Water Resour Manage (2012) 26:1537–1553
DOI 10.1007/s11269-011-9971-2

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

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Received: 26 May 2011 / Accepted: 22 December 2011 /
Published online: 11 January 2012

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 European Union (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 European Union, 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.

Keywords Drought · Water scarcity · Environment · Drought management plans · European Union · Spain

1 Introduction

Drought is a natural hazard that results from a deficiency of precipitation from expected or normal, which can translate into insufficient amounts to meet the water demands of human

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activities and the environment. Although by itself is not a disaster, whether it becomes one depends on its impacts on society and environment (Wilhite and Buchanan-Smith 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 (European Environment Agency 2001). In addition, it is expected that climate change will produce negative direct impacts on the available water resources in the most vulnerable European Union (EU) regions (IPCC 2007).

There are relevant EU policy tools such as the Water Framework Directive 2000/60/EC (European Parliament and Council of European Union 2000) or a specific Communication on water scarcity and droughts entitled "Addressing the challenge of water scarcity and droughts in the European Union" from the European Commission to the European Parliament and Council in 2007. In addition, a policy review on water scarcity and droughts is currently being carried out 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).

The Water Framework Directive 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 Member States of the European Union 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 et al. 2000). The importance of public participation in the decision making process for an adequate water scarcity and drought management has been stressed, and drought management plans have been identified as useful tools to achieve this objective in the European Union.

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 (Ministerio de Medio Ambiente 2000). The gained experience through policies implementation, the new applied tools and technologies as the drought management plans, 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 (Ministerio de Medio Ambiente, Medio Rural y Marino 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 European Union, focusing on the development of drought management plans 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 drought management plans developed for all the Spanish river basins as well as the experience gained during their application for the severe 2004–2008 drought.

2 Water Scarcity and Droughts in the European Union

2.1 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 (European Commission 2007a). At least 11% of the population and 17% of the European territories are affected by water scarcity (European Commission 2007b). Cyprus, Belgium, Spain, FYROM, Malta and Italy show the lowest water availability when comparing their water exploitation index (WEI) (European Environment Agency 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. 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 European Environment Agency (2005) are shown in Fig. 2.

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

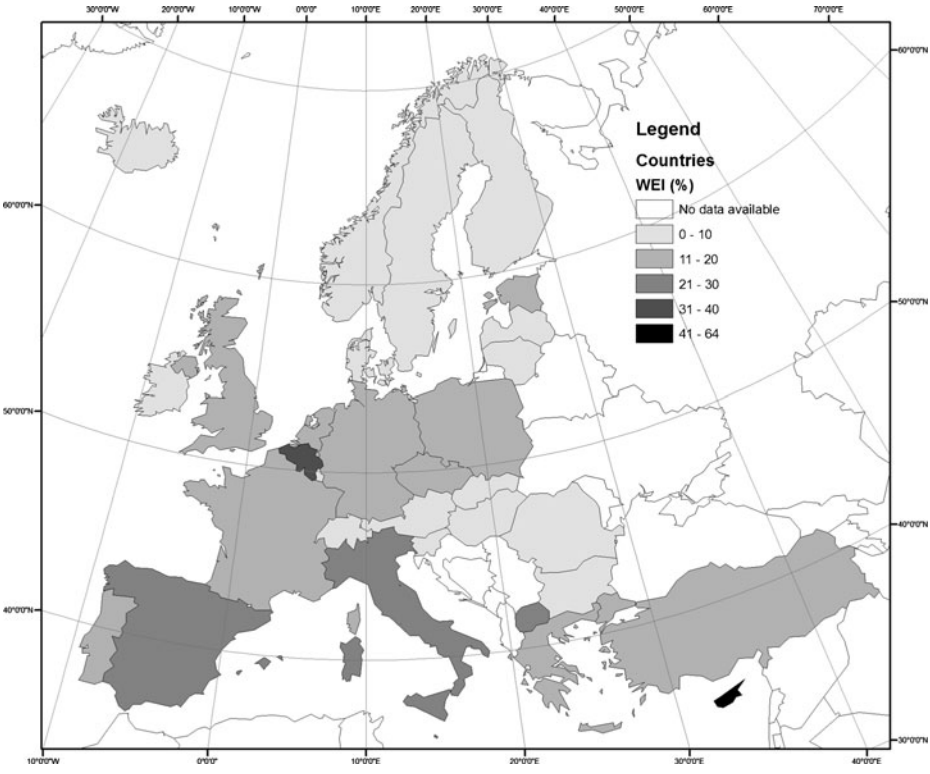

Fig. 1 Water exploitation index in European Union (elaborated with data taken from European Environment Agency web page)

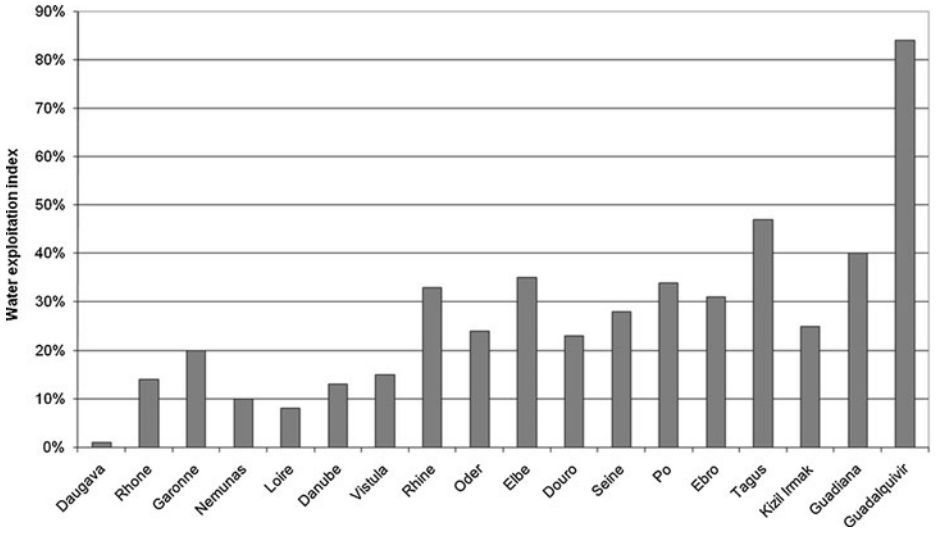

Fig. 2 Water exploitation index in large European river basins for 2000 year (elaborated with data taken from European Environment Agency 2005)

and universally accepted definition of drought adds to the confusion as to whether a drought exists and, if it does, its degree of severity (Wilhite and Buchanan-Smith 2005). According to the European Commission droughts refer to important deviations from the average levels of natural water availability and are considered natural phenomena (European Commission 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 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 (United Nations Development Programme 1994). More recently, and during the past 30 years, drought events have regularly occurred in the European Union. The duration, affected population and area, greatly vary throughout this period, but severe events have occurred on annual basis affecting more than 800.000 km² of the EU territory (37%) and 100 million inhabitants (20%) in 1989, 1990, 1991 and 2003 (European Commision 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 2007). The European Environment Agency (2005) states in "The European Environment—State and outlook 2005" that temperatures in Europe could rise by 2–6°C this century and that the expected impacts include water shortages, more extreme weather, marine species migrations and economic losses.

2.2 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 European Union show significant and useful results to better manage water scarcity and droughts such as ARIDE, SEDEMED, WAMME, PRODIM, MEDROPLAN, WATCH, MIRAGE, 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 drought management plans are now being developed in Europe and therefore 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 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. Alvarez 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 XXth century from monthly rainfall data series. Bordi et al. (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 et al. 2007 and Vangelis et al. 2011) 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 et al. (2007) 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 et al. (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 et al. (2011) assess hydrological droughts by using a water balance derived drought index within an operational context at subwatershed 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 et al. (2007) develop a methodology to link operational drought indicators to policy management actions in regulated water supply systems in the Tagus River Basin Drought Management Plan 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 et al. (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 and Solera (2006) propose, in the framework of the of 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 published by MEDROPLAN (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 7th Framework Programme 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, CIRCE and MIRAGE projects (Quevauviller 2011).

2.3 Political and Technical Responses

Due to the obvious and repetitive related problems, the Council of Ministers of the European Union (EU) launched a policy request to assess the gravity of water scarcity and droughts in Europe in March 2006. The European Commission (EC) responded by an impact assessment developed through Member States and the European Environment Agency feedback. Furthermore, a specific working group was created in 2007 within the Common Implementation Strategy (CIS) of the Water Framework Directive (WFD). This working group which has been led by Italy, Spain, and France (Fig. 3), has assessed technical needs and contributed with technical documents to find common mitigating measures.

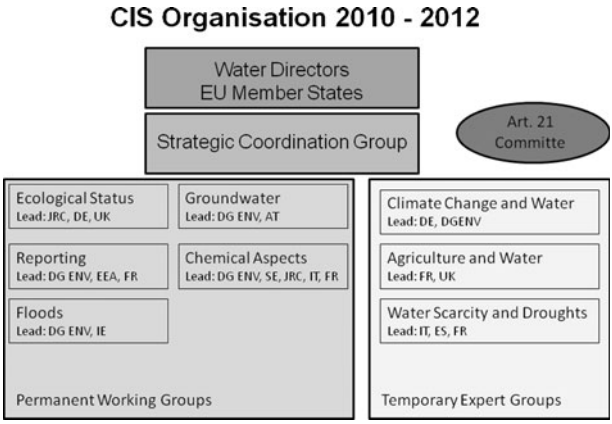

Fig. 3 Scheme of the common implementation strategy of the Water Framework Directive, for the period 2010–2012

After the drafting and discussion process within stakeholder groups, the Communication of the European Commission (2007a) 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: Common Agricultural Policy, Water Framework Directive, 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 drought management plans, supports establishing a European drought strategy, considers using European funds when suffering prolonged droughts, and proposes establishing a European drought observatory.

The European Commission (2011) in the third Follow up Report to the Communication on water scarcity and droughts in the European Union 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 Member States 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 River Basin Management Plans. Also it is highlighted that many Member States 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 Member States, in particular efforts to reduce water consumption and adaptation to climate change. Most Member States (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 drought management plans 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 et al. 2004) or Australia and South Africa (O'Meagher et al. 1998), they are not being implemented in EU countries until very recent dates. Member States participating in the water scarcity and droughts working group in collaboration with the European Commission elaborated in 2007 the technical report "Drought Management Plan Report, including agricultural, drought indicators, and climate change aspects" coordinated by Spain (European Commission 2007c). Its main objective is to serve as a useful tool to elaborate drought management plans (DMPs), supplementing River Basin Management Plans (RBMPs) - according to the Water Framework Directive article 13.5-, providing general criteria, structures, and recommended measures. This guidance document can help EU Member States, 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, organizative, 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 Water Framework Directive are focusing on further developing water scarcity and droughts indicators that could be commonly used by Member States, 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 Droughts in the Water Framework Directive

Droughts are considered in different parts of the Water Framework Directive (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 have been met. Also, the WFD establishes the possibility of supplementing River Basin Management Plans (RBMPs) with detailed programmes and plans to deal with particular aspects of water management. In this case, Drought Management Plans 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 et al. (2006): a) droughts constitute an exemption from certain WFD requirements, b) the declaration of a drought situation must be defined in the RBMP, adopting adequate indicators, c) measures to be adopted in drought situation must be incorporated in the programme of measures 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, Member States 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 drought management plans, 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 Member States for supplying basic demands while protecting water quality and ecosystems.

4 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/yr, varying from 2.200 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 (Ministerio de Medio Ambiente 2000).

There is a clear unbalance of water availability in Spain between northern, central and south-eastern areas (Ministerio de Medio Ambiente 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 1.200, after China, the USA, India and Japan. The capacity of these reservoirs is 56.000 hm^3 (INE 2008).

Water balance issues can worsen by climate change impacts. These impacts were assessed in 2005 by the Spanish Ministry of Environment in the "Assessment report of the preliminary impacts in Spain due to Climate Change" (Ministerio de Medio Ambiente 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 in 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 building tradition of 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 wastewater 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.

Wastewater reuse may provoke quality and health concerns. In consequence, in December of 2007, the use of treated wastewater in Spain was regulated through the Royal Decree RD 1620/2007. This decree determines the necessary requirements to conduct activities in relation to the use of reclaimed wastewater. It establishes the procedures to get the government licenses required by law, and includes the minimum quality criteria required for the use of reclaimed wastewater 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 and Vargas 2008). Similarly to wastewater 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 River Basin Authorities in some aquifers, the intensive use has often produced over-exploitation and saline intrusion problems in coastal areas (Ministerio de Medio Ambiente 2000).

5 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 United Nations Development Programme (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 (European Commission 2007c), 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 updated Water Act (1985) 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 River Basin Authorities. 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 Hydrologic Plan Act established the bases for planned drought management in Article 27. Drought management, which states in Section 1

that The Ministry of Environment, for River Basin Authorities will establish a national hydrologic indicator system that will allow foreseeing these situations, and will serve as general reference for river basin authorities for the formal declaration of emergency situations and eventual drought and in Section 2 that River Basin Authorities will develop Drought Management Plans (DMP) for alert situations and eventual drought, including exploitation rules and measures.

6 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 (Whestphal et al. 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 River Basin Authorities 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 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. 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.

7 Drought Management Plans in Spain

The National Hydrological Plan Act established in 2001 that drought management plans (DMPs) had to be elaborated by the River Basin Authorities. These plans have already been

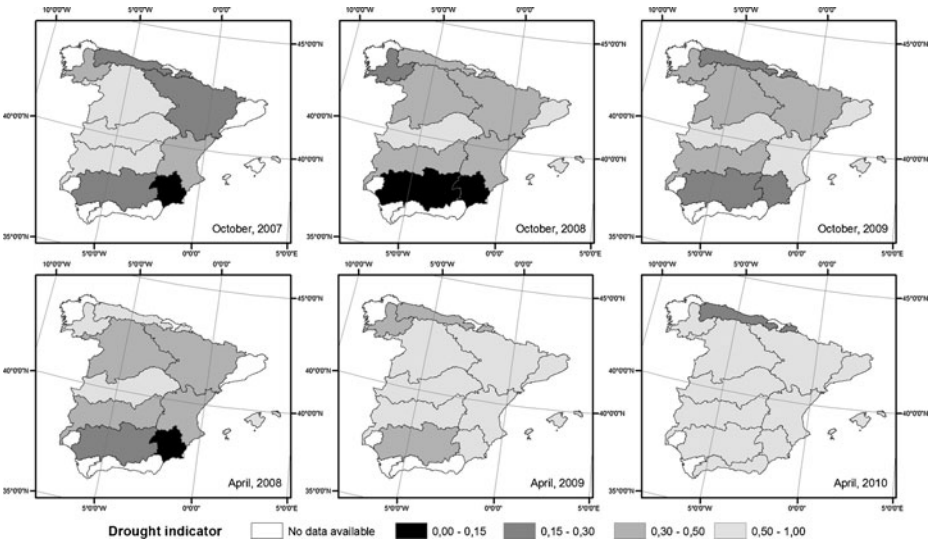

Fig. 4 Maps showing the drought status of Spanish river basin districts in October and April of 2007 to 2009. Legend status: emergency (0,00–0,15), alert (0,15–0,30), pre-alert (0,30–0,50) and normal (0,50–1,00)

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 Hydrological Planning Royal Decree (RD 907/2007), as a specific plan of the River Basin Management Plans (Estrela 2006).

DMPs have proved to be useful and efficient tools to manage water resources under drought episodes. The specific objectives of the DMPs 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 River Basin Management Plans.

To achieve these objectives, 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 the regular management practices. As the drought progresses and a

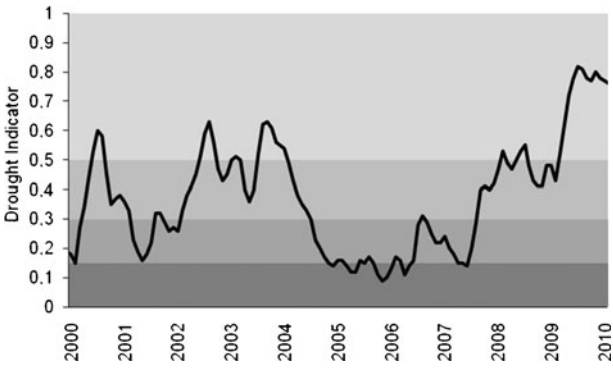

Fig. 5 Evolution of drought indicator at Júcar river basin for 2000–2010 period (elaborated with data taken from Drought Indicator System of Júcar River Basin Authority)

more critical situation takes place, 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 DMP is to establish an adequate link between basin drought status and actions to be taken.

Other key part of the DMPs 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 et al. 2007). Their action methods and established measures must be applied once the interested parties have been 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 (Ministerio de Medio Ambiente 2000).

Last, the 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 the 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 European Union as well as in other regions of the world such as the United States of America (Wilhite et al. 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 et al. 2004; Nelson et al. 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.

8 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 DMPs 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 drillings 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 (RD) 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, RD Law 9/2006 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 (Ministerio de Medio Ambiente, Medio Rural y Marino 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 River Basin Authorities 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 River Basin Authorities, 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, a Royal Decree-Law was passed in 2008, 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 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 DMPs. In the development of the DMPs, 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.

9 Conclusions

The European Union (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 Member States 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 entitled "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 to the Communication of the European Commission in 2011, actions to integrate water scarcity and droughts into sector policies have been undertaken by several Member States, 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 European Union, Spain is a country characterised by presenting a high variability and uneven water resource distribution, being the Mediterranean coast and southeast 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. Drought management plans 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 River Basin Management Plans and have proven to be valuable management tools.

Acknowledgments 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.

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