures and impacts, monitoring and establishment of measures. The document gives recommendations on how to manage the available scientific knowledge and high level of uncertainty in data, or to address specific challenges such as floods and water shortages. For instance, the document

[20] According to its article 19, 'Plans for future Community measures' a revision of the Water Framework Directive (2000) should take place in 2019.

recommends the process for determining if measures are climate proof and ensures revisions for each planning cycle, so updated scientific evidence is considered and uncertainty decreased (see fig. 3.26 on the planning cycle).

Overall, the WFD comprises monitoring, reporting and evaluation systems that could significantly contribute to have a broader and more comprehensive view of climate change impacts in the EU and adaptation actions in the water sector.

As part of the assessment of EU water policies, and more closely on the WFD, the communication of the 'Blueprint' (EC 2012a) also presents a series of actions and recommendations that are directly linked to climate change aspects. These include improving water efficiency (especially in irrigated agriculture), reducing losses in distribution networks, promoting 'green infrastructure' and natural water retention measures that minimise impacts of droughts and floods, better integration of risk management and drought issues in RBMPs, and improving the resilience of aquatic ecosystems (e.g. when facing the impacts of invasive species).

To support these measures, the Communication proposes the use of the 2014–2020 Multiannual Financial Framework (in this instrument, circa 20 % of the funds are allocated to climate related actions), Pillar I of the CAP, Structural and Cohesion Funds or loans from the European Investment Bank.

Finally, it is important to keep in mind the importance of anticipating to adverse effects of climate change and act in ways so these can be prevented or expected damages minimised. It is therefore essential to address the particularities of water-related disasters, which fall under other EU policies such as the Floods Directive (2007), or the strategy on water scarcity and drought and its communication (EC 2007a).

3.8.4. Research and Development projects, science-policy interface

There have been different research and development lines promoted at the EU level to fund specific environmental related projects, and more specifically to water and climate change. Some of these lines were included the 6th and 7th FPs and more recently Horizon 2020 (2014–2020).

Within the European Commission, the Directorate General for Research and Innovation is responsible for Horizon 2020 the largest EU Research and Innovation programme that has commitment to dedicate at least 35 % to climate-related research, through both specific climate research and the inte-

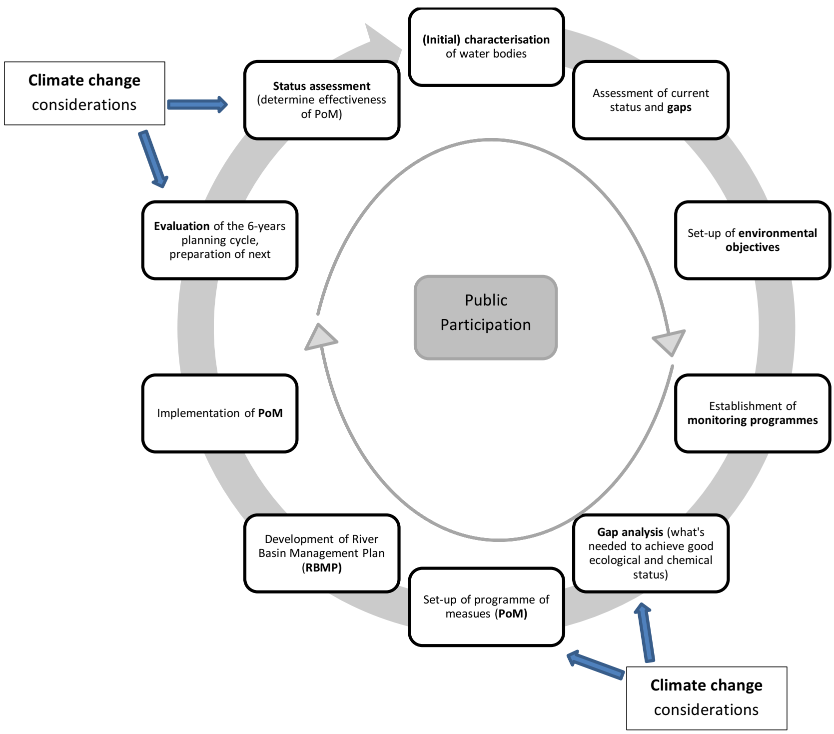

Figure 3.26.: Planning cycle according to the Water Framework Directive to develop River Basin Management Plans, including main steps at which climate change considerations should be incorporated. Own elaboration, based on EC (2009c).

gration of climate into the full research and innovation agenda. Furthermore, the Commission has initiated *A European research and innovation Roadmap for Climate Services* (Street et al. 2015) to be implemented through Horizon 2020. There are also ongoing projects under FP7[21] that are explicitly addressing the topics of adaptation, evaluation of impacts and vulnerability. In addition, EU institutions such as the Joint Research Centre, are also working on several projects addressing impacts, vulnerability and adaptation. For instance, the Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis (PESETA)[22] set of projects cover estimations on projected impacts and costs of climate change in the EU over the 21st century, including impacts on ecosystem services (see box G under section 3.8.8).

There are several examples of projects that have focused on climate change effects on water resources. For instance, and to name a few, the WATCH[23] (2007–2011) project examines climate change impacts on the global water cycle, evaluates uncertainties and addresses vulnerability issues of global water resources cycles. The project EURO-LIMPACS[24] (2004–2009), evaluates global climatic changes on freshwater ecosystems at the catchment scale, examining interactions with other drivers and pressures at multiple time scales. The project CIRCE[25] (2007–2011) covered climate change impact in Mediterranean regions, assessing specific effects in the hydrological cycle, such as changing precipitation patterns. A third specific example is the AquaStress[26] project (2005–2009), which approaches water stress with the integration of management, technical, economic and institutional instruments.

To adopt effective and resilient actions in water management, it will be essential to integrate recent research projects' results within EU water and climate policy cycles; that is to ensure effective science-policy interfacing mechanisms. This type of interfacing would also facilitate connecting scientific results at different scales, the exchange of findings and the identification of required adaptation measures in river basins (Quevauviller 2014; Quevauviller et al. 2012).

[21] Within the European Commission's web site http://cordis.europa.eu projects in the area of 'climate change and carbon cycle research' can be searched and selected.

[22] https://ec.europa.eu/jrc/en/peseta

[23] http://www.eu-watch.org/

[24] European project to evaluate impacts of global change on freshwater ecosystem (EURO-LIMPACS)http://www.eurolimpacs.ucl.ac.uk/

[25] http://climate-adapt.eea.europa.eu/projects1?ace_project_id=30

[26] http://www.aquastress.net

These recent projects' outputs reinforce the conclusions from the IPCC and point out towards more and more frequent extreme phenomena in Europe and more scarce water resources. On a more technical approach, many of the finished projects call for better and more robust data that can be shared through joint repositories, stronger early warning systems, or better policy implementation, among other.

The previously mentioned EU Adaptation Strategy of 2013 also addresses knowledge gaps through research, and aims at promoting information exchange using, for instance, the adaptation platform, Climate-ADAPT[27]. This platform provides different useful resources to support policy and decision-making related to adaptation efforts, such as a toolset for adaptation planning, a database that covers projects and case studies, and information on adaptation actions at different scales (EU, national, regional, local).

While research and technological projects have translated into better cooperation among MS, institutions, and stakeholders, several gaps have been identified between the obtained and expected results. One of the soundest problems relies on transmitting useful information on results to professionals, such as decision and policy makers. Furthermore, the public rarely knows about the existence of on-going projects except for when these tackle local issues and include participative processes. In other occasions, the media or the outreach strategy of the project itself, does not achieve the hard task of approaching the public and translating complex scientific language to a more understandable one.

In Spain a new national strategy on science, innovation and technology (2013–2020) and a new national plan on scientific technical and innovative research Plan (2013–2020) were adopted in 2013. Environmental programmes represented about 4 % of the total national research and development budget in 2014. Actions within these tools correspond to a broad range of areas such as agriculture, marine, mining, energy and environmental sciences. Overall, budgets allocated to environmental research have been falling since 2008 (over 74 million euros in 2008, and just below 20 million euros in 2012) (MAGRAMA 2014, p. 167). A specific assessment on actions, publications and projects would be needed to determine those focusing on water resources and climate change.

Regarding scientific and policy linkages in Spain, projects and initiatives are often developed by academic or scientific institutions, which often lack a direct input from managing authorities on needs and gaps. Thus, while research

[27] http://climate-adapt.eea.europa.eu/

outputs can be innovative and useful for certain sectors, they are rarely tailored to specific needs and knowledge gaps of water managers. Communication and information flow problems are also common within official organisms. For instance, within a large institution such as the Ministry of Agriculture, Food and Environment, departments participating in a research project rarely share information among each other, and less often between Ministries (even when scientific topics are horizontal and clearly affect competences of several public organisms). Thus, there are still gaps in information sharing on a cross-sectorial way within entities and not just in 'top-down' approaches (from research partners to citizens). Transmitting achievements and scientific information from research to citizens is also a pending subject in Spain[28].

3.8.5. Climate change in Spain: administration, plans and measures

Administration in charge of climate change

In Spain, there are several administrative units in charge of climate change adaptation and mitigation at the national and regional level. This article focuses only on those that exist at the national level and set the general guidelines and strategies, which often follow offices or centres from regional governments or those that are related to research practices.

The pivotal structure that is currently in place is the Oficina Española de Cambio Climático -*Spanish National Office of Climate Change* (OECC), dependent on the Ministry of Agriculture, Food and Environment. The OECC, created in 2001, is in charge, among other tasks, of developing the national strategies, promoting the appropriate policy and reporting according to the established international agreements (United Nations Framework Convention on Climate Change, IPCC, etc.). There are however, sectorial coordination structures created as climate change policies became important: the National Climate Council (2001) (formerly the National Climate Commission), the Inter-ministerial Group on Climate Change (2004), the Policy Coordination Committee on Climate Change (2005), the Secretariat of State for Climate Change (2008) and the Government Commission on Climate Change (2008).

[28] For instance, while the XEROCHORE project (2010) provided important information on drought impacts, and made relevant policy and management recommendations, results were usually not transmitted at the national level or outside the main participating institution http://www.feem-project.net/xerochore/partners.php.

Their main aim is to promote administration coordination (at national and regional levels), participative approaches and exchange of views, mainly among institutional entities but also with some stakeholders. However, some argue that additional stakeholders and sectors should participate in these structures (Intermón Oxfam Editorial 2008) and that their effectiveness on influencing sectors to take into account climate change impacts could improve. It should be noted that the assessment of these sectorial structures is out of the scope of this article.

Overall plans and overarching tools

The PNACC (OECC 2006) represents the general framework in Spain for impact assessment, vulnerability and adaptation activities. Moreover, the Spanish Strategy on Climate Change and Clean Energy, approved by the Government in 2007, is the framework that holds together the different climate change policies at the national level and defines basic guidelines for action at the short and medium term (2007 –2012–2020) together with the PNACC. It also includes measures aimed at reducing greenhouse gasses emissions or at adapting to their effects, and promotes various instruments such as the 2005–2010 Renewable Energy Plan or the Plan of Urgent Measures for 2007, among others.

Since 2008, major strategic priorities have been defined with performance targets for reducing emissions leading to specific actions such as the Integrated National Waste Plan, the Savings and Energy Efficiency Plan in government buildings, or more directly linked to agriculture, the Slurry Anaerobic Digestion Plan.

Regarding energy, Spain presents a high dependency compared to other MS, and has traditionally imported energy from neighbouring countries. This dependency has decreased since 2008, due in part to the impulse of renewable energies (solar, wind, hydroelectric, and biomass). Hydropower represents quite a large share of renewable energy production and places Spain at the fifth position as producing country in this category in the EU (Montoya, Aguilera, and Manzano-Agugliaro 2014). However, decreasing river flows and other associated impacts from climate change could greatly decrease this production and alter dependency rates on other sources and from other countries.

Climate Change Adaptation National Plan

The Climate Change Adaptation National Plan or PNACC is the main national tool setting adaptation and mitigation strategies and main working lines for different sectors or activities, the Administration and other public or private interested organizations. The first Work Programme of the National Adaptation Plan envisaged three main sectors: coasts, water and biodiversity. The second Programme, with a timeframe of four years, incorporated new elements and activities with a holistic approach by considering health, agriculture, tourism, forests, soil and the combat against desertification, and its last follow-up report was published in 2011. (See fig. 3.27, which shows the main milestones on climate change and water resources policies in the EU and Spain).

This Plan was developed with the support of the OECC, which has worked with different national and regional governments, as well as stakeholders to disseminate its contents and goals.

According to the EEA (EEA 2014), Spain was one of the first MS to have a national strategy and national authority set up to follow-up its progress and implementation (only Finland developed its national plan in 2005, France had it in 2006 and for most MS this happened between 2007 and 2014). However, the full implementation of the PNACC is lying behind in comparison with other EU countries.

In line with the EU Climate Adapt, the OECC, has set up a reference web portal called AdapteCCa[29] that provides information on any activity, project, or line of action related to climate change. Set up on 2013, this portal also provides a document repository and a searching engine for articles, reports and relevant documents, in addition to working groups in which stakeholders and organisation can take part.

3.8.6. Upraising concerns and water resources management tools in a changing climate

In the EU and beyond

The different impacts derived from climate change are questioning whether conflicts and security issues will increase. The Mediterranean region already witnesses recurrent conflicts and social movements (Arab Spring in 2010, Syrian war 2011...) that often start with the rise of food and energy prices, and

[29] http://www.adaptecca.es/

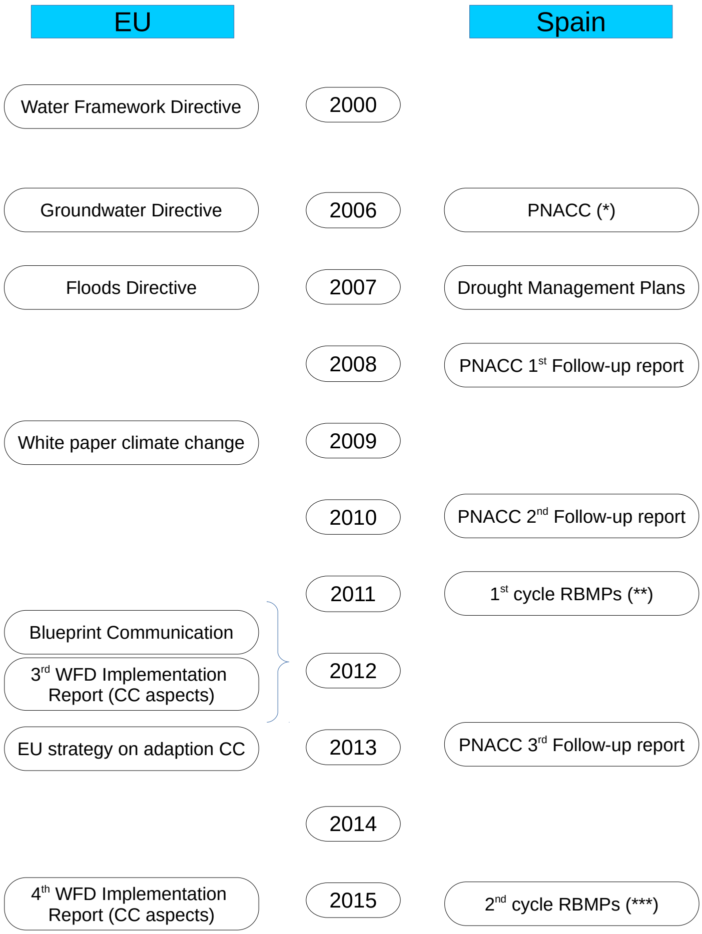

Figure 3.27.: Milestones on climate change and water resources. Main policy and management tools in the EU and Spain.
(*) PNACC: Plan Nacional de Adaptación al Cambio Climático -*Climate Change National Adaptation Plan*
(**) 18 plans adopted out of 25 between 2011 and 2014.
(***) Remaining 1st cycle RBMPs adopted except Lanzarote. 17 of 25 of the 2nd cycle adopted on January 2016.

thus are somehow linked to water management, its use and effects of climate change. For instance, the revolts on Morocco during 2011 led the government to appease revolts by creating a specific fund to ensure affordable prices on local markets for fuel and basic goods (sugar, cereals, oil). Additional military conflicts over the past years have had in one way or another a link to water resources. For instance, Israel has historically targeted the control of water bodies and key infrastructures such as water treatment facilities or bridges (Isaac, Marwan Ayeb, Khalid Abdelmoumni, and Partow 2009; Vargas Amelin 2011, section 3.3 of this thesis). Popular revolts in Algeria due to lack of potable water supply, were also common in 2011.

While conflicts in MS might not be as violent, or might lack military actions, they also exist and are likely to increase if the availability of water resources is reduced over time, as the different economic sectors will still demand their share. Climate change might translate into security threats, although it can provide options for better cooperation as well. The direct effects on threats are likely to depend less on the nature or intensity of climate change direct impacts, and more on the socio-economic aspects, resilience capacity of societies and institution robustness (EC 2011a). Water security will also deal with how societies ensure an appropriate water use, and how they cope with extreme events. As the OECD (2013) points out water security refers to finding a balance between having enough water resources in terms of quantity and quality to address socio-economic and environmental needs, while addressing their destructive nature and finding an acceptable level of risk (e.g. minimizing water-related risks). This organisation calls for better water governance[30] with strong participative strategies, which play a relevant role in minimising conflicts and promoting security.

Possible conflicts and the appropriate management and prioritisation of uses, will be directly linked to the availability of water and the management of the existing demands.

[30]Water governance is the socio-economic, political and administrative systems that exist to manage, develop and use water as a resource within a society. That is the institutions and groups behind all decision making for water use. For instance, within a country, water governance covers institutions and policies that allocate water resources and regulate its use and the administrative processes involved (permits, water services management etc.). See glossary for the Organisation for Economic Co-operation and Development (OECD) definition of water governance.

In Spain

Important protests occurred in Spain on 2001–2004 due to the proposed water transfer from the Ebro basin to the south-eastern part of the country. The issue translated into numerous demonstrations, mobilising for instance up to 200.000 people in a sole protest in Madrid in 2001. Additional conflicts, protests and political tensions often arise from the existing water transfer between the Tagus river and the Segura river (from the centre of the country to the South-East), which actually exists since 1979.

While Spain has tried to shift from supply to demand management (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis), the reality shows that the true change still needs to occur. Important efforts can be spotted and they have been made to improve infrastructures efficiency, promote water savings through public awareness campaigns, and even by the development of secondary water distribution networks (water with less quality than the one used for drinking purposes is used for instance in irrigation). However, on the other hand, within the hydrological planning sector, satisfying existing demands is still a priority and no true public dialogue has been held to determine their feasibility, compatibility with environmental requirements or economic efficiency. This can be seen in the content of the updated RBMPs, for instance in the one published for the Jucar River Basin (CHJ 2015).

Within these Plans' programmes of measures, proposed actions rely primarily on new infrastructures to mobilise new water resources or to increase exploitation guarantee of existing ones. Furthermore, the scarcity of resources, mainly in Mediterranean and other coastal areas (aggravated by climate change effects and demographic pressures) has boosted the use of non-conventional resources, mainly waste water reuse and desalination, which are a way of increasing water supply. Their use has increased over the past years and techniques have modernised, obtaining important energy reduction inputs, where further relevant savings are not foreseeable (Institut Méditerranéen de l'Eau 2014). These resources have actually become part of the overall 'water resources pool' making them almost 'conventional', but major scarcity problems remain unresolved.

Tailored saving campaigns or the application of subsidies for less water consumption in different sectors (public supply, agriculture or industry) are marginal. There is a still a need to promote public awareness, to truly reduce consumption in the most demanding sectors, reduce uptakes form water bodies and thus the pressure made over them. This seems progressively harder as population and economic activities keep growing, and climate change impacts predict less water availability. Furthermore, Spain as most MS, still needs to introduce pricing policies (according to used volumes) and apply instruments to recover the environmental and the resource costs, in particular for the agriculture sector (EC 2012a), as it is described later in section 3.8.8.

There are also important gaps in the data gathering and water use control, which if filled in, could facilitate management decisions, address those water sources with greater pressures and improve resilience of water basins.

For instance, monitoring networks and information systems have improved considerably over the past years and have had a very relevant support from water administrations. However, there is still an important gap on controlling and monitoring water abstractions (demands). This is a very relevant aspect in hydrological planning and modelling to determine future needs, trends and water availability. While many climate change scenarios show important decreases of precipitation values and water availability volumes, having a thorough control of which amount of water is abstracted and used for different economic activities will be paramount to establish the appropriate management and resiliency measures. Tools such as water accounts[31] within a systematic framework (UN 2012) could actually be very helpful in refining knowledge of water abstraction volumes, flows of water between river basin elements, and ultimately better determine which water amounts are available and facilitate decision making (e.g. allocation of water rights during a specific season).

Some pilot projects have been developed on water accounts, and specifically several projects co-financed by the European Commission, shed some light on their feasibility, application, and usefulness for water managers in several Spanish river basins (Tagus, Segura, Jucar, Guadiana, Andalusian Mediterranean basins) (EC 2015d).

[31] EUROSTAT manages relevant sources of information and databases on environmental accounts and socioeconomic indicators. On-going works on sectorial accounts could shed light in the future on determining environmental costs, costs of climate change adaptation, vulnerability of European countries and their adaptive capacity or resilience. http://ec.europa.eu/eurostat/web/environment/overview.

Water-energy-food nexus

The horizontality of water resources and their use in so many productive sectors, complicates even more its management and the integration of water protection in different policy areas. Water is needed to produce energy and food, and thus, the relationship between these three elements is essential for socio-economic development, food security and the development of societies.

Food security is likely to be affected by climate change effects, and its impacts could interfere with access to food products, their use, or price stability in markets (IPCC 2013b). A coherent and multidisciplinary approach would be necessary to establish common goals and objectives, to manage resources according to their status and availability taking into account the existing interconnections (Bizikova et al. 2013). Unfortunately, competences and administrations have specialised and evolved independently, and cooperation and joint policy development have rarely taken place. In addition, managing scales are often different and lie within different administrations schemes, which complicate even more the task of coordinating objectives and instruments.

For instance, while water resources general planning often lays at the national scale, the 'on the ground' management should ideally take place at the river basin level (main principle of the WFD), where interactions with regional and local authorities converge (new infrastructures development, natural sites, tourism...).

Other aspects that can contribute to reduce water demand and build bridges among water consuming sectors relay on focusing on less traditional approaches, and improving efforts on increasing resilience[32] of water ecosystems and populated areas that use or depend upon them. Several actions can increase resilience towards climate change effects. These include the identification of threats (drivers and pressures) to water ecosystems, protecting their biodiversity and avoiding for instance ecological quality deviation, halting environmental degradation that could reduce environmental services, or improve societal knowledge on ecosystems, their functioning and complex interlinks with economic activities and global trends. In addition, there is a need for improving the understanding of ecosystem connectivity, the time

[32] In this context, resilience expresses the ability of a system to cope with expected changes (climate change impacts such as for instance decrease of precipitation values) adapt, and continue its fundamental functioning. An ecosystem with higher plant biodiversity will have a greater capacity to withstand fewer water inputs, and maintain its biological functions and ecosystem services (nutrient filtering capacity, fodder to birds, local products to communities).

frame of variables, impacts and expected responses from the ecosystem (IWMI 2008).

Green infrastructures

To build and develop resilience strategies, administrations and managers need to apply both physical and social techniques, invest in options based on natural ecosystems or processes and use hybrid approaches ('green' and 'grey' infrastructures). Furthermore, it is important to prioritise critical infrastructures that play essential roles for communities as well as conservation efforts for the most valuable and fragile ecosystems (those that will be harder to restore). These actions can take place if administrations incorporate resilience-building in relevant policies such as environmental and water management, climate change adaptation and disaster risk reduction (The Royal Society Science Policy Centre 2014).

More prepared and resilient ecosystems and societies should in turn be less water demanding and be ready to cope with shortages and variations linked to climate change. In this context, green infrastructures and natural water retention measures have been proven to be more environmentally friendly, efficient and often less expensive than traditional 'grey infrastructures' (EC 2014b).

3.8.7. EU policy tools

The EU environmental acquis addresses these conservation concepts and promotes these types of action to build in resilience (Birds Directive 2009; Habitats Directive 1992; Floods Directive 2007; Groundwater Directive 2006; Water Framework Directive 2000). However, the key of increasing societies resilience still depends on reducing vulnerability and exposure, and in this sense, policy implementation might be insufficient without proper administration coordination and participative mechanisms as previously mentioned.

Regarding existing water management tools, three main types of plans exist or are under development: droughts, floods and RBMPs.

According to Floods Directive (2007) MS are required to assess flood risk of water courses and coastal areas, develop risk maps, and coordinate measures to reduce impacts on humans, assets and the environment. The Directive also reinforces public right to access related information and participate in the planning process. MS should report flood management plans focused on prevention, protection and preparedness by 2015. The management of flood risks is a key component of climate change adaptation, and the Directive requires that countries take it into account in the preliminary flood risk assessment. The updated RBMPs should also be ready by the end of 2015 and reported to the European Commission by March 2016 according to the Water Framework Directive (2000).

Policy related tools in Spain

In Spain, DMPs are in place since 2007 and have been proven useful tools for prioritising water allocations and use under drought situations with previously agreed processes and mechanisms among the main water consuming sectors. These plans have as main features the use of indicator systems with established thresholds, the identification of specific measures tailored to each of the drought phases (normal status, pre-alert, alert and emergency), and the prioritisation in the use of water. The objectives are set to sustain population life and health, protect environmental requirements and minimize negative effects on public water supply and on economic activities (such as agriculture). The engagement of stakeholders and affected sectors allowed for a better acceptance of the proposed measures prioritisation and water use restrictions (Estrela Monreal and Vargas Amelin 2008).

The revision of these plans is recommended to take place every six years, and according to different circumstances, as for instance if important changes need to be applied to indicators thresholds or measures as a consequence of models that take into account climate change. These plans vary between river basins, but in general, among the identified measures, they include the use of models that consider climate change effects. Furthermore, these plans already allow for some flexibility and adaptation to their measures if climate effects are observed.

For the first RBMPs, there was already an important delay in Spain. In fact, plans were adopted between 2011 and 2014 and still one of the Canary Islands Plans (at the moment of writing this article) has not been approved (see fig. 3.27). Thus, it is not very likely that all updated plans will be ready by the stated date. By taking into account the available second draft plans, demand management and types of basic and complementary measures are quite similar to the first plans. In addition, the identification of gaps to achieve good ecological status, the link of water management to protected areas and Natura

2000 sites or the establishment of planning strategies to improve aquatic ecosystems in the long-term still need large improvements. For instance, measures for better metering and controlling all abstractions have not been extended, neither has a reassessment of environmental flows to guarantee the link to good water status taken place (WRc plc 2015).

The update of the plans is quite relevant in terms of climate change considerations, since the programme of measures should be climate proof. What is meant by this is that different scenarios should be considered, measures should allow for some flexibility and be adjusted as information and models provide updated and more reliable information (EC 2009c).

Regarding floods, Spain has carried out a preliminary assessment of river basins and coastal areas at risk of flooding and produced comprehensive flood risk maps as requested by the Floods Directives. The first Flood Risk Management Plans (FRMPs) should be presented by December 2015 and reported in March 2016 to the European Commission. Climate change has not been considered in the statistics of flood flows due to linked uncertainties, and it is still to be assessed, whether the first FRMPs will take its impacts into consideration (EC 2015e).

3.8.8. Economic considerations

Climate change is expected to have important economic impacts in many sectors, and a broad effect on the value of financial assets through, among other, changing agriculture and commodity prices, scarcity of essential resources (i.e. water), or damage to infrastructures. It could, however bring new market opportunities, that could be taken by investors, which in turn would also allocate significant capital towards the fight against climate change (Abramskiehn, Wang, and Buchner 2015). Extreme events, for instance, will require greater investments in defensive structures, and lesser water quantity due to drought periods will translate into higher costs for water treatment and investment needs. More frequent droughts and heatwaves have caused electricity cuts and generators overheating, and authorities had to apply emergency measures at high costs. Energy availability has also witnessed limitations affecting the delivery of water services (WWAP 2015).

Under the WFD (art. 5), MS are required to carry out an economic analysis of water use, which mainly includes recovering costs of water services and determining the most cost-effective combination of measures in respect of water uses. The recovery of costs, should include environmental and resource costs associated with damage or negative impact on the aquatic environment (i.e. externalities), according to the polluter-pays principle. To carry out the economic analysis the WFD refers to the need of taking into account long-term forecasts of supply and demand for water in the river basin. In this context, climate change effects and direct impacts on water availability, which will in turn affect water supply, should be clearly considered as potential additional pressures.

As indicated in Guidance document 24, long-term assessments of water supply and demand within the river basin should consider climate change scenarios. The same applies to selecting and determining the most cost-effective measures. While a feasible and useful infrastructure might be considered necessary under the PoM of the RBMP, managers should consider the effects of climate change over it (e.g. reduced water flows will affect stored water in a dam and different scenarios might guide water managers in estimating reductions and impacts) (See fig. 3.26). One of the recommendations of the guidance document stresses the importance of selecting measures that are either robust (will not be affected by climate change impacts) or are flexible enough to adjust under different climatic scenarios. Both cases should translate into economically efficient measures, to avoid wasteful investments. When identifying measures sensitive to climate change, these should be re-evaluated or reconsidered, and adjusted or alternative measures applied, in which case further economic assessment will be required.

The document also refers to water pricing and other incentives to use water resources more efficiently, which can be paramount under climate change conditions where less water availability is expected.

Due to the different conditions that can occur in a changing climate, water managers need, and will need even more in the coming years, to identify water scarcity, determine its causes and apply tailored regulations to achieve sustainable balances. The European Commission and different working groups have recommended using market-based instruments to address water scarcity problems in addition to developing an economic assessment of water uses, determining water´s value and promoting efficiency and saving measures whenever possible. Some of the instruments recommended include block tariffs, metering to determine real consumptions, pricing policies that favour savings and penalise overconsumption, allocating water funding more efficiently, improving drought risk management, and applying stricter control of consumption (demand) to appropriately address management measures (i.e. through better knowledge and data collection (EC 2009c; EC 2007a). In addition, under the supplementary measures for the PoM, the Directive refers to economic or fiscal instruments.

As mentioned, climate change is expected to have important economic impacts on energy and food production. For instance, lower river flows will affect hydropower production and drought and dry periods will affect crop yields and the whole food chain. Thus, under a changing climate prioritisation of uses and establishment of socio-economic activities in the best suited places for each case (opportunity cost) will need public dialogues, political commitment and planning at different scales. The concentration of agricultural practices in sunnier areas will also mean higher needs of water infrastructures, greater pressures to the soil and environment in the form of diffuse pollution, all of which will need to consider climatic variations.

Under the current economic recession, affecting most European countries, but being especially hard in Spain, water managers will also face the dilemma of prioritising investments and approving the most urgent and useful ones. However, political pressures and interests do not always help in applying a transparent and participatory process. In this context, the use of cost-effective measures, green infrastructures and non-structural measures such as education, social awareness, and capacity building, should be considered due to their multi-benefit nature.

As the UN points out, the economic valuation of water can be very useful in different policy areas. It can serve for instance to determine how efficient water management and allocations are. Furthermore, countries should promote an efficient and equitable allocation of water, which takes into account the value of water used by different demanding sectors. This value should, according to the organization, consider the current generation, the allocation of resources between current and future generations and the degree to which anthropogenic impacts affect water quality. Water economic valuation could also serve in establishing water pricing policies and in designing economic instruments, such as taxes on water pollution, to achieve better use of water resources (UN 2012).

Finally, water and climate actions should always take into consideration the cost of inaction, the loss of environmental services and the intrinsic value of water caused by not applying the appropriate measures on time. The European Commission has estimated that the cost to the EU of not adapting to climate change would be at least € 100 billion a year by 2020 and at least € 250 billion a year by 2050 (EC 2014a). These costs could dramatically reduce if small investments are applied for drought and flood prevention measures.

Box G: Ecosystem services

Water is a horizontal natural resource, used in practically all socio-economic activities, and is also essential to sustain life and ecosystems. It supplies different ecosystem services for society and several sectors such as agriculture or forestry. It provides for instance pollution dilution in rivers and habitat protection, allows recreational practices, or reduces risk impacts.

Under the Millennium Ecosystem Assessment, services have been classified as provisioning (e.g. food or water), regulating (e.g. affect climate or floods), cultural (recreational or aesthetics benefits) and supporting (e.g. nutrient cycling or soil formation) (Millennium Ecosystem Assessment 2005).

While important efforts have been achieved in the study and assessment of services, their economic valuation still stirs important debates and faces knowledge gaps (data) and standardised agreed methodologies. As important steps, the SEEA-2003 framework combines accounts on water, land and forests, fisheries, pollution and economics, (UN 2012), and the System of Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting has progressed in the development of a statistical framework for ecosystem accounting (UN et al. 2014).

3.8.9. Identified policy gaps, needed reforms and recommendations

While there is some coherence and coordination among the major water management tools, as for instance between droughts, floods and RBMPs, this is not so evident for other environmental and agricultural tools, as for instance Natura 2000 sites network (Habitats Directive 1992) or rural development programmes (Rural Development Regulation 2013) under the EU CAP. This problem is identified by different organisations and reflected in several reports (European Court of Auditors 2014; EEA 2013a; UN 2015). When competences are distributed among large number of highly compartmentalised administrations, with often limited public funding and human resources, coherence and coordination efforts become complicated. In the Spanish administration all these competences are actually found within the same Ministry. The decision of joining competences as encountered as agriculture and water protection entered into force in 2011 with the creation of the Ministry of Agriculture, Food and Environment (the Ministry of Environment had existed by its own since 1996). However, in practice, competences have been subdivided and carried away independently.

To overcome obstacles and improve policy coherence, better participatory mechanisms could be incorporated among authorities (UN 2015). For instance, inter-ministerial groups (at the technical level) with clear political mandates could be created and supported.

Integrating water policy into other policies (e.g. agriculture) is a problem at the EU wide scale (European Court of Auditors 2014), thus not only affecting Spain, but most MS and even EU institutions.

Within the Common Implementation Strategy of the WFD, efforts have been invested in having a better communication and exchange of information and practices on water and agriculture with limited success. The specific technical group on agriculture proved ineffective in facilitating the integration of water concerns into the implementation of national agricultural policy. In the latest reports a suggestion has been made to elevate the problem to a higher political level to try to achieve better results (EC 2015b).

In addition to improving administrations and departments' coordination, a better effort to communicate the importance of water use and protection in different economic sectors should be promoted.

As discussed, a better approach to water-food-energy-ecosystem nexus could help in improving policy coherence, building in societies' resilience and transmitting the relevance of water to different economic sectors.

Cost-recovery measures within RBMPs are very limited, and water related budgets, even in public administrations, lack transparency. For instance, users, can rarely access detailed water bills that clearly establish a direct link with the actual amount of water consumed or discarded. In addition, there is not always a clear disaggregation of the costs of services (sewage and waste water treatment) (EEA 2013b).

In the context of science-policy-public interface, there is a need of transmitting results to the public, of contributing to awareness raising, and providing recommendations for individual and local actions to combat climate change impacts.

Furthermore, often harmful subsidies exist in the water sector (e.g. subsidised irrigation practices), and the application of 'green taxes' or the appropriate application of the 'polluter-pays principle' is unfortunately not common in MS.

Additional recommendations include the possible incorporation of environmental accounting (e.g. water accounts) in national economic systems, introduce appropriate payment for ecosystem services, provide subsidies for the use of green infrastructures, apply and enforce environmental flows, and use ecosystem-based solutions (which are often more cost-effective).

There is also a need to improve training and professional development on climate change issues and promote information exchange and knowledge transfer between administrations and departments that deal with water, energy and land management. In addition, by ensuring stakeholder involvement in measures assessment and promoting scientific input on updated climate change knowledge that could adjust projections, would translate into more precise and useful management decisions.

3.8.10. Conclusions and recommendations

Negative impacts of climate change in Spain are increasingly evident. The geographical location, its characteristics and predictions from different models and recent studies makes it a highly vulnerable country in the EU. In the case of water resources, Spain studies point towards more frequent and intense droughts and floods, increases in temperature or decrease in river flows, exacerbated water pollution problems and in essence less availability for different uses. In addition to the issues of reduced water availability and increased costs for adaptation measures, pests, invasive species, or a decrease in the amount and quality of crop yields will be part of the foreseeable problems.

Climate change poses a threat to the country's sustainable development, and more specifically on water resources management and protection. Significant efforts have focused on establishing climate change policies, multi-sectoral coordinating bodies, specific adaptation plans and measures for the different sectors. However, there are important gaps, at the policy coherence and implementation levels, which hamper adaptive efforts and resilience building. Economic instruments, prioritisation of cost-effective and 'green' measures and the appropriate use of the cyclic nature of the WFD can all play important roles towards better adaptation and resilience building.

The following points summarise the major recommendations identified throughout the section:

- Knowledge gaps addressed by research projects should be better transmitted to professionals in need of the results. Researchers should also make a greater effort in translating scientific results in a language that can be absorbed and understood by the overall public.

- Horizontal and inter-ministerial climate change structures can be helpful in coordinating efforts to better adapt to expected impacts. The public could be better informed on the existence of these structures and their roles, and a larger number of representative stakeholders could take part of them.

- There is a need for better participatory mechanisms within and among administrations to improve policy coherence. This should include exchange of information and updates on the water policy and management sectors and climate change impacts studies and predictions.

- Participatory mechanisms and better water governance can also be quite relevant for avoiding possible conflicts linked to competing water uses, which under a changing climate are expected to increase.

- A better control of water demands and abstractions, through, for instance better metering, is essential in the shift towards demand management. It is important to remember that countries such as Spain are expected to witness a decrease of water availability, thus supply management approach is likely to be unsustainable.

- Water authorities should use market-based instruments and apply pricing policies that truly incorporate the value of water and that address the impacts economic activities can have in this valuable resource (degradation, pollution, over abstraction, loss of ecosystems services. . .).

- To ensure a better water management under recession conditions, authorities should prioritise measures that are cost-effective and climate proof. In this context, green infrastructures and natural water retention measures can play a relevant role.
- Better training and awareness raising for professionals on climate change and water issues are needed. This could specifically be applied in sectors that have traditionally not considered possible impacts on water resources (for instance, infrastructures departments that develop roads, railroads and infrastructures, which can directly impact water bodies).
- Since a revision of the WFD should take place in 2019, some of the aspects that could be considered include the implicit mention of climate change as anthropogenic pressure, and the inclusion of climate change impacts in the economic analysis of measures. Furthermore, technical developments and common EU guidelines and approaches for considering resource costs and environmental costs could be very useful for applying appropriate pricing policies in MS.

To conclude, at the EU level and in Spain there is a robust environmental legislation and efforts are progressing towards a better incorporation of climate change aspects and coherence with other sectors. However, there are several gaps in policy implementation, in the uptake of societal views or in administrations coordination. Thus, there is still quite a lot of work ahead to ensure a resilient and sustainable management of water resources.

4. Summary of Overall Results

This chapter summarises the main results, based on the presented publications in chapter 3. Under the discussion and conclusions (chapters 5 and 6), an overall assessment is provided on whether these results have answered the stated research questions, and which are the most relevant findings.

4.1. Summary: Water in the Mediterranean Region (section 3.3)

This chapter (Vargas Amelin 2011) of the book (Amirah Fernández, Soler i Lecha, et al. 2011) presents an overall introduction to water resources in the Mediterranean region, main management policies, economic tools and sectors, international initiatives and conflicts linked to water resources. The chapter provides specific examples on agricultural practices and impacts on water resources, as well as detailed figures per country.

The main conclusions are summarised below:

- The Mediterranean region has high pressures from a growing population, urban and industrial activities, mainly occurring in coastal areas.
- While water is a catalyst for development, the region is suffering from its scarcity, uneven distribution, high pollution, conflicts from demanding sectors, and overexploitation of resources (mainly groundwater).
- These water resources problems are aggravated by droughts, floods and climate change impacts.
- Agricultural practices, while having different degrees of economic importance between northern and southern countries, create important pressures in water resources as well as environmental externalities. A better integration of policies and practices in different linked sectors should occur (agriculture, industry, water resources, land-planning...)

- There has been an important progress in water control and regulation, but pricing policies and cost-recovery principles are far from being met.
- A progress towards demand management (instead of supply management) is expected to improve in the upcoming years. In addition, an increase in the use of alternative or non-conventional resources (e.g. waste water reuse) is happening, although their environmental impacts should be considered.
- Water resources also offer a framework of better cooperation, exchange of know-how and conflict resolution. In this context, the EU has launched several promising programs and financing opportunities.
- Implementation of environmental policies is still sometimes weak as well as participative processes in decision-making.

4.2. Summary: Drought Management Plans in the European Union. The Case of Spain (section 3.4)

This article (Estrela Monreal and Vargas Amelin 2012) focuses on extreme phenomena that commonly occur in Mediterranean basins, i.e. drought episodes. It offers an overview of drought management and policies in the EU, analysing the specific case of Spain. In particular, it provides information on the National Drought Indicator System and DMPs.

This article's main conclusions are:

- Important efforts have been done at the EU level to address drought risk evaluation, characterisation of drought episodes and development of specific common indicators.
- The EU has also provided tools and recommendations to better approach drought impacts and minimise their impacts.
- Actions have been undertaken by several MS to better integrate water scarcity and droughts into sector policies, including better management and consideration of climate change impacts.

- Spain is a country characterised by presenting a clear uneven distribution of water resources, and large areas suffer from water scarcity and drought episodes. In the past, these have caused important economic and environmental impacts, and triggered investments in hydraulic works.

- Drought management in Spain has progressively shifted from a crisis to a more planned approach. In this context, DMPs (approved in 2007) have proven to be useful tools to determine drought phases, establish appropriate measures and prioritise water uses.

- DMPs have helped to better plan water availability, avoid public supply restrictions and improve aquatic ecosystem protection.

4.3. Summary: Impacts of Climate Change on Water Resources in Spain (section 3.5)

This article (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012) provides the main insights of climate change effects expected in Spanish water resources. It mainly addresses the complexity of determining those impacts and their degree due, in part, to the natural variability of the water cycle. The article tackles uncertainty issues, and highlights the usefulness of robust hydrological simulation models. In addition, it addresses policy implications and the challenge of implementing policies and measures that ensure optimal levels of adaptation to the projected water resources reductions.

Main conclusions include:

- Climate change is likely to increase hydrological stress, mainly in those areas already facing water scarcity.

- The identification of climate change impacts in water resources is complex, in part because of the natural variability of the water cycle and also due to the effects of water abstractions (not fully monitored).

- The progresses achieved by hydrological water models are noticeable, and have contributed to better understand and estimate expected water reductions.

- Recent assessed studies point out towards greater climate change impacts in semi-arid areas, that is, areas already facing water scarcity and over abstraction.
- Scientific outputs and results obtained from hydrological models have contributed to update water policies.
- Current water demands and their intensive water use should not be maintained. Water management should actually adapt to the identified impacts and consider future scenarios.
- Relevant management tools to incorporate climate change predictions and adaption measures are the PNACC and the second RBMPs.

4.4. Summary: The Challenge of Climate Change in Spain: Water Resources, Agriculture and Land (section 3.6)

This article (Vargas Amelin and Pindado 2014) also provides insights of climate change effects in Spain, but addresses other sectors directly linked to water resources management such as agriculture, soil and land management. It describes imbalances occurring between existing demands and water availability, as over abstraction, which is a generalised problem in water scarce areas. The article summarises the main governmental initiatives to cope with climate change impacts in the mentioned sectors, highlights the role of cross-sectoral entities, plans and measures. It also covers some political concerns such as the complexity of competences in the water field, the need to improve public participation processes, and problems arising from politicised regional interests.

The main conclusions of the article are:

- Recent climate change studies place Spain as one of the most vulnerable countries in Europe.
- Greater mitigation and adaptation efforts will be require to minimise expected impacts in water resources, agriculture and land.
- Expected impacts, such as less water availability, is likely to translate into greater conflicts among demanding sectors.

- Problems like desertification and decreased crop yields are expected to be exacerbated by climatic variations.
- National authorities have launched several initiatives such as modernising irrigation systems, or promoting the use of non-conventional resources (e.g. waste water reuse).
- Coordination among competent authorities is weak, as well as the integration of participative processes in decision-making. The politicisation of water resources often translates into aggravated problems.
- Greater economic resources should be invested in mitigation and adaptation measures, and in cross-sectoral initiatives and administrative structures.

4.5. Summary: Adopting the Framework of River Basin Planning for Climate Change Adaptation in Spain (section 3.7)

Within the book *Adaptation to Climate Change Through Water Resources Management. Capacity, Equity and Sustainability* (Stucker and Lopez-Gunn 2014) a specific case study in Spain is provided in the chapter "Adopting river basin planning as a framework for climate change adaptation in Spain" (Vargas Amelin, López-Gunn, Huelva, and Estrela Monreal 2014). The chapter highlights the high vulnerability of the country given its location in the Mediterranean region, which is considered a hotspot in terms of expected impacts. It provides links to energy impacts, consumption and expected increased needs, adaptation of hydrological planning at the national level and relevant EU policies. However, the main focus of the chapter is the assessment of the role of RBMPs, to determine how well they are designed to cope with climate change impacts, and to be integrated with other regional, local and national initiatives.

The chapter's main conclusions are summarised below:

- Climate change scenarios have some limitations, and downscaling techniques can be challenging and present uncertainties. However, they point out towards non-negligible effects such as lower precipitation levels, decrease of river flows and increase of drought episodes.

- Engaged public society and active social networks could facilitate spontaneous local adaptive capacity building and adaptation.
- Spain has traditionally maximised the use of water resources through infrastructure development.
- Adaptation measures at the regional and local levels have commonly run without a common thread, due to some extent to complex administrative context and levels of competence.
- Climate change aspects have been progressively incorporated in water planning processes, and are being considered to some extent in RBMPs.
- Barriers for strengthening adaptive capacity include inadequate coordination between economic sectors and across administrations.
- Technical experiences should be transferred to society using tailored language to assist in developing adaptive capacities, and in fostering resilience towards for instance droughts and heatwaves.
- The main bridge for adaptation at the river basin scale in Spain will be the successful integration of planning measures with societal demands and capacities.

4.6. Summary: Climate Change Policy and Water Resources in the EU and Spain. A Closer Look Into the Water Framework Directive (section 3.8)

Finally, an assessment of EU policies on climate change and water is developed, providing a parallel study on Spanish legislation and management tools. A closer look is taken for the main overarching WFD, and a gap assessment is done, which addresses, for instance, the lack of policy coherence or the effects of environmental harmful subsidies.

Main conclusions:

- Negative impacts of climate change in Spain are increasingly evident. Reduced water availability and increased costs for adaptation measures, pests, invasive species, or a decrease in the amount and crop yields will be part of the foreseeable problems.

- There are important gaps, at the policy coherence and implementation levels, which hamper adaptive efforts and resilience building. Economic instruments, prioritisation of cost-effective, 'green' measures and the appropriate use of the cyclic nature of the WFD can all play important roles towards better adaptation and resilience building.
- There is still a disconnection between management needs and research studies, and scientific results rarely reach the public with the appropriate language.
- There is a need for better participatory mechanisms within and among administrations to improve policy coherence, and also with citizens.
- A better control of water demands and abstractions, through, for instance, better metering, is essential in the shift towards demand management.
- Water authorities should use market-based instruments and apply pricing policies that truly incorporate the value of water and that address the impacts of economic activities.
- Authorities should prioritise measures that are cost-effective and climate proof, such as green infrastructures and natural water retention measures.

4.7. Main aspects

There are several innovative ideas throughout the presented publications and their conclusions, but two main aspects are the fact that the author indicates areas to take into account in the review process of the WFD for 2019, and gives recommendations at the national level to improve integration of climate change effects in water management and participative processes.

For the WFD review, it is indicated that climate change should be implicitly mentioned as an anthropogenic pressure that will affect water quality, quantity and its management. In addition, there is recommendation to include climate change impacts in the economic analysis of measures, and specific steps within the Directive's cycle are indicated in where to do so (see figure 3.26). This would contribute to the prioritisation (especially under budgetary constraints) and the climate proofing of measures.

The different chapters highlight the overall need to improve participative processes and truly incorporate them into decision-making processes. These are directly linked to climate change adaptation strategies and the ability to increase resilience. Better and more integrated public participation would reduce social conflicts, promote finding joint solutions and knowledge sharing, ensure better public information and understanding of complex processes, and facilitate policy coherence.

5. Discussion

As described in the introduction, the core work of the thesis is composed of six publications, four of them already published (or accepted) in scientific journals and two published as chapters of recent books. The author has followed the initially presented methodology, established objectives, and has answered the stated research questions reflected in chapter 2:

- What is the situation of Mediterranean countries regarding water resources status, access and policy?
- How will climate change impacts affect water resources in the EU, in the region and in Spain?
- What are the existing management tools to address climate change effects in water resources?
- Are EU policies sufficiently robust to pursue a common strategy, especially given the disparity between the availability of resources from one Member State to another?
- Are countries such as Spain prepared to develop sectorial adaptation plans that address climate change effects?
- Are economic considerations and impacts linked to water resources sufficiently considered?

While these questions have been addressed, although, as expressed in chapter 7, additional studies would be required for instance to decrease uncertainty in determining expected climate change impacts or to better implement existing environmental policy.

To develop presented works, the author has carried out an evaluation of various studies on the effect of climate change on water, which used or were based on climatic and hydrological models and made use of historical data series. In addition, European and national adaptation policies were reviewed, a specific study was done on droughts, and policies interlinkages, gaps and administration limitations were assessed. Works have been described in sections 3.3 to 3.8, which also provide case studies, specific examples at national and river basin scales and introduce economic assessments (impacts in different sectors, economic tools, and financial instruments at EU and national levels).

The answers to the main research questions have been reflected in previous chapters, but are also summarised below.

5.1. Mediterranean countries: water resources, access and policy

While countries of the Mediterranean basin share climatic characteristics, and face similar challenges, such as water stress, drought episodes and high natural variabilities and distribution of water resources, there are major differences in terms of policy, administration and access aspects. The situation of Mediterranean countries regarding water resources is therefore quite different, especially between MS and non-EU countries, and the major assessment in this area is provided in section 3.3.

The establishment of EU policy has allowed an important degree of harmonisation in terms of methodologies and goals for water protection, but also for public water supply. In addition, it has favoured the consolidation and empowerment of water administrations, and promoted management at the river basin scale. The situation for non-EU countries, and especially of those of the southern and eastern Mediterranean areas is quite different, being the most acute problem the access to sanitation and potable water sources. However, there have been relevant progresses in past years, and for instance, about 86 % of the population in the Maghreb-Mashreq areas had access to drinking water in 2009 (Programme 2009). Furthermore, as nations have progressed economically, the contribution of agricultural practices to national GDPs has decreased, as well as the dependency of water for this sector. In contrast, agri-food sectors have become more specialised and present higher contributions to national economies and employment rates.

These regional assessments are important to understand progresses achieve at the EU level and in Spain for water management and protection, as well as to existing mismanagement practices and policy gaps.

5.2. Climate change effects in water resources and EU policies

Climate change effects are affecting and will affect water resources. Areas already facing water scarcity and with excess of regulation are actually pointed out as the most vulnerable and least resilient ones. While EU policies pursue a common strategy and present certain flexibility to address the existing disparity between MS in terms of water resources, their fully implementation still needs to occur. The WFD, for instance, does not explicitly mention risks posed by climate change to the achievement of its environmental objectives. Several factors have influenced the degree of policy implementation, including lack of political will, limited human and economic resources, complex administrative organisations and share of competences or lack of data and technical tools.

Spain for instance, is considered one of the most vulnerable countries to climate change within the EU, due to its geographic and socio-economic characteristics. Forecasts obtained from models place it in an area where a further increase in temperature and decrease in precipitation is expected (Estrela Monreal, Pérez-Martín, and Vargas Amelin 2012, section 3.5 of this thesis; EC 2009b).

These effects will be critical to adjust and adapt planning strategies, water infrastructures, and more importantly prioritise water allocation and uses for different economic sectors, while preserving dependent ecosystems.

5.3. Management tools to address climate change

Different management tools are presented throughout chapter 3, but a more in-depth assessment is done on national strategies and sectorial climate change plans, RBMPs, DMPs and indicator systems. Within RBMPs and strategies applied at larger scales, mitigation and adaptation measures are studied, as well as the role of cross-sectoral initiatives and administrative structures.

Taking for instance the example of DMPs, they are highlighted as useful tools to better plan for drought episodes, to shift from a traditional crisis approach, and as a type of plan that is flexible enough to adapt measures as more knowledge on climate change impacts becomes available. They have been proven to be suitable to anticipate to drought events and establish tailored prioritised measures.

However, considering the different examples provided, one of the predominantly obtained conclusion is the lack of integration and coordination of these tools. They are often developed by different administrations, and while they usually present synergies and overlapping goals, the integration of goals and measures is commonly missing. This is the case for instance on the integration of DMPs as complementary plans of RBMPs.

The development, robustness and application of water management tools is essential to better cope with climate change variations and minimise expected impacts.

5.4. The readiness of Spain to develop sectoral adaptation plans

Spain presents a long historical tradition in hydrological planning and a high control of water management, due in part to the limited availability of this resource, especially in Mediterranean areas. The traditional management however, has focused on providing water to all existing demands, even if these were unsustainable in the long-term. The draft second RBMPs, according to the WFD do not show major improvements in this sense. Proposed measures are quite similar to the first plans, and focus on satisfying current demands. In addition, the identification of gaps to achieve good ecological status, the link of water management to protected natural areas or the establishment of planning strategies to improve aquatic ecosystems in the long-term still need large improvements. Measures for better metering and controlling all abstractions have not been extended in most river basins, and a stronger link of environmental flows with good water status should take place (WRc plc 2015). Therefore, while there is a large technical capability and knowledge on water resources, there are still important gaps and problems at the WFD implementation level that can directly affect the applicability of sectorial plans. That is, if RBMPs, the main tools to achieve good ecological status, still present weaknesses, the capacity at the national level to develop adaptation sectorial plans that are fully integrated in water planning is uncertain.

On the other hand, and linked to the historical tradition of water management, the existing policy in Spain is quite robust, and sectorial plans have been implemented addressing to certain extent climate change effects. Also, national and regional strategies have been developed and agreed by several administrations. For instance, Spain was one of the first MS in adopting a

National Plan on Climate Change Adaptation (PNACC) (OECC 2006) and specific water management tools such as DMPs (EC 2008).

Spain, as all MS, should make an enhanced use of the cyclical approach of the WFD, which encompasses specific steps, envisions periodic revisions, and integrates other Directives' domains within its text (habitats, agricultural development) to better adapt to and manage climate change impacts. In this context, it will be important to assess the degree into which the new RBMPs, will be aligned with the PNACC and the guidelines recommended by the European Commission (EC 2009c), or as mentioned, with complementary plans such as DMPs.

5.5. EU policies adequate to pursue a common strategy, given disparities among MS

The EU environmental acquis is quite advanced, ambitious in terms of protection and long-term goals, and specific directives usually have well defined strategies and tools. The WFD is a key piece of legislation that was developed taking into account drivers, pressures on water, water status, impacts (such as decreased quality) and responses (e.g. plans). That is, it can easily follow the DPSIR framework of the EEA (shown in fig. 5.1) (Quevauviller 2014). The directive calls for a risk assessment, to analyse existing drivers and pressures, to establish comprehensive monitoring networks to fully assess water status and impacts, and sets high environmental objectives. Moreover, the economic analysis of environmental objectives is embedded in the 6-years management cycles. The directive presents flexibility, includes periodic revisions at the end of each cycle, and allows continuous integration of scientific and technical progresses.

Thus, the implementation strategy is common and goals can be achieved by all MS regardless their specificities. However, it is true that quantitative issues are less addressed in the Directive, and that some quality objectives might be harder to achieve in areas where water is very scarce, and where variabilities can challenge management or monitoring. In this sense, the Directive was complemented by a comprehensive strategy on water scarcity and droughts, and specific studies on policy gaps, water efficiency targets, or water accounting among other (EC 2015d; EC 2012c; EC 2012a; EC 2007a). All these combined policy tools should be adequate to pursue common water protection goals and take into account climatic impacts.

5.6. Economic considerations and impacts linked to water resources

Economic considerations and impacts linked to water resources, while often reflected in EU and national legislation, have not been sufficiently tackled. Climate change is expected to have important impacts in many economic sectors, a high effect on the value of assets through, for instance changing agriculture and commodity prices, creating a greater scarcity of water, or provoking important damages to infrastructures (e.g. flood control dikes), while it could also bring market opportunities for investors (Abramskiehn, Wang, and Buchner 2015).

The Water Framework Directive (2000), in articles 5 and 9, urges MS to carry out an economic analysis of water use, including recovering costs of water services (comprising environmental costs and resource costs), determining the most cost-effective measures for water use, in addition to applying the 'polluter-pays principle'[1]

The EC has recommended using market-based instruments to address water scarcity problems in addition to developing an economic assessment of water uses, determining water's value and promoting efficiency and saving measures whenever possible. Some of the instruments recommended include (EC 2015d; EC 2009c; EC 2007a):

- Applying block tariffs.
- Metering to determine real consumptions.
- Integrating pricing policies that favour savings and penalise overconsumption.
- Allocating water funding more efficiently.
- Improving drought risk management.
- Applying stricter control of consumption (demand).
- Using water accounts.

[1] In the Water Framework Directive (2000), financial costs refer to costs of providing water services (including operation and maintenance costs of infrastructures). Environmental costs are those representing damage to the environment and ecosystems due to water use, and resource costs are linked to opportunity costs (e.g. cost of forgone opportunities due to the depletion of the resource).

However, in Spain the way in which water is charged, varies among sectors and even among river basin authorities, and cost recovery has not yet been achieved in certain areas. Block tariffs for water consumption are not systematically applied for domestic use, and cross-subsidies are common for agricultural practices (EEA 2013b).

5.7. Link to initial goals, recommendations, conclusions, and future works

The fig. 5.1 links the discussion points and recommendations made throughout the publications, and serves as introduction to the presented conclusions in chapter 6.

Concerning the initially established goals:

a) Provide an introduction to water management in the Mediterranean region.

b) Develop an analysis of EU policies on water and climate change.

c) Analyse the effects of certain extreme events common in Mediterranean basins such as droughts.

d) Determine how previous experience in water management and planning may or may not represent a framework for adaptation to climate change effects.

e) Provide examples of policy gaps and recommendations to improve water protection policies in the future.

The presented publications have common points and interlinked topics, but goal a) has been fully answered in section 3.3, while c) is mainly developed under section 3.4 (even though effects of drought episodes and DMPs are mentioned also in sections 3.6 and 3.7). Goals b), d) and e) are covered in different sections of all the publications presented in chapter 3.

The following chapter, the conclusions, has been written considering the main lessons learnt through the developed research and it is organised based on which have been considered the main topics. That is, first conclusions on climate change effects on water resources are presented as well as possible problems caused by the degree of uncertainty in models. Then, the need of truly applying a management shift in the EU but mainly in Spain is described, highlighting the need of supplying water demands in a sustainable way. In

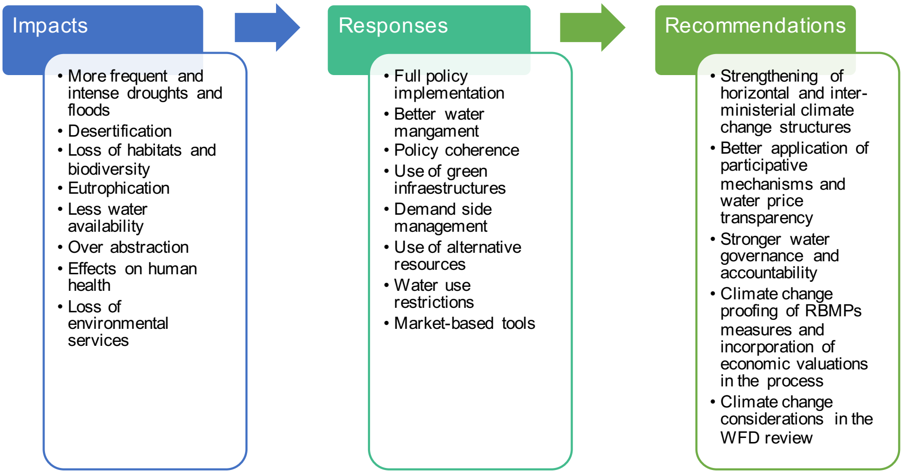

Figure 5.1.: Impacts and responses based on the DPSIR framework, and some of the proposed recommendations. Source: own elaboration based on the causal framework developed by the EEA (extended from *Pressure-State-Response* of OECD works from previous *STress Response Environmental Statistical System–STRESS* by Anthony Friend and David Rapport) that links society and the environment.

this sense, the present and future role of alternative resources, quite valuable in water scarce areas is summarised. Economic impacts of climate change and existing economic tools in the water sector and the main conclusions obtained from the publications are summarised. Linked to all these previous topics, are the existing EU and National policies on water and climate change, their ambitions, the current implementation gaps, and their possible improvements. Finally, the role of society and problems linked to insufficient participative processes are explained.

Future steps and works in the water field are indicated in chapter 7, but as an overall summary these should focus on better integrating existing management tools and applying policy coherence. It will be also important to use the flexibility that management plans present to incorporate climate change aspects and economic assessments. These actions will be essential to better cope with expected climate change impacts (e.g. intense extreme events and less water availability), and to ensure a long-term water and environmental protection.

6. Conclusions

6.1. Climate change effects

As stated by the Intergovernmental Panel on Climate Change (IPCC) the effect of human activities in the climate system are evident (IPCC 2014). Climate change is affecting and will affect water resources in a significant way, and in turn will have socio-economic and environmental implications that cannot be underestimated. Expected impacts will definitely challenge water managers, regions, citizens and politicians, since it will not be possible to sustain demands, as they currently exist, and will exacerbate scarcity and pollution problems.

One of the most recent and comprehensive studies on climate change impacts in water resources in Spain developed for natural regime[1] conditions (CEDEX 2011), predicts a generalised reduction of annual precipitation and water availability, which will increase through time (near -5 %, -9 % and -17 % during the periods 2011–2040, 2041–2070 and 2071–2100 respectively), as reflected in the table 6.1.

These estimates are obtained under the A2 scenario, which assumes the continuation of similar development patterns worldwide, as they currently exist. Similar figures are obtained for a B2 scenario, which is more optimistic, and incorporates more sustainable practices and less acute temperature changes. Figures however, for B2 and the latest horizon (2071–2100) reflect smaller reductions.

In addition, the greatest variability is expected to occur in Spanish Mediterranean coastal areas and in the South-East of the country, as pointed out in this and other studies assessed in the thesis (see sections 3.5 to 3.7). Water bodies that suffer pressures and are under stress (and for instance present water scarcity) are more susceptible to climate change impacts. Climate change can hamper restoration efforts to achieve good status in these water bodies,

[1] Natural regime refers to unaltered conditions by human actions, focuses on more pristine ecological conditions, and can therefore better reflect climate change impacts.

Table 6.1.: Estimated percent average variances for different variables under A2 scenario.

	Percent average variances[a] in % for time horizon		
Variable	2011–2040	2041–2070	2071–2100
Precipitation	-5	-9	-17
Evapotranspiration	-3	-6	-7
Groundwater recharge	-8	-16	-28
Run-off	-8	-16	-28

[a]CEDEX 2011.

and therefore affect their resilience and capacity to absorb additional pressures (EEA 2012b).

Given the importance of water for practically all socio-economic activities and to sustain ecosystems and biodiversity, economic implications will be more and more evident in the upcoming years. Some figures and examples are provided throughout sections 3.3 to 3.8, but for instance, and as an overall European Union (EU) figure, the European Commission has estimated that the cost to the EU of not adapting to climate change would be at least € 100 billion a year by 2020 and at least € 250 billion a year by 2050 (EC 2014a).

6.2. Uncertainty in climate models and research

While predictions are useful and indicative, the degree of uncertainty in climatic models is high, especially for downscaling techniques (e.g. when using global climate models to determine effects and projections at river basin scale). It will be also difficult to determine if extreme events are cause of natural variabilities in climate and water cycles, or if they are a direct result of climate change effects. Future trends in population pressures and water consumptions for the different economic sectors also present certain degree of uncertainty. It is evident then, that finer research and studies on climate change and for the predictions of expected impacts on water are necessary, as well as greater investments in adaptation strategies and training for water professionals.

However, there are specific guidance documents to determine and describe uncertainties, as for instance the guidance notes developed by the IPCC to identify the degree of confidence for the different assessments. For the Spanish territory all assessed studies in the thesis, point out towards similar results such as decrease on water availability and higher number of extreme weather events. Thus, water managers should work under the assumption that hydrological planning should incorporate decreases of water availability in the medium and long-term.

Research should also address management problems and technical knowledge gaps. Hence, a closer collaboration between researchers and managers would be required. Furthermore, mechanisms to link research and policy development and implementation (i.e. S-PI) are necessary if research progresses and results are to be fully used and incorporated, for instance in determining the most appropriate and resilient measures at the river basin scale. Aspects related to Science-Policy Interface (S-PI) and the need of better transmitting and linking research results are covered in section 3.8.

6.3. Shift in water management approach

Regardless the existence of certain degree of uncertainty, it would be expected that predicted climatic impacts in water should be influencing water management, alert decision makers and create greater awareness in terms of water saving, prioritisation of uses and overall thinking of how water should be better used. They should also help in building adaptive capacity and a culture of resilience, and contribute to shifting management practices from supplying any water use, to reducing demands, and to using cost-efficient and smart solutions. The traditional use of 'grey' infrastructures such as dams should be fading, not only due to their high environmental impact, but also given the uncertainty of their future usefulness if lower river flows are expected. Predictions should also be translating into the use of smarter and greener solutions, such as nature and ecosystem-based approaches, which are often less costly and can present higher resilience to climatic changes (EC 2013b).

Some studies point out a beginning of economic grow in Spain only in 2014, after three years of acute recession (EC 2015c). This economic recession has not contributed to the abovementioned expected shifts or to better prepare regions and river basins to face climate change challenges. Budgetary cuts have had an important effect in water management, and proposed measures within the updated River Basin Management Plans (RBMPs) that would have contributed to better water protection and climate change adaptation, might not find the required economic support. Examples of these measures include proposed river restorations or the development of natural water retention measures. However, useful tools exist to help water managers in prioritising measures and projects, and determining the cost effectiveness of restoration (Scemama and Levrel 2015).

The presented publications in this thesis (sections 3.3 to 3.8), cover a time period of about four years in which the recession has influenced political priorities, managers' decisions and public perceptions towards existing problems. One of the most affected pillars could be considered the implementation of EU environmental policy.

6.4. Alternative water resources

In countries where water resources are limited, and climate change effects predict decreases in their availability (i.e. Spain), a main increase in supply might be expected from alternative resources, such as waste water reuse and desalination (this is referred in most of the presented publications as non-conventional resources). Spain witnessed a very high increase of both techniques in recent years, and desalination production between 2004 and 2009, placed the country as the fourth world largest producer with an annual peak production of 700×10^6 m^3 (MARM 2009b). However, most of the large desalination plants in the Mediterranean coast, which had EU funding support, are being underused (EC 2015a) due in part to more favourable weather conditions and to the high cost of desalinated water production. Wastewater reuse is also broadly use in water scarce areas, and in 2011 the annual produced volume was estimated at 430×10^6 m^3 (see sections 3.4 and 3.6).

The production of alternative resources usually implies new infrastructures and their maintenance, high costs of energy, and in some cases environmental impacts that should be considered. The application of these techniques should therefore be assessed case by case, in areas well suited to them, and where other alternatives might have fewer socio-economic and environmental benefits. In other words, they should be considered when all other water supply options have been explored and assessed (EC 2012a).

Water managers should also keep in mind that increasing supplies to growing economic sectors and populations, when precipitation and river flows will progressively decrease due to climate change, will not provide any long-term solution. In fact, with these techniques major scarcity problems will remain unsolved. Efforts should centre on applying a demand side management, on refocusing the most water demanding activities (i.e. agriculture), and on maximising efficiency and savings.

6.5. Economic tools

There have been three main areas of economic aspects considered throughout the thesis' chapters: funding opportunities, market-based instruments applied to water resources, and valuation of economic impacts generated by climate change.

Funding opportunities have been highlighted both for EU and non-EU countries, to promote regional cooperation, support research activities or finance measures and projects. Thus, they are pointed out as support tools to improve water management, climate related risks and address technical knowledge gaps. These include for instance, European regional development funds and cohesion funds, but also the European Neighbourhood Policy (ENP) and other instruments for non-EU countries in the Mediterranean region (mainly addressed in section 3.3). In addition, research and development lines promoted at the EU level to fund specific environmental related projects, and more specifically to water and climate change are assessed (e.g. section 3.8).

Within the European Commission, the largest EU Research and Innovation programme 'Horizon 2020' has the commitment to dedicate at least 35 % of the budget to climate-related research, through both specific climate research and the integration of climate into the full research and innovation agenda. In addition, within the European Structural and Investment Funds (ESIF) 25 % of their overall budget between 2014 and 2020 has been allocated to climate-related actions (mainly focused on energy efficiency and transport).

Specific figures on budgets for research actions are provided at the national level, but also the explanations on the existing problems to link research results to water management problems (see for instance 3.6.).

Regarding market-based instruments, most of the thesis' publications address the need of using them to comply with the Water Framework Directive (2000). This Directive sets in its article 9 the need to take into account the principle of cost recovery from water services and ensure water-pricing schemes, and, according to article 5 apply the 'polluter-pays-principle'. These instruments have not been broadly applied in the first cycle of the Water Framework Directive 2000/60/EC (WFD), water services definition by Member States of the European Union (MS) is often quite narrow, and many Members States, including Spain, subsidise water-demanding sectors such as agriculture (Zandstra 2015). As already pointed out in the assessment of the EU 'Blueprint' communication (EC 2012a) a common methodology for calculating cost-recovery, taking into account the 'polluter-pays-principle', is still pending as well as more efficient and incentivised water pricing schemes.

Concerning environmental harmful subsides, an important commitment has been established at the EU level to ensure they are phased out by 2020 (EC 2011b), but progresses are slow, and irrigation subsidies and the lack of full cost pricing in Spain are still pointed out in recent studies as areas to tackle (Withana et al. 2012).

For instance, sections 3.6 and 3.8 describe the problem of setting an appropriate and transparent water price that contributes to cost-recovery of management and sanitation practices. Unfortunately, Spain has very limited measures for cost-recovery within RBMPs, which mainly focus on water supply and treatment, and still has a rather low price of water in comparison with other MS (EEA 2013b). Furthermore, the cost of water should better include environmental costs associated with damage or negative impact on the aquatic environment (i.e. externalities), according to the 'polluter-pays principle', and also include resource cost, linked to forgone opportunities. Adequate water pricing policies, the better application of cost-recovery of water services, higher transparency of prices and subsidies as well as greater investments in the irrigation sector could all foster water savings, mainly in the agricultural sector (EC 2015a). Thus, important steps and progresses are needed in these areas and national policy priorities or measures included in the new RBMPs do not point to this direction.

As remarked, climate change effects might impact economic sectors, affect food production and reallocation of water rights, or impact infrastructures such as dams or flood protection dikes. Thus, climate change impacts will likely have a direct impact in water management measures, and more precisely in the Programme of Measuress (PoMs) within RBMPs. One of the missing steps identified in the publications and included as relevant recommendation is a better integration of climate change considerations in specific steps of the WFD cyclic implementation. These steps include the gap analysis to achieve good ecological status, the set-up of PoMs, the evaluation of the planning cycle and the status assessment (fig. 3.26).

6.6. EU and national policy

While the EU has an advance and respected environmental legislation, which sets high standards for water protection, such as the WFD, its implementation, for instance in Spain, is far from being reached. Required updates of water treatment facilities[2] have not taken place, nor an in-depth assessment of gaps to reach good ecological status in all water bodies coupled with tailored management measures. Furthermore, implementation efforts have not incorporated the appropriate interlinkages with climate adaptation. Thus, policy coherence with other sectors such as the agricultural one, is quite limited. In fact, the agricultural sector, is the most water demanding one in Spain, and provokes high pressures in terms of abstractions and diffuse pollution mainly by nitrates (Fuentes 2011; Vargas Amelin and Pindado 2014, section 3.6 of this thesis). In terms of demands, irrigation represents 75 %, the largest water consumption in Spain (see section 3.6). While decreasing trends for nitrates concentrations in rivers have been observed in the EU during the past years, 30 % of the Spanish rivers exhibit a rising trend and 22 % of the groundwater monitoring stations showed in 2009 exceedance to the limit set at the EU level (50 mg/l) (Eurostat 2015).

Most river basins affected by water scarcity also present intensive irrigation practices and could be even more vulnerable to climate change impacts. However, the Spanish draft RBMPs, do not provide a full picture of the link to the Nitrates Directive and the required measures to improve water protection. Over abstraction of groundwater and surface waters due to agricultural activities is an additional major risk for reaching the targets set by the WFD, but little progress has been attained in monitoring and prosecuting illegal water abstractions (EC 2012a).

In Spain, we are witnessing important delays in EU policy implementation and the continuity of traditional demand-driven approaches, while greater additional efforts would be needed to address the gaps to ensure ecological protection and climatic resilience. Again, budgetary restrictions in the environmental sector, and reduction of resources in river basin authorities, are hampering a shift in this trend. Political priorities have drifted apart from environmental protection, and essential tools such as modelling or water monitoring have witnessed decreasing funds. However, the economic recession

[2] Updates and the well functioning of urban waste water treatment facilities are priorities of the Urban Waste Water Directive (1991). However, they are directly linked to the achievement of the goals set by the Water Framework Directive (2000).

cannot be blamed solely for not complying with policy's obligations. The complexity of water competences, the lack of accountability from administrations, or the limited coordinating efforts among different administrative scales are all part of the problem.

6.7. Complexity of competences within the water sector

The complex Spanish network of administrations in charge of water management, protection, distribution and pricing, has contributed to some extent to the delays in policy implementation. This network is highly dispersed, competences are shared by public and private entities, and clashing political wills from local, regional, river basin and national based entities often shape water regulation. There is also a wide range of water prices for end-users, lack of transparency in establishing prices, tariffs and subsides. These circumstances have for instance affected cost-recovery mechanisms, which are limited to waste water treatment and sanitation practices (EEA 2013b). While decentralisation and specialisation of competences could have had positive impacts in water management and protection, the lack of coordination among administrations and the limited combined sources of information have caused important gaps. For instance, the maze of authorities acting at different scales poses difficulties to easily access information related to water use or to its price. It has also hampered the possibility of better coordinating participative processes, which would allow citizens to better engage in decision-making. When involving communities and stakeholders in water management, the degree of success in proposed solutions is more likely to increase (Stucker and Lopez-Gunn 2014).

6.8. The role of society in water protection

Societal challenges are complex and would require further assessment. Some of these challenges include for instance the lack of knowledge of existing environmental problems, limited active participation in water management and actions to combat climate change effects, better uptake of research outputs or the need to build up resilience capacities. The presented publications provide some insights on these existing problems (for instance section 3.7).

A deep cultural change in water exploitation perception should take place in Spain. Traditionally, in water scarce areas, the maximum possible use of water has been pursued, and water reaching the sea was perceived as wasted water. Unfortunately, this way of thinking is still quite rooted in the Spanish society as well as the aim of promoting regional and local interests at the expense of exploiting water resources elsewhere (see section 3.6). There is still a lack of basic environmental knowledge, and many water users do not fully understand ecosystems dependency on water, the necessity of respecting aquifer recharge requirements, or the need of sediments in coastal areas and deltas to provide environmental and societal services. Increasing dependency in water and practices that overexploit resources would only translate into unsustainable water use, and less resilient societies and ecosystems towards climate change impacts. Water systems that already present critical water balances and are water stressed would have little 'safety margins' to cope with unexpected extreme phenomena.

In Spain, it would be required to better transmit basic environmental needs to society as well as information on expected climatic changes. Local Non-Governmental Organisations (NGOs) and Civil Society Organisations (CSOs) could play an important educational role in awareness raising, but also in promoting local actions to increase resilience and adaptive capacity. This is very rarely seen, which could be in part due to the slow and progressive on-sets of climate change impacts.

In this context, actions focused on S-PI could help in bridging sectors and also in better incorporating society's needs and concerns in research and management practices. These actions could facilitate practical results, extract useful information from research projects to water managers and citizens, and provide demonstration through practical cases. For this, mediators, which could be technicians dedicated full time to bridging efforts, would be needed in Spanish administrations.

7. Scientific Contributions and Future Lines of Work

7.1. Science and policy

The publications presented provide an important assessment of policies in climate change and water resources. Some scientific contributions include the assessment of data series, expected climate impacts, or assessment of the progress of water policy and the integration of climate change considerations. The S-PI is also addressed through the publications, and important policy and implementation gaps are highlighted throughout the conclusions. Additional efforts are essential and still need reinforcement for instance in integrating policies such as agricultural development, land planning and water resources management. While policy coherence might be a priority for European institutions, the reality shows that the horizontality of water as a resource and the maze of competent authorities make hard its coherence even at the national levels. Thus, Spain still needs to better consider the water-energy-food nexus, or truly use the support of cross-sectoral entities or initiatives that aim at aligning water protection objectives among administrations and ministries. Additional studies and initiatives would be needed to provide useful recommendations and practical solutions for better policy coherence.

7.2. Main management tools within policies

Within chapter 3 there are comprehensive assessments of management tools, such as climate national strategies, RBMPs, Drought Management Plans (DMPs), indicators, hydrological and climatic models. Data are also gathered from information systems fed by monitoring networks. Some of the highlighted findings include the lack of coherence and integration of plans (as for instance DMPs as complementary plans of RBMPs), as well as the couplement with national climate change plans and strategies (for instance, with the Plan Nacional de Adaptación al Cambio Climático -*Climate Change National Adaptation Plan* (PNACC) in Spain).

Future lines of work would include an in-depth assessment of management tools integration based on the second RBMPs to be published by the end of 2015. This assessment and the identification of best practices in certain MS, could be highlighted, and the transfer to other countries promoted.

On the other hand, the fine-tuning of hydrological models that would provide more robust results at smaller scales could be beneficial for water managers. The necessity for this improvement is mainly linked to the scale of the measures included in RBMPs, which are often designed to address problems in a specific water body or groups of water bodies. Thus, the future use of better downscaling or regionalisation techniques could provide better results for assessing climate change impacts per sector, improve how economic and environmental impacts are determined, and identify required actions.

7.3. Economic considerations: costs, tools and indicators

As mentioned in the discussion, some recommendations have been provided on how to better incorporate climate change considerations in the WFD cycles, and how to couple them with economic analysis of measures. In the assessment of the upcoming RBMPs, also an evaluation should take place on how MS have coupled economic assessment and climate change proofing of management measures.

Regarding resource cost and environmental cost, while there are some introductory guidelines available (EC 2003a), additional works are needed on how to apply them and how to harmonise methodologies at the EU level.

Furthermore, an assessment is pending on how efficient has been Spain in the uptake of EU cohesion and structural funds (e.g. for the 2007–2013 programming period), their specific use in water planning, natural risk management and climate change adaptation, as well as the overall results.

Some insights of the use of alternative (non-conventional) resources are provided in chapter 3, including advantages and disadvantages such as required energy inputs and possible environmental impacts. Additional economic studies would be required to justify and determine their efficiency case by case, or at least at river basin scale, considering environmental externalities. In this context, future studies could focus on decreasing energy inputs and related costs required for reusing waste water treatment or desalinating water in specific coastal areas in which other supply alternatives have been explored.

As for economic tools and policy implementation, managers often lack figures that could help justifying proposed measures or infrastructures to back up requested investments (e.g. for environmental protection). Further assessment should be done in the costs and benefits of applying water policy and better considering climate change impacts. It is estimated that the cost of non-action will, in the long-term, be much more costly to MS than applying management tools and implementing directives on time. For instance, it has been estimated that the cost to the EU of not adapting to climate change would be at least €100 billion a year by 2020 and at least €250 billion a year by 2050 (EC 2014a). These costs could be reduced if small gradual investments are applied to better implement water protection policies and for drought and flood prevention measures. In this context, studies on the valuation of green infrastructures and their effects would be particularly helpful for water managers and administrations.

The use of water accounts to determine economic impacts per sector at the river basin level, should also be considered a future line of work. So far, most of the works developed on water accounts lack the economic components, and thus the valuation of services provided by water, or the cost of the water degradation caused by economic activities. Recent efforts have focused on further standardization of the use of System of Environmental-Economic Accounting for Water (SEEA-Water) tables at the EU level (EC 2015d) and recent studies propose their use to better estimate cost recovery ratios in Europe (Borrego-Marín, Gutiérrez-Martín, and Berbel 2015), areas that should be further explored. By using climatic estimations (e.g. reduction of precipitation inputs) and models, water accounts could also determine the expected reduction of water availability per component in a river basin, which in turn would help in prioritising uses, taking into account economic and environmental factors, and water use reallocation.

Additional studies could also focus on determining how water as a key resource may limit future development with the use for instance of 'material criticality evaluation'. Section 3.3 addresses development aspects especially in non-EU Mediterranean countries. This type of studies could determine if the lack of water could become a limiting factor for certain socio-economic activities in regions or river basins and assess vulnerability of sectors to the lack of this natural resource. In addition, they could evaluate the ability of these sectors to adapt to restrictions (which could be directly linked to resilience to climate change effects in the long-term and the assessment of different scenarios).

In addition, the more generalised use of specific water and economic indicators, such as the revised Water Exploitation Index (WEI+)[1], the underground water depletion, or the Water use intensity by economic activity, could help in better determining the efficiency of water use and the level of protection among different MS.

Additional current studies are focusing on valuing ecosystem services, which would use as building blocks specific accounts (water, forest, biodiversity. . .). Outputs of such studies would allow putting monetary values on natural capital, increase awareness raising, help putting water as a priority in the political agendas, and overall contribute to environmental protection.

7.4. Role of society and stakeholders

Moreover, there is need of better assessing participative processes and their impact in improving water management and incorporating climate change considerations. Additional studies would be required to consider and compare bottom-up approaches, their impacts and effectiveness. In addition, the role of NGOs and CSOs, could be better assessed and practical recommendations obtained. This could promote individual, local and community actions to increase knowledge on expected climate change impacts and build on adaptive capacity.

Furthermore, EU citizens usually lack knowledge on EU mechanisms or environmental acquis, which often hampers their direct participation in policy development and implementation. Additional actions could be developed to determine the degree of average knowledge of EU citizens on water and climate change policies and how water administrations implement them. These could in turn help to determine how to better integrate citizens' participation.

There is a maze of water administrations with competences at national, regional, local and river basin scales, while the implementation of climate change strategies are often applied at national and regional levels. Future studies should focus on how complementarities and administrations coordination could improve to better apply existing management tools, and coordinate joint public participatory mechanisms.

[1] The Water Exploitation Index (WEI) represents annual total water abstractions over renewable water resources, expressed as percentage. This indicator has been traditionally calculated at national scales, often masking regional water scarcity problems. The revised Water Exploitation Index (WEI+), also represents annual total water abstractions (minus returns) over renewable freshwater resources but in a given territory and time scale. This regionalisation of the index, and its broader use at river basin scale, could provide more accurate information on water scarcity and better reflect economic pressures on the environment.

8. Bibliography

The Chapter of bibliographical references is divided into two sections. The first one, *Publications of Elisa Vargas Amelin* (section 8.1) is structured according to the type of publication: chapters of books and reports (section 8.1.1), international scientific indexed journals papers (section 8.1.2), and papers for scientific conferences (section 8.1.3). The second *Thesis's references* (section 8.2) has the references cited in the text of the thesis. The second section, in turn, is divided into legislation (section 8.2.1) and other references (section 8.2.2).

The bibliographic style used is of the type author-year. The style is applied over a *biblatex*[1][2] database of references compiled and stored using *Zotero*[3] research sources management tool. The author of the Thesis made some custom modifications over the standard author-year style of the *biblatex* package that are explained below.

Legal references are listed by common short name and year. The rest of references are ordered by the first author and year. For repeated first author and year, then the surname of the second author is used and so on.

Where some references have the same author or authors in the same order, the names of the authors are replaced by a dash to shorten the bibliography.

The number of authors indicated in the bibliography before summarising with *et al* is nine, whereas citations within the thesis text are shortened after the fourth author.

For homogeneity, within the body of this thesis, the authors have been expressed by the initial of the name, and the complete known family name. Especially for the author of the thesis and the more direct related authors with her work. Therefore, some of the references are not shown exactly the same as in the original publications. This homogenisation has been selected because, for instance, the author of the thesis is named up to five different ways in her works (Elisa Vargas, E. Vargas, E. Vargas Amelin, Vargas Amelin, Elisa or Elisa Vargas-Amelin). In order to avoid difficulties in finding references, most have

[1] https://www.ctan.org/pkg/biblatex
[2] Using *biber* as bibliographic compiler.
[3] https://zotero.org

a numerical identifier such as the ISBN/DOI, and a URL to access the original document. In addition, the compiled database of bibliographical references is publicly available at the following Internet address: https://www.zotero.org/groups/thesis_elisa_vargas .

If the author/editor (for organisations) has a known commonly used abbreviation, then this is used, showing the full name, after the year in the bibliography. Also, most abbreviations can be found in the section *Acronyms*.

In bibliographic references for books, the year is marked in bold.

The degree of participation of Elisa Vargas Amelin in the publications is expressed after the corresponding references.

References (citations) in the body of the thesis are shown by the first author, following up to four other authors (prior to summarising with *et al*) and the year. If the references are for legislative documents, then these are indicated with the usual name of the Directive / Reglament / Rule with the year in parentheses.

8.1. Publications of Elisa Vargas Amelin

8.1.1. Chapters in books and reports

Brachet, C. and D. Valensuela, coordinator (**2012**). *The handbook for integrated water resources management in transboundary basins of rivers, lakes and aquifers*. INBO. 124 pp. ISBN: 978-91-85321-85-8. URL: http://www.gwp.org/Global/ToolBox/References/The%20Handbook%20for%20Integrated%20Water%20Resources%20Management%20in%20Transboundary%20Basins%20of%20Rivers,%20Lakes,%20and%20Aquifers%20(INBO,%20GWP,%202012)%20ENGLISH.pdf. E. Vargas Amelin as contributor.

CHJ (**2004**). Confederación Hidrográfica del Júcar. *Júcar Pilot River Basin, Provisional Article 5 Report Pursuant to the Water Framework Directive*. Ed. by T. Estrela. Valencia: Confederación Hidrográfica del Júcar. 208 pp. ISBN: 84-922007-2-3. URL: http://www.chj.es/es-es/ciudadano/participacion_publica/Documents/Plan%20Hidrol%EF%BF%BDgico%20de%20cuenca/Jucar_pilot_river_basin_Parte_1.pdf. E. Vargas Amelin as contributor and translator.

Estrela Monreal, T. and E. Vargas Amelin (2008a). “Los Problemas del Agua, Una visión global sobre los recursos hídricos disponibles”. In: *La Desalación en España*. Aguas de las Cuencas Mediterráneas, S.A., pp. 13–42. E. Vargas Amelin as co-author.

– (2008b). "Water Issues, overview of available water resources". In: *La desalación en España*. Ed. by Aguas de las Cuencas Mediterráneas S.A. (Acuamed). Madrid: Sociedad Estatal Aguas de las Cuencas Mediterráneas, pp. 13–42. E. Vargas Amelin as co-author.
– (2010). "Effects of Climate Change on Hydrological Resources in Europe: The Case of Spain". In: *Global Warming and Climate Change: Prospects and Policies in Asia and Europe*. Ed. by A. Marquina. Palgrave Macmillan UK, pp. 58–77. ISBN: 978-1-349-31510-9. URL: http://link.springer.com/chapter/10.1057/9780230281257_4 (visited on 03/11/2016). E. Vargas Amelin as co-author.
Grath, J., K. Hinsby, J. Schutten, M. Craig, M. Petitta, and H. Prchalova (**2015**). *Technical report on groundwater associated aquatic ecosystems No 9*. Ed. by T. Marsland. In collab. with B. Horvath, E. Vargas Amelin, and I. Davey. Luxembourg: Publications Office. 57 pp. ISBN: 978-92-79-53895-7. URL: http://bookshop.europa.eu/uri?target=EUB:NOTICE:KH0415917:EN:HTML. E. Vargas Amelin as contributor/coordinator.
Mediterranean Groundwater Working Group (Med-EUWI WG on Groundwater) (2007). *Groundwater management in the Mediterranean and the Water Framework Directive*. Technical report 5. Joint Mediterranean EUWI/WFD Process, pp. 125–125. URL: http://bookshop.europa.eu/en/mediterranean-groundwater-report-pbKHX107045/. E. Vargas Amelin as co-author.
Vargas Amelin, E. (2011). "El agua en la cuenca Mediterránea". In: *El Mediterráneo tras 2011*. Ed. by J. M. López Bueno. Melilla: FHIMADES, pp. 151–185. ISBN: 978-84-615-2658-1. URL: http://www.fhimades.org/documentos/el-mediterraneo-tras-2011/. E. Vargas Amelin as leading author.
– (2013). "Planes, medidas y herramientas de adaptación. El caso de los balances hídricos en la cuenca del Júcar." In: *Cambio Climático e Hidrología: Desde la Ciencia a la Práctica en Gestión Hídrica y Manejo del Suelo*. Red. by S. García Galiano. Cartagena: Universidad Politécnica de Cartagena, pp. 85–96. ISBN: 978-84-616-5700-1. E. Vargas Amelin as leading author.
Vargas Amelin, E., E. López-Gunn, G. Huelva, and T. Estrela Monreal (2014). "Adopting river basin planning as a framework for climate change adaptation in Spain". In: *Adaptation to Climate Change Through Water Resources Management. Capacity, Equity and Sustainability*. Ed. by S. Dominic and E. López-Gunn. Earthscan/Routledge, pp. 353–373. ISBN: 978-0-415-63593-6. URL: www.routledge.com/9780415635936. E. Vargas Amelin as leading author.
Vargas Amelin, E., V. Ramírez Perea, A. Nieto Arias, E. Mino, and J. El-Kharraz (2013). *Halting Desertification in the Júcar River Basin (HALT-JÚCAR-DES)*. Technical report Final. Madrid: European Commission, p. 55. URL: http://ec.europa.eu/environment/water/blueprint/pdf/HJD_Final%20Technical%20Report.pdf (visited on 03/20/2016). E. Vargas Amelin as co-author.

8.1.2. ISI journal papers

Escribano Francés, G., P. Quevauviller, E. San Martín González, and E. Vargas Amelin (in review). "Climate change policy and water resources in the EU and Spain". In: *Environmental Science & Policy*. E. Vargas Amelin as leading author.

Estrela Monreal, T., M. Á. Pérez-Martín, and E. Vargas Amelin (2012). "Impacts of climate change on water resources in Spain". In: *Hydrological Sciences Journal* 57, pp. 1154–1167. DOI: 10.1080/02626667.2012.702213. (Visited on 03/21/2016). E. Vargas Amelin as co-author.

Estrela Monreal, T. and E. Vargas Amelin (2012). "Drought Management Plans in the European Union. The Case of Spain". In: *Water Resources Management* 26, pp. 1537–1553. DOI: 10.1007/s11269-011-9971-2. (Visited on 03/21/2016). E. Vargas Amelin as co-author.

Vargas Amelin, E. and P. Pindado (2014). "The challenge of climate change in Spain: Water resources, agriculture and land". In: *Journal of Hydrology*. Climatic change impact on water: Overcoming data and science gaps 518, Part B, pp. 243–249. DOI: 10.1016/j.jhydrol.2013.11.035. (Visited on 03/21/2016). E. Vargas Amelin as leading author.

8.1.3. International conference papers

Bonaiti, G., T. Davy, T. Estrela, and E. Vargas Amelin (2009). "Water scarcity and droughts". In: *European Regional Document*. 5th World Water Forum. Ed. by European Regional Coordination Committee. Istanbul: 5th World Water Forum, pp. 36–41. URL: http://www.ewp.eu/wp-content/uploads/2009/03/European-Regional-Document-final.pdf. E. Vargas Amelin as co-author.

Estrela Monreal, T. and E. Vargas Amelin (2007). "Planes Especiales de Sequía en las Demarcaciones Hidrográficas Españolas". In: International Forum on Drought. Sevilla, Spain: MARM. URL: http://www.emwis.net/thematicdirs/events/2007/06/sev180144/generate_pdf?url=thematicdirs/events/2007/06/sev180144&lang=en. E. Vargas Amelin as co-author.

Ramírez Perea, V. and E. Vargas Amelin (2010). "Sobre el acceso a la información obtenida o elaborada por las Administraciones Públicas, la medición de la calidad de las observaciones y la creación de repositorios distribuidos de acceso centralizado". In: *Comunicaciones técnicas*. X Congreso Nacional del Medio Ambiente CONAMA 10. Madrid, Spain: CONAMA. ISBN: 978-84-614-6112-7. URL: http://www.conama10.vsf.es/conama10/download/files/CT%202010/41248.pdf. E. Vargas Amelin as co-author.

Vargas Amelin, E. and V. Ramírez Perea (2010). "La producción de bioetanol en Brasil y sus impactos medioambientales e hídricos". In: *Comunicaciones técnicas*. X Congreso Nacional del Medio Ambiente CONAMA 10. Ed. by Fundación CONAMA. Madrid, Spain: Congreso Nacional de Medio Ambiente. ISBN: 978-84-614-6112-7. URL: http://www.conama10.es/conama10/download/files/CT%202010/41229.pdf. E. Vargas Amelin as leading author.

8.2. Thesis's References

8.2.1. Legislation

Birds Directive (2009). *Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0149&from=EN.

Direct Payments (2013). *Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02013R1307-20150603&qid=1464138538507&from=ES.

Environmental quality standards in the field of water policy (Priority Sustance Directive) (2008). *Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0105&from=EN.

Financing, Management and Monitoring CAP (2013). *Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02013R1306-20140101&from=EN.

Floods Directive (2007). *Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (Text with EEA relevance)*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0060.

Groundwater Directive (2006). *Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006L0118-20140711.

Habitats Directive (1992). *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01992L0043-20130701.

Markets Organisation (2013). *Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007*. URL: https://wirtschaft.hessen.de/sites/default/files/media/hmwvl/allgem-vo_2013-11-13.pdf.

National Hydrological Plan (2001). *Ley 10/2001, de 5 de julio, del Plan Hidrológico Nacional*. URL: https://www.boe.es/buscar/pdf/2001/BOE-A-2001-13042-consolidado.pdf.

Nitrates Directive (1991). *Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01991L0676-20081211.

Rural Development Regulation (2013). *Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02013R1305-20150523&from=EN.

Spanish Hydrological Planning Regulation (2007). *Real Decreto 907/2007, de 6 de julio, por el que se aprueba el Reglamento de la Planificación Hidrológica*. URL: https://www.boe.es/boe/dias/2007/07/07/pdfs/A29361-29398.pdf.

Spanish Hydrological Planning Regulation amended (2010). *Real Decreto 1161/2010, de 17 de septiembre, por el que se modifica el Real Decreto 907/2007, de 6 de julio, por el que se aprueba el Reglamento de la Planificación Hidrológica*. URL: http://www.boe.es/boe/dias/2010/09/18/pdfs/BOE-A-2010-14307.pdf.

Technical Instruction on Hydrological Planning (2008). *Orden ARM/2656/2008, de 10 de septiembre, por la que se aprueba la instrucción de planificación hidrológica*. URL: https://www.boe.es/boe/dias/2008/09/22/pdfs/A38472-38582.pdf.

Urban Waste Water Directive (1991). *Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01991L0271-20140101&qid=1460129134784&from=EN.

Urgent Measures Drought (2006). *Real Decreto-Ley 9/2006, de 15 de septiembre, por el que se adoptan medidas urgentes para paliar los efectos producidos por la sequía en las poblaciones y en las explotaciones agrarias de regadío en determinadas cuencas hidrográficas*. URL: http://www.boe.es/boe/dias/2006/09/16/pdfs/A32645-32648.pdf.

– (2008). *Real Decreto-Ley 8/2008, de 24 de octubre, por el que se adoptan medidas urgentes para paliar los efectos producidos por la sequía en determinados ámbitos de las cuencas hidrográficas*. URL: https://www.boe.es/boe/dias/2008/10/25/pdfs/A42410-42413.pdf.

Water Act (2001). *Real Decreto Legislativo 1/2001, de 20 de julio, por el que se aprueba el texto refundido de la Ley de Aguas*. URL: https://www.boe.es/buscar/pdf/2001/BOE-A-2001-14276-consolidado.pdf.

Water Framework Directive (2000). *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy*. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02000L0060-20141120.

Water Reuse Regulation (2007). *Real Decreto 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas*. URL: http://www.boe.es/buscar/pdf/2007/BOE-A-2007-21092-consolidado.pdf.

Water rights (2005). *Real Decreto-Ley 15/2005, de 16 de diciembre, de medidas urgentes para la regulación de las transacciones de derechos al aprovechamiento de agua*. URL: https://www.boe.es/boe/dias/2005/12/17/pdfs/A41337-41340.pdf.

8.2.2. References

Abramskiehn, D., D. Wang, and B. Buchner (2015). *The Landscape of Climate Exposure for Investors*. Technical report. Climate Policy Initiative. URL: http://climatepolicyinitiative.org/wp-content/uploads/2015/08/The-Landscape-of-Climate-Exposure-for-Investors_full-report.pdf.

Adamo, K. and P. Garonna (2009). "Euro-mediterranean integration and cooperation: prospects and challenges". In: *UN Economic Commission for Europe Report 2009*. Annual report ECE/INF/2009/1. New York and Geneva: United Nations Economic Commission for Europe, pp. 73–84. URL: http://www.unece.org/oes/nutshell/2009/9_EuroMediterranean.pdf.

AEMET. Agencia Estatal de Meteorología. *Proyecciones climáticas para el siglo XXI - Agencia Estatal de Meteorología - AEMET. Gobierno de España*. URL: http://www.aemet.es/es/serviciosclimaticos/cambio_climat.

AEMET (**2008**). Agencia Estatal de Meteorología and M. Brunet. *Generación de escenarios regionalizados de cambio climático para España*. Madrid, Spain: Ministerio de Medio Ambiente, Medio Rural y Marino. 157 pp. ISBN: 978-84-8320-470-2. URL: http://publicacionesoficiales.boe.es/detail.php?id=001031008-0001.

Álvarez, J. and T. Estrela (2003). "Regionalisation and Identification of Droughts in Mediterranean Countries of Europe". In: *Tools for Drought Mitigation in Mediterranean Regions*. Ed. by G. Rossi, A. Cancelliere, L. S. Pereira, T. Oweis, M. Shatanawi, and A. Zairi. Water Science and Technology Library 44. Springer Netherlands, pp. 123–146. DOI: 10.1007/978-94-010-0129-8_8.

Ameziane, T. et al. (**2007**). *Drought Management Guidelines*. Ed. by A. Iglesias, A. Cancelliere, D. Gabiña, A. López-Francos, M. Moneo, and G. Rossi. EC - EuropeAid Co-operation Office, MEDA Water and MEDROPLAN. URL: http://www.iamz.ciheam.org/medroplan/guidelines/archivos/guidelines_english.pdf.

Amirah Fernández, H., E. Soler i Lecha, et al. (**2011**). *El Mediterráneo tras 2011*. Ed. by J. M. López-Bueno. Melilla, Spain: FHIMADES. 237 pp. ISBN: 978-84-615-2658-1. URL: http://ramonpuchades.com/wp-content/uploads/2012/03/El-Mediterr%C3%A1neo-tras-2011.pdf.

Amirah Fernández, H. and R. Youngs (2005). "Proceso de Barcelona: Balance de una década de Asociación Euromediterránea". In: *Análisis Real Instituto Elcano* 137/2005, p. 10. URL: http://biblioteca.ribei.org/853/.

Andreu Álvarez, J. and A. Solera Solera (2006). "Methodology for the analysis of drought mitigation measures". In: *Drought Management and Planning for Water Resources*. Ed. by J. Andreu Álvarez, G. Rossi, F. Vagliasindi, and A. Vela Mayorga. CRC Press. Taylor and Francis, pp. 133–168. ISBN: 978-1-56670-672-8.

Antolín, M. (2008). "Drought Management as Example for the Adaptiveness of Spanish Water Management". Sevilla, Spain.

Arnell, N. W. (**1996**). *Global Warming, River Flows and Water Resources*. Wiley. 234 pp. ISBN: 978-0-471-96599-2. URL: http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0471965995.html.

– (1999). "Climate change and global water resources". In: *Global Environmental Change* 9, Supplement 1, S31–S49. DOI: 10.1016/S0959-3780(99)00017-5.

– (2004). "Climate change and global water resources: SRES emissions and socio-economic scenarios". In: *Global Environmental Change* 14, pp. 31–52. DOI: 10.1016/j.gloenvcha.2003.10.006.

Arnell, N. W., C. Liu, R. Compagnucci, L. da Cunha, K. Hanaki, C. Howe, G. Mailu, I. Shiklomanov, and E. Stakhiv (2001). "Hydrology and Water Resources". In: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. by J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White. In collab. with P. Döll, A. Becker, and J. Zhang. Cambridge: Cambridge University Press, pp. 191–233. ISBN: 0 521 80768 9. URL: https://ipcc.ch/ipccreports/tar/wg2/.

Ayala Carcedo, F. J. (1996). "Reducción de los recursos hídricos en España por el posible cambio climático". In: *Tecno ambiente: Revista profesional de tecnología y equipamiento de ingeniería ambiental* 64, pp. 43–48. ISSN: 1133-4665. URL: https://dialnet.unirioja.es/servlet/articulo?codigo=176951.

Ayala Carcedo, F. J. and A. Iglesias López (2000). "Impactos del posible cambio climático sobre los recursos hídricos, el diseño y la planificación hidrológica en la España peninsular". In: *El Campo de las ciencias y las artes* 137, pp. 201–222. URL: https://dialnet.unirioja.es/servlet/articulo?codigo=202406.

Bizikova, L., D. Roy, D. Swanson, H. D. Venema, and M. McCandless (2013). *The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management*. Technical report. Winnipeg, MB, Canada: International Institute for Sustainable Development. URL: http://www.iisd.org/sites/default/files/publications/wef_nexus_2013.pdf.

Blue Plan (2008). *The Blue Plan's Sustainable Development Outlook for the Mediterranean*. Technical report. Sophia Antipolis, France: United Nations Environment Programme, Mediterranean Action Plan, Blue Plan – Regional Activity Centre. URL: http://planbleu.org/sites/default/files/publications/upm_en_1.pdf.

Boix, D. et al. (2010). "Response of community structure to sustained drought in Mediterranean rivers". In: *Journal of Hydrology*. Water Quality and Assessment under Scarcity. Prospects and challenges in Mediterranean watersheds 383, pp. 135–146. DOI: 10.1016/j.jhydrol.2010.01.014.

Bordi, I., K. Fraedrich, and A. Sutera (2009). "Observed drought and wetness trends in Europe: an update". In: *Hydrology and Earth System Sciences* 13, pp. 1519–1530. DOI: 10.5194/hess-13-1519-2009.

Borrego-Marín, M. M., C. Gutiérrez-Martín, and J. Berbel (2015). "Estimation of Cost Recovery Ratio for Water Services Based on the System of Environmental-Economic Accounting for Water". In: *Water Resources Management* 30, pp. 767–783. DOI: 10.1007/s11269-015-1189-2.

Buchanan-Smith, M. and D. A. Wilhite (2005). "Drought as Hazard". In: *Drought and Water Crises*. Ed. by D. A. Wilhite. Books in Soils, Plants, and the Environment. CRC Press, pp. 3–29. ISBN: 978-0-8247-2771-0. URL: http://dx.doi.org/10.1201/9781420028386.pt1.

Budyko, M. I. and O. A. Drozdov (1953). "The laws of water cycle in the atmosphere". In: *Bull. Acad. Sci. USRR. Scr.: Georg* 4, pp. 167–170.

Cancelliere, A., G. D. Mauro, B. Bonaccorso, and G. Rossi (2006). "Drought forecasting using the Standardized Precipitation Index". In: *Water Resources Management* 21, pp. 801–819. DOI: 10.1007/s11269-006-9062-y.

Ceballos-Barbancho, A., E. Morán-Tejeda, M. Á. Luengo-Ugidos, and J. M. Llorente-Pinto (2008). "Water resources and environmental change in a Mediterranean environment: The south-west sector of the Duero river basin (Spain)". In: *Journal of Hydrology* 351, pp. 126–138. DOI: 10.1016/j.jhydrol.2007.12.004.

Cembrero, I. (2011). *El año de las revueltas: 2011. Una ola de cambio. Revueltas en Marruecos*. URL: http://web.archive.org/web/20110429055418/http://www.elpais.com/especial/revueltas-en-el-mundo-arabe/marruecos/.

CEDEX (1998). Centro de Estudios y Experimentación de Obras Públicas. *Estudio sobre el impacto potencial del cambio climático en los recursos hídricos y demandas de agua de riego en determinadas regiones de España*. Technical report CEDEX: 43–496–1–089. Madrid, Spain: Ministerio de Medio Ambiente.

– (2010). Centro de Estudios y Experimentación de Obras Públicas. *Estudio de los impactos del cambio climático en los recursos hídricos y las masas de agua. Ficha 1. Evaluación del impacto del cambio climático en los recursos hídricos en régimen natural*. Technical report CEDEX: 42–407–1–001. Madrid, Spain: Ministerio de Medio Ambiente y Medio Rural y Marino. URL: http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/ImpactoCCSintesis_tcm7-310167.pdf.

CEDEX (2011). Centro de Estudios y Experimentación de Obras Públicas. *Evaluación del Impacto del cambio climático en los recursos hídricos en régimen natural.* Memoria. Madrid, Spain: Ministerio de Medio Ambiente y Medio Rural y Marino. URL: http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/ImpactoCCSintesis_tcm7-310167.pdf.

Cerdá Tena, E. (2011). "Comercio internacional y cambio climático". In: *Información Comercial Española, ICE: Revista de economía* 862, pp. 97–110. ISSN: 0019-977X. URL: http://www.revistasice.com/CachePDF/ICE_862_97-110__8EF0B71F48FAF4EBAA2ADDF4DD47732D.pdf.

Cerdá Tena, E. and X. Labandeira (**2010**). *Climate Change Policies*. Edward Elgar Publishing. 304 pp. DOI: 10.4337/9781781000885.

Chirivella Osama, V. (2010). "Caracterización de los futuros escenarios climáticos en la Comunidad Valenciana: propuestas de mejora para la evaluación de la oferta y demanda de recursos hídricos". phd. Tesis Doctoral. Universidad Politécnica de Valencia. Valencia, España.

Chirivella Osama, V., J. E. Capilla Romá, and M. Á. Pérez-Martín (2011). "Impacto del cambio climático en los recursos hídricos de la Cuenca Hidrográfica del Júcar". In: *Risk Analysis, Dam Safety, Dam Security and Critical Infrastructure Management*. 3rd international forum on risk analysis, dam safety, dam security and critical infraestructure management (3IWRDD-FORUM). Ed. by I. Escuder Bueno, E. Matheu, L. Altarejos García, and J. T. Castillo Rodríguez. Valencia, Spain: CRC Press/Balkema. ISBN: 978-0-415-62078-9. URL: https://www.crcpress.com/Risk-Analysis-Dam-Safety-Dam-Security-and-Critical-Infrastructure-Management/EscuderBueno-Matheu-AltarejosGarca-T-CastilloRodrguez/9780415620789.

CHGuadiana (2007). Confederación Hidrográfica del Guadiana. *Plan especial ante situación de alerta y eventual sequía de la cuenca del Guadiana*. URL: http://www.chguadiana.es/corps/chguadiana/data/resources/file/sequia/Plan_Especial_de_Sequias.pdf.

CHJ (2007). Confederación Hidrográfica del Júcar. *Plan especial ante situación de alerta y eventual sequía de la cuenca del Júcar*. URL: http://www.chj.es/es-es/medioambiente/gestionsequia/Documents/Plan%20Especial%20Alerta%20y%20Eventual%20Sequia/PES_Marzo_2007.pdf.

– (2009). Confederación Hidrográfica del Júcar. *Esquema provisional de temas importantes de la Demarcación Hidrográfica del Júcar*. URL: http://www.chj.es/es-es/medioambiente/planificacionhidrologica/Documents/Plan-Hidrologico-cuenca-2009-2015/EpTI.pdf.

– (2015). Confederación Hidrográfica del Júcar. *Propuesta de proyecto de revisión del Plan Hidrológico. Memoria. Ciclo de planificación hidrológica 2015-2021; Demarcación Hidrográfica del Júcar*. URL: http://www.chj.es/Descargas/ProyectosOPH/Consulta%20publica/PHC-2015-2021/PHJ1521_postCP_Memoria.pdf.

CHS (2007). Confederación Hidrográfica del Segura. *Plan especial ante situación de alerta y eventual sequía de la cuenca del Segura*. URL: https://www.chsegura.es/chs/cuenca/sequias/pes/eeapes.html#doc_completa.

Costello, A. et al. (2009). "Managing the health effects of climate change". In: *The Lancet* 373, pp. 1693–1733. DOI: 10.1016/S0140-6736(09)60935-1.

Dai, A. (2011). "Drought under global warming: a review". In: *Wiley Interdisciplinary Reviews: Climate Change* 2, pp. 45–65. DOI: 10.1002/wcc.81.

Diffenbaugh, N. S., J. S. Pal, F. Giorgi, and X. Gao (2007). "Heat stress intensification in the Mediterranean climate change hotspot". In: *Geophysical Research Letters* 34, p. L11706. DOI: 10.1029/2007GL030000.

Escribano Francés, G., P. Quevauviller, E. San Martín González, and E. Vargas Amelin (in review). "Climate change policy and water resources in the EU and Spain". In: *Environmental Science & Policy*. E. Vargas Amelin as leading author.

Escribano Francés, G. and E. San Martín González (2011). "La energía y la "primavera" árabe". In: *El Mediterráneo tras 2011*. Ed. by J. M. López-Bueno. Melilla: FHIMADES, pp. 248–248. ISBN: 978-84-615-2658-1. URL: http://www.fhimades.org/documentos/el-mediterraneo-tras-2011/.

Estrela Monreal, T. (2006). "La gestión de las sequías en España". In: *Ingeniería y Territorio*. Catástrofes naturales 74, pp. 52–57. ISSN: 1695-9647. URL: http://www.ciccp.es/revistaIT/textos/pdf/06-Teodoro%20Estrela.pdf.

Estrela Monreal, T., F. Cabezas Calvo-Rubio, and F. Estrada Lorenzo (2001). "The Water Resources Assessment in the White Paper on Water in Spain. Country Paper of Spain." In: *Water modelling as a tool in river basin management within the framework directive*. Ed. by CEDEX. Red. by EurAqua (European Network of Freshwater Research Organizations). Vol. 7. EurAqua technical review. Madrid: EurAqua, pp. 113–136. ISBN: 978-84-7790-370-3.

Estrela Monreal, T., J. Ferrer Polo, M. Á. Pérez Martín, and V. Font (2004). "Modelo hidrogeológico del acuífero de la Mancha Oriental para el análisis de los efectos de las diferentes alternativas de sustitución de extracciones por aguas superficiales". In: *VIII Simposio de Hidrogeología. Asociación Española de Hidrogeólogos*. Ed. by Instituto Geológico y Minero de España. Instituto Geológico y Minero de España.

Estrela Monreal, T., F. Gallart, and A. Iglesias López (2005). "Impactos sobre los recursos hídricos". In: *Evaluación preliminar de los impactos en España por efecto del cambio climático. Proyecto ECCE - INFORME FINAL.* In collab. with J. Andreu Álvarez, L. Hernández Barrios, and M. Á. Pérez-Martín. Madrid, Spain: Ministerio de Medio Ambiente, pp. 303–355. ISBN: 84-8320-303-0. URL: http://www.magrama.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/evaluacion_preliminar_impactos_completo_2_tcm7-12439.pdf.

Estrela Monreal, T., M. Á. Pérez-Martín, and E. Vargas Amelin (2012). "Impacts of climate change on water resources in Spain". In: *Hydrological Sciences Journal* 57, pp. 1154–1167. DOI: 10.1080/02626667.2012.702213. E. Vargas Amelin as co-author.

Estrela Monreal, T. and E. Vargas Amelin (2008). "Water Issues, overview of available water resources". In: *La desalación en España*. Ed. by Aguas de las Cuencas Mediterráneas S.A. (Acuamed). Madrid: Sociedad Estatal Aguas de las Cuencas Mediterráneas, pp. 13–42. E. Vargas Amelin as co-author.

– (2010). "Effects of Climate Change on Hydrological Resources in Europe: The Case of Spain". In: *Global Warming and Climate Change: Prospects and Policies in Asia and Europe*. Ed. by A. Marquina. 1st ed. Energy, Climate and the Environment. Basingstoke: Palgrave Macmillan UK, pp. 58–77. DOI: 10.1057/9780230281257. E. Vargas Amelin as co-author.

– (2012). "Drought Management Plans in the European Union. The Case of Spain". In: *Water Resources Management* 26, pp. 1537–1553. DOI: 10.1007/s11269-011-9971-2. E. Vargas Amelin as co-author.

Estrela, T. et al. (**2001**). *Extreme hydrological events: floods and droughts*. Sustainable water use in Europe Part 3. Copenhagen: European Environment Agency. URL: https://www.researchgate.net/profile/Teodoro_Estrela/publication/250666444_Sustainable_water_use_in_Europe/links/00b4953a2d95081448000000.pdf.

Europe External Policy Advisors (2011). *Home - ENPI Programming*. URL: http://enpi-programming.eu/.

EC (**2003a**). European Commission. *Economics and the environment the implementation challenge of the water framework directive. No 1. No 1.* Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance document No 1. Luxembourg: OPOCE. ISBN: 978-92-894-4144-5. URL: http://bookshop.europa.eu/uri?target=EUB:NOTICE:KH4502781:EN:HTML.

– (2003b). European Commission. *Wider Europe — Neighbourhood: A New Framework for Relations with our Eastern and Southern Neighbours*. Communication from the Commission to the Council and the European Parliament 104 final. European Commission. URL: http://eeas.europa.eu/enp/pdf/pdf/com03_104_en.pdf.

– (2006). European Commission. *Establishing an Environment Strategy for the Mediterranean*. Communication from the Commission to the Council and the European Parliament 475 Final. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52006DC0475&from=EN.

– (2007a). European Commission. *Addressing the challenge of water scarcity and droughts in the European Union*. Communication from the Commission to the European Parliament and the Council COM(2007) 414 final. European Union. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0414&from=EN.

– (2007b). European Commission. *Water Scarcity and Droughts*. Interim report 2. European Union. URL: http://ec.europa.eu/environment/water/quantity/pdf/comm_droughts/2nd_int_report.pdf.

– (2009a). European Commission. *Adapting to climate change: Towards a European framework for action*. White paper COM(2009) 147 final, p. 17. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009DC0147&from=EN.

– (2009b). European Commission. *Impact Assessment*. Commission Staff Working Document accompanying the 'White Paper. Adapting to climate change: Towards a European framework for action' SEC(2009) 387. European Commission, p. 134. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009SC0387&from=EN.
– (**2009c**). European Commission. *River basin management in a changing climate*. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance document No 24. Luxembourg: EUR-OP. ISBN: 978-92-79-14298-7.
– (2010). European Commission. *Agriculture in the European Union*. Statistical and economic information 2009. European Union. URL: http://ec.europa.eu/agriculture/agrista/2009/table_en/2009enfinal.pdf.
– (**2011a**). European Commission. *Climate Change Impacts on Water and Security in Southern Europe and neighbouring regions*. Luxembourg: Publications Office of the European Union. 25 pp. DOI: 10.2777/56413.
– (2011b). European Commission. *Roadmap to a Resource Efficient Europe*. Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the regions COM(2011) 571 final. Brussels: European Union, pp. 25–25. URL: http://ec.europa.eu/food/safety/food_waste/library/docs/com2011_571_en.pdf.
– (2011c). European Commission. *Third Follow up Report to the Communication on water scarcity and droughts in the European Union COM (2007) 414 final*. Report from the Commission to the European Parliament and the Council COM(2011) 133 final. European Union. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0133&from=en.
– (2012a). European Commission. *A Blueprint to Safeguard Europe's Water Resources*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM(2012) 673 final. European Union. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0673&from=EN.
– (2012b). European Commission. *Agriculture in the European Union*. Statistical and economic information 2012. European Commission, p. 353. URL: http://ec.europa.eu/agriculture/statistics/agricultural/2012/pdf/full-report_en.pdf.
– (2012c). European Commission. *Report on the Review of the European Water Scarcity and Droughts Policy*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committe and the Committe of the Regions COM(2012) 672 final. European Union, pp. 15–15. URL: http://ec.europa.eu/environment/water/quantity/pdf/COM-2012-672final-EN.pdf.
– (**2012**). *The common agricultural policy: a story to be continued*. Luxembourg: EUR-OP. ISBN: 978-92-79-23265-7. URL: http://ec.europa.eu/agriculture/50-years-of-cap/files/history/history_book_lr_en.pdf.

EC (2013a). European Commission. *An EU Strategy on adaptation to climate change.* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committe of the Regions COM(2013) 216 final. European Union, p. 11. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0216&from=EN.

– (2013b). European Commission. *Green Infrastructures (GI) -Enhancing Europe's Natural Capital*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM(2013) 249 final. European Union, p. 11. URL: http://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF.

– (2013c). European Commission. *Green Paper A 2030 framework for climate and energy policies*. URL: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013DC0169.

– (**2014a**). European Commission. *Adaptation to climate change*. European Union. 4 pp. DOI: 10.2834/68959.

– (2014b). European Commission. *Natural Water Retention Measures*. Technical Report 2014-082. Luxembourg: European Commission, pp. 18–18. DOI: 10.2779/227173.

– (2015a). European Commission. *Country Report Spain 2015, including an in-depth review on the prevention and correction of macroeconomic imbalances*. Commission Staff Working Document SWD(2015) 28 final. Brussels: European Commission, pp. 89–89.

– (2015b). European Commission. *Discussion paper on the CIS Work Programme 2016-2018. Water Directors – Riga 26-27 May 2015.*

– (**2015c**). European Commission. *European economic forecast Winter 2015.* European Economy series ISSN 1725-3217. Luxembourg: Publications Office. DOI: 10.2765/330642(online).

– (**2015d**). European Commission. *Guidance document on the application of water balances for supporting the implementation of the WFD*. version 6.1. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance document No 34. Luxembourg: Office for Official Publications of the European Communities. 126 pp. ISBN: 978-92-79-52021-1. E. Vargas Amelin as contributor/coordinator.

– (2015e). European Commission. *Report on the progress in implementation of the Floods Directive*. Commission Staff Working Document Accompanying the document Communication from the Commission to the European Parliament and the Council, The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks SWD(2015) 51 final. Brussels: European Union, pp. 82–82.

European Council (2014). *Conclusions of European Council on 23 and 24 October 2014*. Cover note CO EUR 13 CONCL 5. European Council, p. 16. URL: http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf.

European Court of Auditors (**2014**). *Integration of EU water policy objectives with the CAP: a partial success*. Special Report 04. Luxembourg: Publications Office of the European Union. 68 pp. DOI: 10.2865/15216.

EEA (1999). European Environment Agency. *Environmental indicators: typology and overview*. Technical report No 25/1999. Copenhagen: European Environment Agency, p. 19. URL: www.eea.europa.eu/publications/TEC25/at_download/file.

– ed. (2005). *The European environment - state and outlook 2005*. Luxembourg: Office for Official Publications of the European Communities. 570 pp. ISBN: 978-92-9167-776-4.

– (**2007a**). European Environment Agency. *Climate change the cost of inaction and the cost of adaptation*. Luxembourg: Office for Official Publications of the European Communities. DOI: 10.2800/14754.

– ed. (2010). *The European environment - state and outlook 2010: synthesis ; [SOER 2010]*. Copenhagen: Publications Office of the European Union [u.a.] 222 pp. DOI: 10.2800/45773.

– (**2012a**). European Environment Agency. *Climate change, impacts and vulnerability in Europe 2012. An indicator-based report*. Copenhagen: Office for Official Publications of the European Union. 304 pp. DOI: 10.2800/66071.

– ed. (2012b). *European waters: assessment of status and pressures*. EEA report 8/2012. Luxembourg: Office for Official Publications of the European Union. 96 pp. DOI: 10.2800/63266.

– (**2013a**). European Environment Agency. *Adaptation in Europe, Addressing risks and opportunities from climate change in the context of socio-economic developments*. Copenhagen: Publication Office of the European Union. 136 pp. DOI: 10.2800/50924.

– (**2013b**). European Environment Agency. *Assessment of cost recovery through water pricing*. Luxembourg: Publications Office. ISBN: 978-92-9213-409-9. URL: http://dx.publications.europa.eu/10.2800/93669.

– (**2014**). European Environment Agency. *National adaptation policy processes in European countries 2014*. Luxembourg: Publications Office. DOI: 10.2800/21394.

EEA, EC-JRC, and WHO, eds. (2008). *Impacts of Europe's changing climate: 2008 indicator-based assessment: joint EEA-JRC-WHO report*. EEA report no. 4/2008. Copenhagen : Luxembourg: Office for Official Publications of the European Communities. 246 pp. DOI: 10.2800/48117.

EEA (**2007b**). European Environment Agency, A. Footitt, and M. McKenzie Hedger. *Climate change and water adaption issues*. Luxembourg: Office for Official Publications of the European Communities. ISBN: 978-92-9167-917-1. URL: http://reports.eea.europa.eu/technical_report_2007_2/en/eea_technical_report_2_2007.pdf.

EU (2011). European Union. *European Union - EEAS (European External Action Service) | The Association Agreement EU-Morocco*. URL: http://www.eeas.europa.eu/morocco/association_agreement/index_en.htm.

Eurostat (2015). *Agri-environmental indicator - nitrate pollution of water - Statistics Explained*. URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_nitrate_pollution_of_water.

Fairén Le Lay, V. (2008). "Crónicas del Agua". In: *Revista 100cias@uned*. Problemas del Medio Ambiente 1 nueva época, pp. 92–105. ISSN: 1989-7189. URL: http://e-spacio.uned.es/fez/eserv/bibliuned:revista100cias-2008-1ne-2000/Doumento.pdf.

Fernandez Carrasco, P. (2002). "Estudio del impacto del cambio climático sobre los recursos hídricos : Aplicación en diecinueve pequeñas cuencas en España". phd. E.T.S.I. Caminos, Canales y Puertos (UPM). 267 pp. URL: http://oa.upm.es/140/.

Ferragina, E. (2010). "Water Policy in the Mediterranean: An Overview". In: *Focus, Observatory of Euro-mediterranean Policies (IEMedObs)*, pp. 4–4. URL: http://www.iemed.org/observatori-en/arees-danalisi/arxius-adjunts/copy_of_focus/Water_Policy_in_the_Mediterranean__An_Overview_Ferragina.

Fisher, F. and A. Huber-Lee (2005). *Liquid Assets: An Economic Approach for Water Management and Conflict Resolution in the Middle East and Beyond*. Technical report. Stockholm Environment Institute. URL: http://www.sei-international.org/publications?pid=923.

Flores, V. and M. J. de Miguel (2007). "La Medida de Forestación de Tierras Agrícolas". In: *Foresta* 39, pp. 12–15. ISSN: 1575-2356.

FAO (2011). Food and Agriculture Organization of the United Nations. *AQUASTAT website*. URL: http://www.fao.org/nr/water/aquastat/main/indexesp.stm.

Francis Mateo (2011). *L'UpM mobilise 400 M€ pour assainir l'eau à Gaza*. URL: http://www.econostrum.info/L-UpM-mobilise-400-M-pour-assainir-l-eau-a-Gaza_a5806.html.

Fuentes, A. (2011). *Policies Towards a Sustainable Use of Water in Spain*. OECD Economics Department Working Papers. Paris: Organisation for Economic Co-operation and Development. URL: http://www.oecd-ilibrary.org/content/workingpaper/5kgj3l0ggczt-en.

Gallardo, C., A. Arribas, J. A. Prego, M. A. Gaertner, and M. De Castro (2001). "Multi-year simulations using a regional-climate model over the Iberian Peninsula: Current climate and doubled CO2 scenario". In: *Quarterly Journal of the Royal Meteorological Society* 127, pp. 1659–1681. DOI: 10.1002/qj.49712757511.

Ganoulis, J. (2006). "Water resources management and environmental security in Mediterranean transboundary river basins". In: *Environmental Security and Environmental Management: The Role of Risk Assessment*. Ed. by B. Morel and I. Linkov. NATO Security Through Science Series 5. Springer Netherlands, pp. 49–58. DOI: 10.1007/1-4020-3893-3_04.

García-Ruiz, J. M., J. I. López-Moreno, S. M. Vicente-Serrano, T. Lasanta–Martínez, and S. Beguería (2011). "Mediterranean water resources in a global change scenario". In: *Earth-Science Reviews* 105, pp. 121–139. DOI: 10.1016/j.earscirev.2011.01.006.

Garrote de Marcos, L. (2009). "Cambio climático: Impactos sobre los recursos hídricos y disponibilidad de agua". Universidad Politécnica de Valencia.

Garrote de Marcos, L., I. C. Rodríguez Medina, F. Estrada Lorenzo, and J. Muñoz Bravo (1999). "Una evaluación de la capacidad de regulación de las cuencas de la España Peninsular". In: VI Jornadas Españolas de Presas. Ed. by Comité Nacional Español de Grandes Presas. Vol. 2. Málaga, pp. 645–656.

Garrote, L., A. Iglesias, and F. Flores (2009). "Development of Drought Management Plans in Spain". In: *Coping with Drought Risk in Agriculture and Water Supply Systems*. Ed. by A. Iglesias, A. Cancelliere, D. A. Wilhite, L. Garrote, and F. Cubillo. Advances in Natural and Technological Hazards Research 26. Springer Netherlands, pp. 175–186. DOI: 10.1007/978-1-4020-9045-5_13.

Garrote, L., F. Martin-Carrasco, F. Flores-Montoya, and A. Iglesias (2006). "Linking Drought Indicators to Policy Actions in the Tagus Basin Drought Management Plan". In: *Water Resources Management* 21, pp. 873–882. DOI: 10.1007/s11269-006-9086-3.

Garrote, L., M. Moneo, A. Iglesias, and F. Flores (2009). "Drought and climate risks". In: *Water Policy in Spain*. Ed. by M. Ramón Llamas and A. Garrido. CRC Press, pp. 62–75. ISBN: 978-0-415-55411-4. URL: http://dx.doi.org/10.1201/9780203866023.ch7.

Giorgi, F. (2006). "Climate change hot-spots". In: *Geophysical Research Letters* 33, p. L08707. DOI: 10.1029/2006GL025734.

Grove, A. T. and E. Lopez-Gunn (2010). *Uncertainty in Climate Change (working paper)*. URL: http://www.realinstitutoelcano.org/wps/portal/web/rielcano_en/contenido?WCM_GLOBAL_CONTEXT=/elcano/elcano_es/especiales/especial+cambio+climatico/publicaciones+rie/ari+y+dt/dt25-2010.

Hermosilla, J. (**2006**). *Las galerías drenantes del Sureste de la Península Ibérica. Uso tradicional del agua y sostenibilidad en el Mediterráneo español*. Ed. by Ministerio de Medio Ambiente. Madrid, Spain: Ministerio de Medio Ambiente. 228 pp. ISBN: 84-8320-370-7.

Hernández Barrios, L. (2007). "Efectos del cambio climático en los sistemas complejos de recursos hídricos. Aplicación a la cuenca del Júcar." phd. Valencia, Spain: Universidad Politécnica de Valencia, Spain. URL: https://www.educacion.gob.es/teseo/mostrarRef.do?ref=415107.

Hisdal, H. and L. M. Tallaksen (2003). "Estimation of regional meteorological and hydrological drought characteristics: a case study for Denmark". In: *Journal of Hydrology* 281, pp. 230–247. DOI: 10.1016/S0022-1694(03)00233-6.

HLPE (2011). *Price volatility and food security*. Technical report. Rome: Food and Agriculture Organization of the United Nations. URL: http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE-price-volatility-and-food-security-report-July-2011.pdf.

Iglesias, A., A. Cancelliere, D. A. Wilhite, L. Garrote, and F. Cubillo, eds. (2009). *Coping with Drought Risk in Agriculture and Water Supply Systems*. Dordrecht: Springer

Netherlands. ISBN: 978-1-4020-9044-8. URL: http://link.springer.com/10.1007/978-1-4020-9045-5.

Iglesias, A., L. Garrote, F. Flores, and M. Moneo (2006). "Challenges to Manage the Risk of Water Scarcity and Climate Change in the Mediterranean". In: *Water Resources Management* 21, pp. 775–788. DOI: 10.1007/s11269-006-9111-6.

Institut Méditerranéen de l'Eau (2014). "Synthèse générale & Conclusions". In: *2ème Forum Méditerranéen de l'Eau*. 2ème Forum Méditerranéen de l'Eau. Ed. by Institut Méditerranéen de l'Eau. Murcia, Spain, pp. 6–6. URL: http://www.ime-eau.org/2eme-forum-mediterraneen-de-leau/.

INE (2008a). Instituto Nacional de Estadística. *Encuesta sobre la Estructura de las Explotaciones Agrícolas 2007*. Press release. URL: http://www.ine.es/prensa/np531.pdf.

– (2008b). Instituto Nacional de Estadística. "Estadísticas e indicadores del agua 2008". In: *Colección Cifras INE*. ISSN: 1579-2277. URL: http://www.ine.es/revistas/cifraine/0108.pdf.

– (2011). Instituto Nacional de Estadística. *Anuario estadístico de España. 2011*. Anuario estadístico 2011. Instituto Nacional de Estadística. URL: http://www.ine.es/prodyser/pubweb/anuario11/anu11_02demog.pdf.

IPCC (**2000**). Intergovernmental Panel on Climate Change. *Special report on emissions scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change*. Ed. by N. Nakićenović and R. Swart. Cambridge ; New York ; Melbourne ; Madrid: Cambridge University Press. 599 pp. ISBN: 0-521-80081-1. URL: https://www.ipcc.ch/ipccreports/sres/emission/emissions_scenarios.pdf.

– (**2007a**). Intergovernmental Panel on Climate Change. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. by M. L. Parry, O. Canziani, J. Palutikof, P. van der Linden, and C. Hanson. Cambridge, UK: Cambridge University Press. ISBN: 978 0521 70597-4. URL: https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf.

– (**2007b**). Intergovernmental Panel on Climate Change. *Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change.* Ed. by The Core Writing Team, R. K. Pachauri, and A. Reisinger. Geneva, Switzerland: IPCC. 104 pp. ISBN: 978-92-9169-122-7. URL: https://www.ipcc.ch/report/ar4/syr/.

– (**2008**). Intergovernmental Panel on Climate Change. *Climate change and water, IPCC Technical Paper VI*. Ed. by B. Bates, Z. W. Kundzewicz, S. Wu, and J. Paulutikof. IPCC Technical Paper VI. Geneva: IPPC Secretariat. 210 pp. ISBN: 978-92-9169-123-4. URL: https://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.shtml.

– (**2013a**). Intergovernmental Panel on Climate Change. *Climate Change 2013: The Physical Sience Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. by T. F. Stocker et al. Cambridge and New York: Cambridge University Press. 1535 pp. ISBN: 978-1-107-66182-0. URL: http://www.ipcc.ch/report/ar5/wg1/.

– (2013b). Intergovernmental Panel on Climate Change. "Summary for Policymakers". In: *Climate Change 2013: The Physical Sience Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. by T. F. Stocker et al. Cambridge and New York: Cambridge University Press, p. 28. ISBN: 978-1-107-66182-0. URL: http://www.ipcc.ch/report/ar5/wg1/.

– (2014). Intergovernmental Panel on Climate Change. "Climate Change 2014: Impacts, Adaptation, and Vulnerability; Summary for Policy Makers". In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. by C. B. Field et al. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, pp. 1–32. URL: https://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf#page=38&zoom=auto,-39,386.

Intermón Oxfam Editorial (**2008**). *La realidad de la ayuda 2008-2009. Una evaluación independiente de la ayuda al desarrollo española e internacional*. Intermón Oxfam Editorial. 199 pp. ISBN: 84-8452-592-9.

IEA (2011). International Energy Agency. *Electricity generation Egypt 2009. IEA - Report website*. URL: http://www.iea.org/statistics/statisticssearch/report/?country=Egypt&product=electricityandheat&year=2009.

IEA and OECD (**2010**). International Energy Agency and Organisation for Economic Co-operation and Development. *Turkey 2009 review*. Paris: OECD/IEA. ISBN: 978-92-64-06041-8. URL: http://public.eblib.com/choice/publicfullrecord.aspx?p=581490.

IWMI (2008). International Water Management Institute. *Water implications of biofuel crops: understanding tradeoffs and identifying options*. IWMI Water Policy Brief 30. Colombo, Sri Lanka, pp. 4–4. URL: http://www.iwmi.cgiar.org/Publications/Water_Policy_Briefs/PDF/WPB30.pdf.

Isaac, J., H. M. K. Marwan Ayeb, F. Khalid Abdelmoumni, and H. Partow (**2009**). *Consecuencias económicas y ecológicas de los conflictos en el mundo árabe*. Ed. by O. Orozco de la Torre and D. Gil Flores. Madrid: Casa Árabe e Instituto Internacional de Estudios Árabes y del Mundo Musulmán. ISBN: 978-84-613-0812-5.

ITC (2009). *SODAMEE, Sistema de desalación de agua del mar accionado por energía eólica*. URL: http://www.itccanarias.org/web/itc/proyectos-agua/sodamee.jsp?lang=es.

Jerch, M., A. V. Lorca, and G. Escribano (2005). "De Barcelona a Luxemburgo: la política euromediterránea". In: *Política Exterior n107* 107. ISSN: 0213-6856. URL: http://www.politicaexterior.com/articulos/politica-exterior/de-barcelona-a-luxemburgo-la-politica-euromediterranea/.

Lázaro-Touza, L. and E. López-Gunn (2012). "Climate Change Policies—Mitigation and Adaptation at the Local Level: The Case of the City of Madrid (Spain)". In: *Sustainable Systems and Energy Management at the Regional Level: Comparative Approaches*. Ed. by

M. Tortora. IGI Global, pp. 261–287. ISBN: 978-1-61350-344-7 978-1-61350-345-4. URL: http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-61350-344-7.

Lázaro-Touza, L. and E. López-Gunn (2014). “Climate change diplomacy in Spain ' s future foreign policy”. In: *Real Instituto Elcano*. Spain’s Foreign Strategy 18/2014 (June), pp. 1–21. URL: http://www.realinstitutoelcano.org/wps/portal/web/rielcano_en/contenido?WCM_GLOBAL_CONTEXT=/elcano/elcano_in/zonas_in/eee18-2014-lazaro-lopezgunn-climate-change-in-spain-future-foreign-policy#.VABRcGNaYgk.

Lloyd-Hughes, B. and M. A. Saunders (2002). “A drought climatology for Europe”. In: *International Journal of Climatology* 22, pp. 1571–1592. DOI: 10.1002/joc.846.

Lopez-Gunn, E. (2009a). “Agua para todos: The new regionalist hydraulic paradigm in Spain”. In: *Water Alternatives* 2.3, p. 370. URL: http://search.proquest.com/openview/f723efdbd156bff8d1d8f0db3b26e24c/1?pq-origsite=gscholar.

– (2009b). *Spain, Water and Climate Change in COP 15 and Beyond: Aligning Mitigation and Adaptation through Innovation working paper)*. URL: http://biblioteca.ribei.org/1797/.

MAE, Ambassade de France en Israel (2005). *L’eau en Israël*. Dossier du service pour la science & la technologie. Ministère des Affaires Étrangères. URL: http://www.haifa-israel.info/eauenisrael.pdf.

Magnan, A., G. Benjamin, R. Billé, F. Gemenne, and S. Hllaegatte (2009). *The Future of the Mediterranean: From Impacts of Climate Change to Adaptation Issues*. Technical report. Paris: Institut du développement durable et des relations internationales (IDDRI), pp. 43–43. URL: http://www.iddri.org/Publications/The-Future-of-the-Mediterranean-From-Impacts-of-Climate-Change-to-Adaptation-Issues.

Martin, Q. (1991). “Drought Management Plan for Lower Colorado River in Texas”. In: *Journal of Water Resources Planning and Management* 117, pp. 645–661. DOI: 10.1061/(ASCE)0733-9496(1991)117:6(645).

Masters, G., L. Norgrove, et al. (2010). “Climate change and invasive alien species”. In: *CABI Working Paper 1* 1, p. 30. URL: http://www.cabi.org/Uploads/CABI/expertise/invasive-alien-species-working-paper.pdf.

Meadows, D. (1999). *Leverage Points: Places to Intervene in a System*. URL: http://www.donellameadows.org/wp-content/userfiles/Leverage_Points.pdf.

Milano, M., D. Ruelland, S. Fernandez, A. Dezetter, J. Fabre, and E. Servat (2012). “Facing climatic and anthropogenic changes in the Mediterranean basin: What will be the medium-term impact on water stress?” In: *Comptes Rendus Geoscience* 344, pp. 432–440. DOI: 10.1016/j.crte.2012.07.006.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being; A Framework for Assessment*. Technical report. Millennium Ecosystem Assessment, pp. 245–245. URL: http://www.millenniumassessment.org/en/Framework.html.

MAPM (2011). Ministère de l’Agriculture et des Pêches Maritimes. “Plan Maroc Vert”. URL: http://www.invest.gov.ma/upload/secteurs/fr_Document_100.pdf.

MAGRAMA (2011). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Sistema Integrado de Información del Agua*. URL: http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/sia-/.

– ed. (2012a). *Agricultura, alimentación y medio ambiente en España 2011*. 2011. Madrid: Ministerio de Agricultura, Alimentación y Medio Ambiente, Centro de Publicaciones. ISBN: 978-84-491-1208-9. URL: http://www.magrama.gob.es/es/ministerio/servicios/publicaciones/Agricultura_Alimentaci%C3%B3n_y_Medio_Ambiente_en_Espa%C3%B1a_2011_tcm7-213900.zip.

– (2012b). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Mapa de fase de sequía declarada*. URL: http://www.magrama.gob.es/ministerio/pags/Biblioteca/Revistas/pdf_MSS%2FMSS_2012_Diciembre.pdf.

– (2013a). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Encuesta sobre Superficies y Rendimientos de Cultivos 2012*. Technical report 2012. Ministerio de Agricultura, Alimentación y Medio Ambiente. URL: http://www.magrama.gob.es/es/estadistica/temas/estadisticas-agrarias/memo2013esyrcepdfa_tcm7-325292.pdf.

– (2013b). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Inventario de Gases de Efecto Invernadero de España (serie 1990-2013): Sumario de Resultados.* Technical report. Ministerio de Agricultura, Alimentación y Medio Ambiente. URL: http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/temas/sistema-espanol-de-inventario-sei-/2__Sumario_inventario_GEI_Espa%C3%B1a_-_Serie_1990-2013_Def_tcm7-362874.pdf.

– (2013c). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Sistema Integrado de Información del Agua*. URL: http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/sia-/.

– (2014). Ministerio de Agricultura, Alimentación y Medio Ambiente. *Perfil Ambiental de España 2013. Informe basado en Indicadores*. Technical report. Madrid: Ministerio de Agricultura, Alimentación y Medio Ambiente, pp. 402–402. URL: http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/publicaciones/Perfil_Ambiental_2013_tcm7-357526.pdf.

MAGRAMA and R. Allué Téllez, eds. (2013). *Agricultura, alimentación y medio ambiente en España 2012*. 2012. Madrid: Ministerio de Agricultura, Alimentación y Medio Ambiente, Centro de Publicaciones. ISBN: 978-84-491-1299-7. URL: http://www.magrama.gob.es/es/ministerio/servicios/publicaciones/Memoria-agricultura-2013_tcm7-347430.pdf.

Ministerio de Medio Ambiente, ed. (2000). *Libro blanco del agua en España*. Madrid: Ministerio de Medio Ambiente. 656 pp.

– (2002). Ministerio de Medio Ambiente. *Plan Forestal Español*. URL: http://www.magrama.gob.es/es/desarrollo-rural/temas/politica-forestal/pfe_tcm7-30496.pdf.

MMA (**2008**). Ministerio de Medio Ambiente. *La gestión de la sequía de los años 2004 a 2007*. In collab. with T. Estrela Monreal and A. Rodríguez Fontal. [Madrid]: Ministerio de Medio Ambiente. ISBN: 978-84-8320-419-1.

MARM (2008a). Ministerio de Medio Ambiente y Medio Rural y Marino. *Anuario de Estadística 2008*. Anuario de Estadística 2008. Madrid: Ministerio de Medio Ambiente y Medio Rural y Marino, p. 1199. URL: http://www.magrama.gob.es/estadistica/pags/anuario/2008/AE_2008_Completo.pdf.

– (2008b). Ministerio de Medio Ambiente y Medio Rural y Marino. *Programa de Acción Nacional contra la Desertificación*. URL: http://www.magrama.gob.es/es/biodiversidad/publicaciones/pand_agosto_2008_tcm7-19664.pdf.

– (2009a). Ministerio de Medio Ambiente y Medio Rural y Marino. *Comunicación Nacional España*. Technical report 5. New York: Convención Marco de las Naciones Unidas sobre el Cambio Climático. URL: http://unfccc.int/resource/docs/natc/esp_nc5.pdf.

– (2009b). Ministerio de Medio Ambiente y Medio Rural y Marino. *Perfil Ambiental de España 2009. Informe basado en indicadores*. Technical report. Ministerio de Medio Ambiente y Medio Rural y Marino, p. 337. URL: http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/temas/informacion-ambiental-indicadores-ambientales/indicadores-ambientales-perfil-ambiental-de-espana/perfil-ambiental-de-espana-2009/.

– (2010). Ministerio de Medio Ambiente y Medio Rural y Marino. *Anuario de aforos 2007-2008*. Anuario. Madrid: Ministerio de Medio Ambiente y Medio Rural y Marino.

Ministerio de Obras Públicas, Transportes y Medio Ambiente (1995). *Programa Nacional del Clima*. Programa. Madrid: Ministerio de Obras Públicas, Transportes y Medio Ambiente.

Montoya, F. G., M. J. Aguilera, and F. Manzano-Agugliaro (2014). "Renewable energy production in Spain: A review". In: *Renewable and Sustainable Energy Reviews* 33, pp. 509–531. DOI: 10.1016/j.rser.2014.01.091.

Morata Gasca, A. (**2014**). *Guía de escenarios regionalizados de cambio climático sobre España a partir de los resultados del IPCC-AR4*. Ed. by Ministerio de Agricultura, Alimentación y Medio Ambiente. Agencia Estatal de Meteorología. Madrid, Spain: Ministerio de Agricultura, Alimentación y Medio Ambiente. 202 pp. URL: http://www.aemet.es/documentos/es/conocermas/publicaciones/Guia_IPCC/Guia_IPCC.pdf.

Moreno Rodríguez, J. M. et al. (2005). *A Preliminary Assessment of the Impacts in Spain due to the Effects of Climate Change*. Technical report. Madrid, Spain: Ministerio de Medio Ambiente. URL: http://www.magrama.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/full_report_tcm7-199440.pdf.

Nelson, R., M. Howden, and M. S. Smith (2008). "Using adaptive governance to rethink the way science supports Australian drought policy". In: *Environmental Science & Policy* 11, pp. 588–601. DOI: 10.1016/j.envsci.2008.06.005.

Nordhaus, W. D. and J. Tobin (1973). "Is Growth Obsolete?" In: *The Measurement of Economic and Social Performance*. Ed. by Milton Moss. Studies in Income and Wealth. NBER, pp. 509–564. ISBN: 0-87014-259-3. URL: http://www.nber.org/books/moss73-1.

OECC, ed. (2006). *Plan Nacional de Adaptacion al Cambio Climatico; Marco para la coordinación entre administraciones públicas para las actividades de evaluación de impactos, vulnerabilidad y adaptación al cambio climático.* Madrid: Ministerio de Medio Ambiente. 59 pp. URL: http://www.magrama.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/pna_v3_tcm7-12445.pdf.

Olcay Ünver, İ. (11-12/oct/2001). "Southeastern Turkey: Sustainable Development and Foreign Investment". In: *GAP Regional Development Administration*. OECD-China Conference on FDI in China's Regional Development, p. 9. URL: https://www.oecd.org/investment/investmentfordevelopment/2350280.pdf.

O'Meagher, B., L. G. du Pisani, and D. H. White (1998). "Evolution of drought policy and related science in Australia and South Africa". In: *Agricultural Systems*. Drought Policy, Assessment and Declaration 57, pp. 231–258. DOI: 10.1016/S0308-521X(98)00017-1.

OECD, ed. (2008). *Environmental performance of agriculture in OECD countries since 1990*. OECD environmental performance reviews. Paris: OECD. 210 pp. ISBN: 978-92-64-04092-2.

– (**2013**). Organisation for Economic Co-operation and Development. *Water Security for Better Lives*. Paris: Organisation for Economic Co-operation and Development. DOI: 10.1787/9789264202405-en.

PAM (2011). Parliamentary Assembly of the Mediterranean. *PAM website*. URL: http://www.pam.int/.

Peña Olivas, J. M. de la (2006). "Diferencia del concepto de obra pública actual y en la Roma clásica". In: *Ingeniería civil* 142, pp. 57–72. ISSN: 0213-8468. URL: http://www.traianvs.net/pdfs/2006_opublica.pdf.

Pérez García, F. et al. (**2011**). *Crecimiento y competitividad: trayectoria y perspectivas de la economía española*. 1st ed. Informe Fundación BBVA-Ivie. Bilbao: Fundación BBVA. 267 pp. ISBN: 978-84-92937-13-4. URL: http://www.fbbva.es/TLFU/dat/DE_2011_Ivie_crecimiento_competitividad_trayectoria.pdf.

Pérez-Martín, M. Á. (2005). "Modelo distribuido de simulación del ciclo hidrológico con calidad de aguas integrado en sistemas de información geográfica para grandes cuencas. Aportación al análisis de presiones e impactos de la Directiva Marco Europea del Agua". phd. Valencia, Spain: Universidad Politécnica de Valencia, Spain.

Pirie, R. L., R. C. de Loë, and R. Kreutzwiser (2004). "Drought planning and water allocation: an assessment of local capacity in Minnesota". In: *Journal of Environmental Management* 73, pp. 25–38. DOI: 10.1016/j.jenvman.2004.05.007.

Quevauviller, P. (2011). "Adapting to climate change: reducing water-related risks in Europe – EU policy and research considerations". In: *Environmental Science &*

Policy. Adapting to Climate Change: Reducing Water-related Risks in Europe 14, pp. 722–729. DOI: 10.1016/j.envsci.2011.02.008.

Quevauviller, P. (2014). "European water policy and research on water-related topics – An overview". In: *Journal of Hydrology*. Climatic change impact on water: Overcoming data and science gaps 518, Part B, pp. 180–185. DOI: 10.1016/j.jhydrol.2014.02.007.

Quevauviller, P. et al. (2012). "Integration of research advances in modelling and monitoring in support of WFD river basin management planning in the context of climate change". In: *Science of The Total Environment*. Integrated modelling and monitoring at different river basin scales under global change 440, pp. 167–177. DOI: 10.1016/j.scitotenv.2012.07.055.

Rodríguez Medina, I. C. (2004). "Sensibilidad de los sistemas de explotación de recursos hídricos frente al cambio climático en España." phd. Madrid: Universidad Politécnica de Madrid, Spain.

Rossi, G., A. Cancelliere, and G. Giuliano (2005). "Case Study: Multicriteria Assessment of Drought Mitigation Measures". In: *Journal of Water Resources Planning and Management* 131, pp. 449–457. DOI: 10.1061/(ASCE)0733-9496(2005)131:6(449).

Ruf, T. and M.-J. Valony (2007). "Les contradictions de la gestion intégrée des ressources en eau dans l'agriculture irriguée méditerranéenne". In: *Cahiers Agricultures* 16, pp. 294–300. DOI: 10.1684/agr.2007.0120.

Ruiz García, J. M. (1998). "Modelo hidrológico de simulación para evaluar recursos hídricos en grandes cuencas hidrográficas". phd. Valencia, Spain: Universidad Politécnica de Valencia, Spain. URL: https://www.educacion.gob.es/teseo/mostrarSeleccion.do.

Saverio Civiili, F. (2010). "The Land-Based Pollution of the Mediterranean Sea: Present State and Prospects". In: *Mediterranean Yearbook*. IEMed Mediterranean Yearbook, pp. 257–261. ISSN: 1697-8897 / e-ISSN 2013-3812. URL: http://www.iemed.org/anuari/2010/earticles/Saverio_contaminacion_es.pdf.

Scemama, P. and H. Levrel (2015). "Using Habitat Equivalency Analysis to Assess the Cost Effectiveness of Restoration Outcomes in Four Institutional Contexts". In: *Environmental Management* 57, pp. 109–122. DOI: 10.1007/s00267-015-0598-6.

SEMIDE/EMWIS (2005). *Local Water Supply, Sanitation and Sewage*. Country Report Morocco. Système Euro-Méditerranéen d'Information sur les savoir-faire dans le Domaine de l'Eau, pp. 16–16. URL: http://www.emwis.org/countries/fol749974/semide/PDF/Sogesid-morocco.

Somot, S., F. Sevault, M. Déqué, and M. Crépon (2008). "21st century climate change scenario for the Mediterranean using a coupled atmosphere–ocean regional climate model". In: *Global and Planetary Change*. Mediterranean climate: trends, variability and change 63, pp. 112–126. DOI: 10.1016/j.gloplacha.2007.10.003.

Street, R., M. Parry, J. Scott, D. Jacob, and T. Runge (**2015**). *A European research and innovation Roadmap for Climate Services*. Ed. by European Commission and Directorate

General for Research and Innovation. Luxembourg: Publications Office. ISBN: 978-92-79-44342-8.

Struglia, M. V., A. Mariotti, and A. Filograsso (2004). "River Discharge into the Mediterranean Sea: Climatology and Aspects of the Observed Variability". In: *Journal of Climate* 17, pp. 4740–4751. DOI: 10.1175/JCLI-3225.1.

Stucker, D. and E. Lopez-Gunn, eds. (2014). *Adaptation to Climate Change Through Water Resources Management. Capacity, Equity and Sustainability*. Abingdon: Routledge. 446 pp. ISBN: 978-0-415-63593-6. URL: https://www.routledge.com/products/9780415635936.

Sundseth, K. (**2009**). *Natura 2000 in the Mediterranean region*. Ed. by S. Wegefelt. Red. by European Commission. Natura 2000. Luxembourg: Office for Official Publications of the Europ. Communities. 11 pp. DOI: 10.2779/77695.

Tallaksen, L. M., H. Hisdal, and H. A. J. V. Lanen (2009). "Space–time modelling of catchment scale drought characteristics". In: *Journal of Hydrology* 375, pp. 363–372. DOI: 10.1016/j.jhydrol.2009.06.032.

Teegavarapu, R. S. V. (2010). "Modeling climate change uncertainties in water resources management models". In: *Environmental Modelling & Software* 25, pp. 1261–1265. DOI: 10.1016/j.envsoft.2010.03.025.

The Government Office for Science (2011). *Foresight. The Future of Food and Farming*. Final project. London: The Government Office for Science, pp. 40–40. URL: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288329/11-546-future-of-food-and-farming-report.pdf.

The Royal Society Science Policy Centre (**2014**). *Resilience to extreme weather*. 02/14 DES3400. London: The Royal Society. ISBN: 978-1-78252-113-6.

Tsakiris, G., D. Pangalou, and H. Vangelis (2006). "Regional Drought Assessment Based on the Reconnaissance Drought Index (RDI)". In: *Water Resources Management* 21, pp. 821–833. DOI: 10.1007/s11269-006-9105-4.

UNEP/MAP-Plan Bleu (**2009**). *State of the Environment and Development in the Mediterranean - 2009*. Athens: United Nations Environment Porgramme/Mediterranean Action Plan (UNEP/MAP)-Plan Bleu. 204 pp. ISBN: 978-92-807-3061-6. URL: http://planbleu.org/sites/default/files/publications/soed2009_en.pdf.

UN (**1993**). United Nations. *Integrated environmental and economic accounting: interim version*. 61. New York: United Nations Pubns. ISBN: 92-1-161359-0.

– (**2009**). United Nations. *The millennium development goals report 2009*. United Nations Department of Economic and Social Affairs. ISBN: 978-92-1-101196-8. URL: http://www.un.org/millenniumgoals/pdf/MDG_Report_2009_ENG.pdf.

– ed. (2012). *System of environmental-economic accounting for water: SEEA-water*. Economic & Social Affairs. New York: United Nations. 197 pp. ISBN: 978-92-1-161554-8.

– (2015). United Nations. *Transforming our world: the 2030 Agenda for Sustainable Development*. Resolution of the Heads of State and Government and High Representatives

A/RES/70/1. New York, USA: United Nations. URL: https://sustainabledevelopment.un.org/content/documents/7891Transforming%20Our%20World.pdf.

UNDP (1994). United Nations Development Programme. *Drought and Famine, second edition. Disaster Management Training Programme*.

– (**2009**). United Nations Development Programme. *Arab Human Development Report 2009. Challenges to Human Security in the Arab Countries.* New York: United Nations Environment Porgramme. 288 pp. ISBN: 978-92-1-126211-7. URL: http://www.arab-hdr.org/publications/other/ahdr/ahdr2009e.pdf.

WWAP (**2015**). United Nations World Water Assessment Programme. *The United Nations world water development report 2015: Water for a sustainable world*. Paris: United Nations Educational, Scientific and Cultural Organization. 139 pp. ISBN: 978-92-3-100099-7. URL: http://unesdoc.unesco.org/images/0023/002318/231823E.pdf.

UN, EC, FAO, OECD, and WBG, eds. (2014). *System of environmental-economic accounting 2012: experimental ecosystem accounting.* 198 pp. ISBN: 978-92-79-43926-1.

Vangelis, H., M. Spiliotis, and G. Tsakiris (2010). "Drought Severity Assessment Based on Bivariate Probability Analysis". In: *Water Resources Management* 25, pp. 357–371. DOI: 10.1007/s11269-010-9704-y.

Vargas Amelin, E. (2011). "El agua en la cuenca Mediterránea". In: *El Mediterráneo tras 2011*. Ed. by J. M. López Bueno. Melilla: FHIMADES, pp. 151–185. ISBN: 978-84-615-2658-1. URL: http://www.fhimades.org/documentos/el-mediterraneo-tras-2011/. E. Vargas Amelin as leading author.

Vargas Amelin, E., E. López-Gunn, G. Huelva, and T. Estrela Monreal (2014). "Adopting river basin planning as a framework for climate change adaptation in Spain". In: *Adaptation to Climate Change Through Water Resources Management. Capacity, Equity and Sustainability*. Ed. by S. Dominic and E. López-Gunn. Abingdon: Earthscan/Routledge, pp. 353–373. ISBN: 978-0-415-63593-6. URL: www.routledge.com/9780415635936. E. Vargas Amelin as leading author.

Vargas Amelin, E. and P. Pindado (2014). "The challenge of climate change in Spain: Water resources, agriculture and land". In: *Journal of Hydrology*. Climatic change impact on water: Overcoming data and science gaps 518, Part B, pp. 243–249. DOI: 10.1016/j.jhydrol.2013.11.035. E. Vargas Amelin as leading author.

Vargas Amelin, E., V. Ramírez Perea, A. Nieto Arias, E. Mino, and J. El-Kharraz (2013). *Halting Desertification in the Júcar River Basin (HALT-JÚCAR-DES)*. Technical report Final. Madrid: European Commission, p. 55. URL: http://ec.europa.eu/environment/water/blueprint/pdf/HJD_Final%20Technical%20Report.pdf. E. Vargas Amelin as co-author.

Vasiliades, L., A. Loukas, and N. Liberis (2010). "A Water Balance Derived Drought Index for Pinios River Basin, Greece". In: *Water Resources Management* 25, pp. 1087–1101. DOI: 10.1007/s11269-010-9665-1.

Waslekar, S., A. Vishwanath, G. Bakshi, and P. R. Motwani (**2011**). *The blue peace: rethinking Middle East water*. In collab. with Strategic Foresight Group (Mumbai, India). Mumbai: Strategic Foresight Group. 152 pp. ISBN: 978-81-88262-14-4.

WSDEN (2007). Water Scarcity and Droughts Expert Network. *Drought Management Plan Report, Including Agricultural, Drought Indicators and Climate Change Aspects*. Technical report 2008 - 023. European Commission. URL: http://ec.europa.eu/environment/water/quantity/pdf/dmp_report.pdf.

– (2008). Water Scarcity and Droughts Expert Network. *Drought Management Plan Report, including agricultural, drought indicators and climate change aspects*. Technical Report 023. European Commission, pp. 132–132. URL: http://ec.europa.eu/environment/water/quantity/pdf/dmp_report.pdf.

Westphal, K., R. Laramie, D. Borgatti, and R. Stoops (2007). "Drought Management Planning with Economic and Risk Factors". In: *Journal of Water Resources Planning and Management* 133, pp. 351–362. DOI: 10.1061/(ASCE)0733-9496(2007)133:4(351).

Wilby, R. L., H. G. Orr, M. Hedger, D. Forrow, and M. Blackmore (2006). "Risks posed by climate change to the delivery of Water Framework Directive objectives in the UK". In: *Environment International*. Environmental Risk Management - the State of the Art 32, pp. 1043–1055. DOI: 10.1016/j.envint.2006.06.017.

Wilhite, D. A., M. J. Hayes, C. Knutson, and K. H. Smith (2000). "Planning for Drought: Moving from Crisis to Risk Management1". In: *JAWRA Journal of the American Water Resources Association* 36, pp. 697–710. DOI: 10.1111/j.1752-1688.2000.tb04299.x.

Willaarts, B. (2012). "Linking Land Management to Water Planning". In: *Water, Agriculture and the Environment in Spain*. Ed. by M. Ramón Llamas. Leiden, The Netherlands: CRC Press, pp. 139–151. ISBN: 978-0-415-63152-5. URL: http://www.crcnetbase.com/doi/abs/10.1201/b13078-15.

Withana, S., P. ten Brink, L. Franckx, M. Hirschnitz-Garbers, I. Mayeres, F. Oosterhuis, and L. Porsch (2012). *Study supporting the phasing out of environmentally harmful subsidies*. Final report Project Number: 07.0307/2011/611259/ENV.F.1. Brussels: the Institute for European Environmental Policy (IEEP), Institute for Environmental Studies -Vrije Universiteit (IVM), Ecologic Institute and Vision on Technology (VITO) for the European Commission - DG Environment. URL: http://ec.europa.eu/environment/enveco/taxation/pdf/report_phasing_out_env_harmful_subsidies.pdf.

WTTC (2011). World Travel & Tourism Council. *WTTC | Mediterranean. Key Facts at a Glance*. URL: http://web.archive.org/web/20111113054745/http://www.wttc.org/research/economic-impact-research/regional-reports/mediterranean/.

VWWF, ed. (2009). *Regional Document. Mediterranean*. Istanbul, Turkey: World Water Forum Secretariat. URL: http://www.worldwaterforum5.org/fileadmin/WWF5/Final_Report/SU_FORUMU_AKDENIZ.pdf.

WRc plc (2015). *Screening Assessment of Draft Second Cycle River Basin Management Plans*. Technical report UC 10741.01. Swindon, Wiltshire, UK: European Commission, pp. 133–133.

Zandstra, T. (**2015**). *Water legislation*. 'Cost of Non-Europe' study PE 536.369. Brussels: European Added Value Unit of the Directorate for Impact Assessment and European Added Value, within the Directorate–General for Parliamentary Research Services of the Secretariat of the European Parliament. DOI: 10.2861/303057.

A. Summary in Dutch

A.1. Inleiding

A.1.1. Overzicht

Het Middellandse Zeegebied neemt een strategische ligging in op de grens van drie continenten. Het klimaat heeft volkeren doorheen de geschiedenis geleid tot de vestiging van en een sociaal-economische groei die daarmee samenhing. Momenteel zijn er echter, door de druk die wordt gevormd door groei van de bevolking, toerisme en stadsontwikkeling, vooral in de kustgebieden ernstige milieuproblemen die van invloed zijn op de ontwikkeling van het gebied. Hoewel het één van de rijkste gebieden aan ecosystemen is, en als een van de belangrijkste plaatsen inzake biodiversiteit in de wereld wordt gezien (Sundseth 2009), is het als gevolg van deze druk en daarmee nauw samenhangende milieuproblemen zoals waterschaarste, puntbronnen en diffuse verontreiniging, overexploitatie van waterlopen, ontbossing, bodemerosie en woestijnvorming, tegelijkertijd een van de meest kwetsbare in de wereld.

Water is een katalysator voor ontwikkeling, van essentieel belang voor vrijwel alle sociaal-economische activiteiten en is een onmisbare natuurlijke hulpbron voor het milieu, maar is zeer ongelijk verdeeld in ruimte en tijd in de regio, en niet altijd verstandig beheerd. Het is zeer schaars in een gebied dat gemakkelijk toegankelijk is voor menselijk gebruik, en beperkt beschikbaar in de vereiste kwaliteit en benodigde hoeveelheid, waardoor het een beperkende factor wordt voor economische activiteiten, ontwikkeling en productie van voedsel en energie. De belangrijkste watergerelateerde problemen worden nog verergerd door droogte, overstromingen en de gevolgen van de klimaatveranderingen, de toename in sociale problemen en uitdagingen in het waterbeheer', en door conflicten tussen verschillende sectoren.

A.1.2. Klimaatverandering

Gezien de nauwe band tussen beschikbaarheid van water en de weersomstandigheden is dit proefschrift toegespitst op de verwachte gevolgen van de klimaatverandering in de regio en met name in Spanje. Volgens het IPCC (IPCC 2013b) zal in het Middellandse Zeegebied de temperatuurstijging in verband met klimaatverandering leiden tot een groter aantal extreme weersomstandigheden, een verhoging van de intensiteit daarvan, en een vermindering van de beschikbare waterreserves.

Er wordt een daling verwacht in de neerslag, toenemende droogte en extreme droogtes in Zuid-Europa en het Midden-Oosten (Dai 2011), alsook veranderingen in de zeewatertemperatuur en een daling van het rivierwaterpeil. In Spanje in het bijzonder, wijzen de conclusies van één van de eerste uitgebreide studies, de voorlopige algemene beoordeling van de effecten in Spanje vanwege de gevolgen van de klimaatverandering (Moreno Rodríguez e.a. 2005), met betrekking tot de waterreserves op: a) een algemene daling van de watervoorraden en een toenemende vraag naar irrigatiesystemen, b) een vermindering in bijdragen tot 50 % in semi-aride gebieden, c) een verhoging van de jaarlijkse variabiliteit d) vraag naar beheer als vervangend middel e) de noodzaak tot verbetering en uitbreiding van de monitoringnetwerken, onderzoeksprojecten in dit gebied en het belang van beleid en regelgeving op de watervoorraden ten gevolge van klimaatverandering.

Reeds tien jaar geleden, in 1995, hadden naar schatting 1,400 miljoen mensen te maken met waterstress in hoofdzakelijk het Midden-Oosten en het Middellandse-Zeegebied (Arnell 1996; Arnell 2004). Het is dan ook waarschijnlijk dat de daling in de afvoerramingen voor de nabije toekomst zal leiden tot nog hogere percentages van stress als gevolg van een daling van de beschikbaarheid van water.

De kwaliteit van studies is verbeterd, en hoewel er nog steeds onzekerheid bestaat en efficiënte technieken nog een uitdaging vormen, zijn de voorspelde effecten vergelijkbaar. Bijvoorbeeld, een recentere studie uit 2011 gepubliceerd door de (CEDEX 2011), heeft de effecten op nationaal niveau uitgelicht en voorspelt een algemene daling van de neerslag en de beschikbaarheid van water (in de buurt van -5 %, -9 % en -17 % in de periode 2011–2040, 2041–2070 respectievelijk 2071–2100), met de grootste variabiliteit aan de Middellandse Zeekust en in het zuidoosten van het land. Bovendien voorspelt de studie een stijging van de temperatuur, verdamping en evapotranspiratie, daling van grondwaterinjecties en afvoer.

De effecten van de klimaatverandering zullen invloed hebben op de beschikbaarheid en distributie van water, en hierdoor op de voedselproductie, door de invloed op de productie van gewassen en vee. Extreme weersomstandigheden die verband houden met water, droogte en overstromingen, zullen hoogstwaarschijnlijk nog slechter worden, en zijn belangrijke factoren bij het beoordelen van het hydrologisch plan en waterbeheer om tekorten te voorkomen of de schade aan personen en goederen tot een minimum te beperken. Voorts zullen er in specifieke sectoren, zoals in de landbouwsector, waarschijnlijk hogere eisen gesteld worden aan de evapotranspiratie processen door de gevolgen van de temperatuurstijging. Daar water een steeds schaarser goed wordt, zou de klimaatverandering gevolgen in combinatie met een groeiende vraag kunnen hebben voor het beheer van prioriteiten in de verdeling van middelen (Estrela Monreal en Vargas Amelin 2008).

Zoals vermeld, benadrukken sommige auteurs (Magnan e.a. 2009) de onzekerheid van de klimaatmodellen en hydrologische gegevens of CO_2-emissies, de onvoorspelbaarheid van de natuurlijke variabiliteit van het klimaat, het gebrek aan consistentie in gegevens en brede marges van de ramingen van de bevolkingsgroei en het waterverbruik. Het lijkt dan ook noodzakelijk om degelijker studies te ontwikkelen inzake klimaatverandering en prognoses van verwachte effecten, alsook om meer te investeren in aanpassingsstrategieën (UNEP/MAP-Plan Bleu 2009). In elk geval moet, uitgaande van de situatie die de regio biedt, met zwakke waterbalansen, worden verwacht dat iedere klimaatschommeling leidt tot een relevante impact op sociaal- en landbouwgebied.

Het onderzoek van de auteur heeft geleid tot in totaal zes publicaties in wetenschappelijke tijdschriften (zoals Water Resources Management, Hydrological Sciences Journal, Journal of Hydrology) en door gerenommeerde academische uitgevers geredigeerde boeken. Dit proefschrift is een collectie van alle publicaties, gecombineerd met een discussie hoofdstuk, conclusies, de belangrijkste werkrichtingen.

Publicaties die in dit proefschrift aangehaald worden(in de inleiding van deze samenvatting), benaderen deze kwesties, verstrekken recente referenties, gegevensvaststellingen, beleidsstudies op EU- en nationaal niveau, en bepalen lacunes bij de vaststelling van de klimaatverandering in het kader van het waterbeheer.

A.1.3. Beleidsmaatregelen

Op EU niveau zijn er verschillende milieubeleidsplannen die gericht zijn op betere bescherming en op een duurzaam gebruik van de natuurlijke hulpbronnen. Er is echter een aantal wetgevende instrumenten, die de ruggengraat vormen van waterbescherming en die rechtstreeks verband houden met klimaatschommelingen. De uitvoering van bepaalde EU beleidsmaatregelen, in het bijzonder de kaderrichtlijn water (KRW) 2000/60/EG heeft het mogelijk gemaakt dat de lidstaten convergeren naar doelstellingen op het vlak van kwaliteit en bescherming. De richtlijn is innovatief door de waterbekken als een afzonderlijk systeem voor waterbeheer in te stellen, om een goede toestand van alle wateren te beogen en door het oprichten van stroomgebiedsbeheersplannen (SGBP's) als de belangrijkste instrumenten bij programma's van maatregelen ter verwezenlijking van die status. Het is een beleid dat specifieke deadlines stelt, en dat wordt ondersteund door heffingen in combinatie met economische sancties. Daarnaast sluit de richtlijn inzake overstromingen (2007/60/EG), aan bij deze waterbescherming, door te streven naar een verbetering in beheer in periodes van overstromingen en beperking van de risico's, vooral in waterlopen en in de kustgebieden. Dit vereist het in kaart brengen van gebieden met verhoogd risico en de ontwikkeling van beheersplannen. Voorts heeft de Europese Commissie (EC) verscheidene projecten en studies gefinancierd om de effecten van de klimaatverandering op de watervoorraden vast te stellen en heeft tal van verslagen en rapporten gepubliceerd om de basis te leggen voor een aanpassingsbeleid.

Het beleid wordt echter vaak ontwikkeld rekening houdend met de beschikbaarheid van water, en territoriale kenmerken die zeer verschillend zijn van die in Spanje, en veel meer vergelijkbaar met die van de buurlanden in het Middellandse-Zeegebied. Bovendien is de verwezenlijking van de doelstellingen van deze maatregelen meer dan onzeker als gevolg van oude en opkomende uitdagingen. De EG heeft een uitgebreide evaluatie ontwikkeld van de bestaande richtlijnen, de resultaten daarvan en de oorzaken van het niet verwezenlijken van de oorspronkelijk vastgestelde doelstellingen voor de waterkwaliteit, beheer en bescherming. Dit initiatief, genaamd Blauwdruk ter Waarborging van Water in Europa, met het jaar 2020 als eerste blikveld, richt zich op vier belangrijke gebieden:[1] In het kader van de KRW ontwikkelde stroomgebiedbeheersplannen, een herziening van de Europese actie tegen

[1] Mededeling van de Commissie: Een blauwdruk voor het behoud van de Europese watervoorraden. COM/2012/673 final.

waterschaarste en droogte, de evaluatie van de kwetsbaarheid van watervoorraden door klimaatverandering en andere antropogene druk, en een algemene fitness-check van het waterbeleid van de EU.

Echter, aanbevelingen en instrumenten vermeld in de blauwdruk zullen moeten worden beoordeeld in de komende SGBP's, die moeten worden ingediend door de lidstaten tegen het einde van 2015 en hun gegevens gerapporteerd in maart 2016. Bovendien is er een herziening van de kaderrichtlijn water voorzien in 2019, wanneer de redenen voor niet-uitvoering en een mogelijke herziening van de tekst van de richtlijn zou kunnen plaatsvinden.

A.1.4. Spaanse stroomgebieden

Veel Spaanse stroomgebieden worden geconfronteerd met waterschaarste, aanhoudende droogte, bodemdegradatie en persistente overexploitatie van watervoorraden. En al deze problemen hebben de neiging te worden verergerd door de gevolgen van de klimaatverandering. Mediterrane stroomgebieden in Spanje, zoals bijvoorbeeld de Júcar en de Segura stroomgebieden, zijn typische voorbeelden van gebieden die te kampen hebben met de gevolgen van deze verschijnselen, en met een groot oppervlak van semi-aride gebieden (volgens de Unesco droogte index). Zij lijden vaak onder verschillende extreme gebeurtenissen zoals overstromingen en stortregens (of stortvloeden), terwijl zij intensief water onttrekken voor hoofdzakelijk agrarische toepassingen.

De bijgewerkte SGBP's moeten dus nog worden gerapporteerd aan de Europese Commissie, en zouden een interessante gelegenheid moeten bieden om onderzoek te doen naar de mogelijke gevolgen van de klimaatverandering op de beschikbaarheid van water, de voorgestelde technische maatregelen, en uitvoering van de economische beoordeling. De publicaties in dit proefschrift bieden een aantal inzichten op het voorontwerp van de stroomgebiedbeheerplannen en beoordelen de bestaande beleidsmaatregelen en de relatie tussen de twee.

A.1.5. Opmerkingen

Sommige van de hangende kwesties in de watersector betreffen de fasering van de gevolgen van klimaatverandering op de waterplanning, en betere acceptatie van economische overwegingen in technische maatregelen en aanpassingsprocessen. Dit proefschrift geeft een overzicht van de gevolgen van de klimaatverandering voor de watervoorraden, zowel op regionaal als op nationaal niveau en geeft een aantal voorbeelden van de economische gevolgen. De effecten van de klimaatverandering wijzen op de noodzaak aan intensivering van bepaalde maatregelen die reeds worden gebruikt: besparingsmaatregelen voor vraagbeheer, energiebesparing en het gebruik van niet-conventionele middelen (ontzilting en hergebruik van afvalwater), verzekering van duurzaam gebruik van het grondwater, groter gebruik van groene infrastructuurontwikkeling, modernisering van irrigatiesystemen, alsmede specifieke plannen en maatregelen gericht op overstromings- en droogtebeheer.

A.2. Conclusies

Dit hoofdstuk vat enkele belangrijke conclusies van dit proefschrift samen. Aanvullende aspecten en details zijn volledig uitgewerkt terug te vinden in hoofdstuk 6 van dit proefschrift.

Er kan worden geconcludeerd dat de gevolgen van menselijke activiteiten een directe impact hebben gehad op het klimaat (IPCC 2014), en dat dit in aanzienlijke mate van invloed is op en gevolgen zal hebben voor watervoorraden, en dat het op zijn beurt sociaal-economische en ecologische gevolgen zal hebben. De verwachte effecten zullen zeker een uitdaging vormen voor waterbeheerders, regio's, burgers en politici, omdat het niet mogelijk zal zijn om aan de huidige eisen te blijven voldoen, die tot meer verontreiniging zullen leiden. Een van de meest recente en uitvoerige studies over de effecten van de klimaatverandering op de watervoorraden in Spanje (CEDEX 2011), voorspelt een algemene daling in neerslag en beschikbaarheid van water, die in de loop van de tijd zal toenemen (in de buurt van -5 %, -9 % en -17 % in de periode 2041–2070 en 2071–2100, respectievelijk). Bovendien zal naar verwachting de grootste variabiliteit plaatsvinden in de kustgebieden van het Middellandse Zeegebied en in het zuidoosten van het land. Gezien het belang van water voor vrijwel alle sociaal-economische activiteiten en voor de instandhouding van ecosystemen en biodiversiteit, worden de economische gevolgen steeds duidelijker in de komende jaren.

Alhoewel voorspellingen nuttig en indicatief zijn, is de onzekerheid van de klimatologische modellen hoog, met name voor efficiënte technieken (bv. naar de effecten op stroomgebiedniveau). Het is dan ook duidelijk, dat meer degelijk onderzoek en studies inzake klimaatverandering en voor prognoses van de te verwachten effecten nodig zijn evenals hogere investeringen op het gebied van aanpassingsstrategieën en opleiding van specialisten op het gebied van water. Bovendien zou het onderzoek gericht moeten zijn op problemen op niveau van beheer en lacunes in technische kennis aanpakken. Zo zou een nauwere samenwerking tussen onderzoekers en managers nodig zijn. Voorts zijn mechanismen om de band tussen onderzoek en beleidsontwikkeling en -uitvoering (d.w.z. de interface tussen wetenschap en beleid) noodzakelijk indien de geboekte vooruitgang in onderzoek en de resultaten volledig dienen te worden gebruikt en verwerkt, bijvoorbeeld bij het bepalen van de meest geschikte en veerkrachtige maatregelen op niveau van stroomgebied.

Ongeacht het bestaan van bepaalde onzekerheid, zou kunnen worden verwacht dat de voorspelde klimaateffecten op water van invloed zullen zijn op het beheer van water, besluitvormers zou waarschuwen en een groter bewustzijn zou creëren op het gebied van waterbesparing, prioriteiten stellen van de watertoepassingen en het algemeen denken over hoe water beter zou moeten worden gebruikt. Zij moeten ook helpen bij het vergroten van het aanpassingsvermogen en een weerbaarheidscultuur, en bijdragen tot het verschuiven van de werkwijze in beheer van het verstrekken van water, naar het verminderen van de vraag en het gebruik van kostenefficiëntie en slimme oplossingen. Het traditionele gebruik van „grijze" infrastructuur zoals dammen moet wegebben, niet alleen vanwege de kosten, maar ook vanwege de onzekerheid over hun toekomstig nut als lagere rivierlopen worden verwacht. Ook moeten voorspellingen worden vertaald naar het gebruik van slimmere en groenere oplossingen, die vaak minder kostbaar zijn en beter bestand tegen klimaatverandering.

Sommige studies wijzen op een begin van economische groei in Spanje pas in 2014, na drie jaar van acute recessie (EC 2015a). Deze economische recessie heeft niet bijgedragen tot de bovengenoemde verwachte verschuivingen of tot het beter voorbereiden van gewesten en stroomgebieden om de uitdagingen van klimaatverandering onder ogen te zien. Bezuinigingen hebben een belangrijke impact op het gebied van waterbeheer gehad, en de voorgestelde maatregelen in de bijgewerkte SGBP's die zouden kunnen bijdragen tot een betere waterbescherming en aanpassing van de klimaatsverandering, zouden wel eens niet de vereiste economische steun kunnen krijgen. Voorbeelden van deze maatregelen zijn onder meer voorgestelde herstelactiviteiten of de ontwikkeling van op natuurlijke processen gebaseerde waterretentiemaatregelen. Er bestaan echter nuttige instrumenten voor waterbeheerders die hen helpen bij het stellen van prioriteiten voor maatregelen en projecten, en bij het bepalen van de kosteneffectiviteit van het herstel (Scemama en Levrel 2015).

De voorgestelde publicaties in dit proefschrift hebben betrekking op een periode van ongeveer vier jaar gedurende waarin de recessie invloed heeft gehad op de politieke prioriteiten, beheerdersbeslissingen en de publieke perceptie. De uitvoering van het EU-beleid kan als een van de meest getroffen pijlers worden beschouwd.

Hoewel de EU een van de meest vooruitstrevende en gerespecteerde milieuwetgevingen heeft, die hoge eisen stelt aan de bescherming van water, zoals de kaderrichtlijn water (KRW), is bijvoorbeeld in Spanje de uitvoering ervan nog lang niet bereikt. Vereiste updates van waterzuiveringsinstallaties hebben niet plaatsgevonden, noch een diepgaande beoordelingsexpertise van tekortkomingen om een goede ecologische toestand te bereiken van alle waterlichamen gekoppeld aan specifieke beheersmaatregelen. Verder werden er met de uitvoeringsinspanningen niet de passende verbanden gelegd met de klimaataanpassing. Aldus wordt de samenhang met andere sectoren, zoals de landbouwsector, zeer beperkt. In Spanje is de landbouwsector de grootste vrager naar water, en dit leidt tot een hoge druk in termen van onttrekkingen en vooral diffuse verontreiniging door nitraten (Fuentes 2011; Vargas Amelin en Pindado 2014). De meeste stroomgebieden die zijn getroffen door waterschaarste, vertonen ook intensieve irrigatiepraktijken waardoor ze nog kwetsbaarder zouden kunnen worden voor de gevolgen van klimaatverandering. De voorlopige Spaanse SGBP's, geven geen volledig beeld van het verband met de nitraatrichtlijn en de vereiste maatregelen ter verbetering van de bescherming van het water.[2] Overmatige onttrekking van grondwater en oppervlaktewater door agrarische activiteiten vormt een extra grote bedreiging voor het verwezenlijken van de doelstellingen van de KRW, maar er is weinig vooruitgang geboekt op het gebied van toezicht op en de vervolging van illegale wateronttrekkingen (EC 2012a).

In Spanje zijn we getuige van aanzienlijke vertragingen in de uitvoering van het EU-beleid en de continuïteit van traditionele vraaggestuurde benaderingen, terwijl grotere extra inspanningen zouden moeten worden geleverd om de hiaten aan te pakken om te zorgen voor ecologische bescherming en klimatologische veerkracht. Nogmaals, budgettaire beperkingen in de milieusector, en verminderde middelen in stroomgebiedautoriteiten belemmeren een verschuiving van deze trend. Politieke prioriteiten hebben zich afgewend van milieubescherming, en essentiële instrumenten zoals modellering en mo-

[2] Richtlijn 91/676/EEG van de Raad van 12 december 1991 inzake de bescherming van water tegen verontreiniging door nitraten uit agrarische bronnen

nitoring van de waterkwaliteit hebben een afname van fondsen gekend. De economische recessie mag evenwel niet uitsluitend worden toegeschreven aan het niet naleven van de verplichtingen. De complexiteit van de bevoegdheden, het gebrek aan verantwoordingsplicht van de overheden en de beperkte coördinatie tussen de verschillende administratieve niveaus maken allen deel uit van het probleem.

Het complexe Spaanse netwerk van bestuursinstanties die belast zijn met het waterbeheer, de bescherming, verspreiding en de prijsstelling, heeft tot op zekere hoogte bijgedragen aan de vertraging bij de tenuitvoerlegging van het beleid. Dit netwerk is zeer versnipperd, bevoegdheden worden gedeeld door openbare en particuliere entiteiten, en botsende politieke wil vanuit lokale, regionale en nationale hoek en stroomgebieden bepalen vaak de waterregelgeving. Ook is er een breed scala aan waterprijzen voor de eindgebruikers, gebrek aan transparantie van prijzen, tarieven en subsidies. Deze omstandigheden hebben bijvoorbeeld invloed op de kostendekkende mechanismen, die zeer beperkt zijn voor de behandeling van afvalwater en sanitair gebruik (EEA 2013b). Terwijl decentralisatie en specialisatie van bevoegdheden positieve effecten zouden kunnen hebben in waterbeheer en bescherming, heeft het gebrek aan coördinatie tussen administraties en de beperkte gezamenlijke informatiebronnen grote hiaten veroorzaakt. Bijvoorbeeld het doolhof van instanties die op verschillende niveaus optreden levert moeilijkheden op om gemakkelijk toegang te krijgen tot informatie in verband met het watergebruik of haar prijs, en staat de mogelijkheid in de weg van een betere coördinatie van participatieve processen, die het mogelijk zouden maken om de burgers beter bij de besluitvorming te betrekken.

Maatschappelijke uitdagingen zijn ingewikkeld en vereisen verdere beoordeling, maar de voorgestelde publicaties geven een aantal inzichten in de bestaande problemen. Een diepgaande culturele verandering in waterexploitatiewaarneming zou moeten plaatsvinden. Van oudsher wordt in gebieden waar waterschaarste heerst, optimaal gebruik van water nagestreefd, en water dat de zee bereikte werd als verspild water beschouwd. Deze manier van denken is helaas nog steeds verankerd in de Spaanse samenleving. Er is nog steeds een gebrek aan elementaire ecologische kennis, en veel gebruikers begrijpen niet volledig de afhankelijkheid van ecosystemen van water, de noodzaak van respecteren van de voorschriften voor aanvulling van waterlopen, of de behoeften van sedimenten in kustgebieden en delta's om milieu- en maatschappelijke diensten te voorzien. Toenemende afhankelijkheid van water en praktijken van overexploitatie van de voorraden zou enkel leiden tot niet-duurzaam watergebruik, een minder veerkrachtige samenleving en ecosystemen. Watersystemen die reeds kritische waterbalansen kennen en die waterschaars zijn, hebben weinig „veiligheidsmarges" om het hoofd te kunnen bieden aan onverwachte extreme verschijnselen. Spanje zal aan de samenleving beter moeten laten uitschijnen wat de fundamentele ecologische behoeften en de verwachte klimaatveranderingen zijn. Lokale NGO's en maatschappelijke organisaties zouden een belangrijke rol kunnen spelen in het bewustmakingsproces, maar ook in de ondersteuning van lokale acties ter verbetering van veerkracht en aanpassingsvermogen. Dit is zeldzaam, wat deels een gevolg kan zijn van de langzame en geleidelijke on-sets van de gevolgen van klimaatverandering.