Defining the planning purpose, framework and concepts [Part 1. Components of drought planning. 1.1. The planning framework]

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in

**Iglesias A. (ed.), Moneo M. (ed.), López-Francos A. (ed.).
Drought management guidelines technical annex**

**Zaragoza : CIHEAM / EC MEDA Water
Options Méditerranéennes : Série B. Etudes et Recherches; n. 58**

2007
pages 17-27

Chapter 2. Defining the planning purpose, framework and concepts

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SUMMARY – This component of the MEDROPLAN Guidelines for Drought Management defines the purpose for developing drought planning at the local, regional and national levels, and highlights the need to respond to changing pressures in the environment and society. Drought has a wide range of effects in different sectors, social groups, or the environment. Whether the drought plan addresses the full range of possible risks or focus in a few, it is necessary to establish the final purpose from the onset. The purpose determines the choice of methodologies for developing the plan. Proposed drought management actions can be applied at different time scales, with different objectives and at different points of the system. All these aspects are to be taken into account and defined throughout the management plan so that timeframes and responsibilities are clear enough to ensure the adequate application of the management plan.

Key words: Drought, impacts, language, stakeholders, proactive, reactive.

Defining the planning purpose and process

This component of the MEDOPLAN Drought Management Guidelines defines the purpose for developing drought planning at the local, regional and national levels, and highlights the need to respond to changing pressures in the environment and society.

Mediterranean countries are continuously adapting to their structural limitations and pressures –imbalanced distribution of water resources, conflicts among users, and between countries, large demographic changes, and recent globalization– but it seems likely that climate change will lead to further development of adaptation of different systems and populations.

Farmers and agricultural policy will have to adapt to the slow evolution of climate. If projections become a reality, water scarcity is expected to rise in the next decades posing additional problems to water managers and users. The combination of temperature increase and changes in the hydrological cycle limit some of the current adaptation measures, such as the increase of the volume of irrigation water. The human dimension of climate change impacts in the Mediterranean might not stop at the country level. There is the potential for more pronounced water conflicts with neighbouring countries (i.e. transboundary issues in rivers and many shared aquifers).

Adaptation capacity in the Mediterranean region is challenged in particular, as climate change comes in conjunction with high development pressure, increasing populations, water management that is already regulating most of available water resources, and agricultural systems that are often not adapted (any more) to local conditions.

Defining the purpose

Drought has a wide range of effects in different sectors, social groups, or the environment. Whether the drought plan addresses the full range of possible risks or focus in a few, it is necessary to establish the final purpose from the onset. The purpose determines the choice of methodologies for developing the plan.

The dynamic character of drought management plans

Drought management plans are always in progress. As technologies evolve, new programs are developed, and institutional responsibilities change, these plans have to be revised and updated; therefore all components need to be considered dynamic (Fig. 1).

The proposed guidelines for drought planning are the result of more than three years of research and they should be considered as an integrating framework, which takes into account almost every aspect of mitigating drought for the time being. It is true, though that from time to time it should be reviewed and probably edited and updated.

Fig. 1. Development and revision of a drought management plan based on the guidelines.

Defining a common language among stakeholders

The need to establish multi-stakeholder dialogue from the onset

(i) To increase the quality and acceptance of drought management plans.

(ii) To increase acceptance of or trust in the science that feeds into the planning.

(iii) To provide essential information and insights about drought preparedness, since the relevant wisdom is not limited to scientific specialists and public officials.

Challenges for involving stakeholders

(i) What are the incentives and means for engaging stakeholders?

(ii) How to represent stakeholder decision making in realistic terms?

(iii) How to ensure that complex models are transparent and provide insight to individual users?

Basic concepts for drought management

Drought, aridity, water shortage and desertification are common and overlapping processes in Mediterranean countries (Fig. 2) and often are misinterpreted and used. Starting with clear and agreed definitions and concepts contributes to the development of clear methods and the interpretation of the results for developing drought management plans. A glosary of terms in included at the end of this document.

	Nature produced	Man induced
Temporary	• Drought	• Water shortage
Permanent	• Aridity	• Water scarcity • Desertification

Fig. 2. Basic concepts related to water availability.

(i) *Drought:* Natural causal (random) temporary condition of consistent reduction in precipitation of water availability with respect to the normal values, spanning along a significant period of time and covering a wide region. It results from persistent lower-than-average precipitation.

(ii) *Aridity:* Natural permanent climatic condition with very low average annual or seasonal precipitation.

(iii) *Water shortage:* Man-induced temporary water imbalance. Water shortage in a water supply system represents a water deficit with respect to the demand, which can occur due to a drought or other antropic causes (e.g. low water quality, ill services).

(iv*) Water scarcity* indicates a permanent condition of unbalance between water resources and water demands in a region (or in a water supply system) characterized by an arid climate and/or a fast increasing of water demand, associated to growth of population, extension of irrigated agriculture, etc.

(v) *Desertification:* The degradation of land in arid, semi-arid and other areas with a dry season; caused primarily by over-exploitation and inappropriate land use interacting with climatic variance.

According to the different component of the natural hydrologic cycle affected by a drought event, it is possible to distinguish among: meteorological, agricultural or hydrological drought (see Fig. 3).

In particular, a *meteorological drought* indicates a condition of reduction of precipitation with respect to normal values, consequent to precipitation variability probably caused by earth processes (as geophysical and oceanographic interactions), interactions with the biosphere and maybe by sunlight energy fluctuations.

As a direct consequence of meteorological drought, a soil moisture deficit occurs (agricultural drought), depending on the entity of the *meteorological drought* transformed by the water storage effect. In particular, such water storage causes a delay in the deficit occurrence and modifies its entity in relation to the initial condition and to the evapo-transpiration process. Agricultural drought affects especially agriculture and livestock systems in rainfed conditions.

Subsequently, when the previous deficit affects surface water bodies (rivers) and underground bodies (aquifers), a *hydrological drought,* as a surface and/or groundwater flow decreasing with respect to the normal values, occurs.

Finally, drought can have effects on water supply systems leading to water shortages. The latter is sometimes defined as *operational drought,* and in relation with the environmental, economical and social system features it can have economic and intangible impacts. Both the water availability reduction and its impacts depend, besides the importance of the drought event, on the efficiency of the mitigation measures adopted in water supply and social-economic systems.

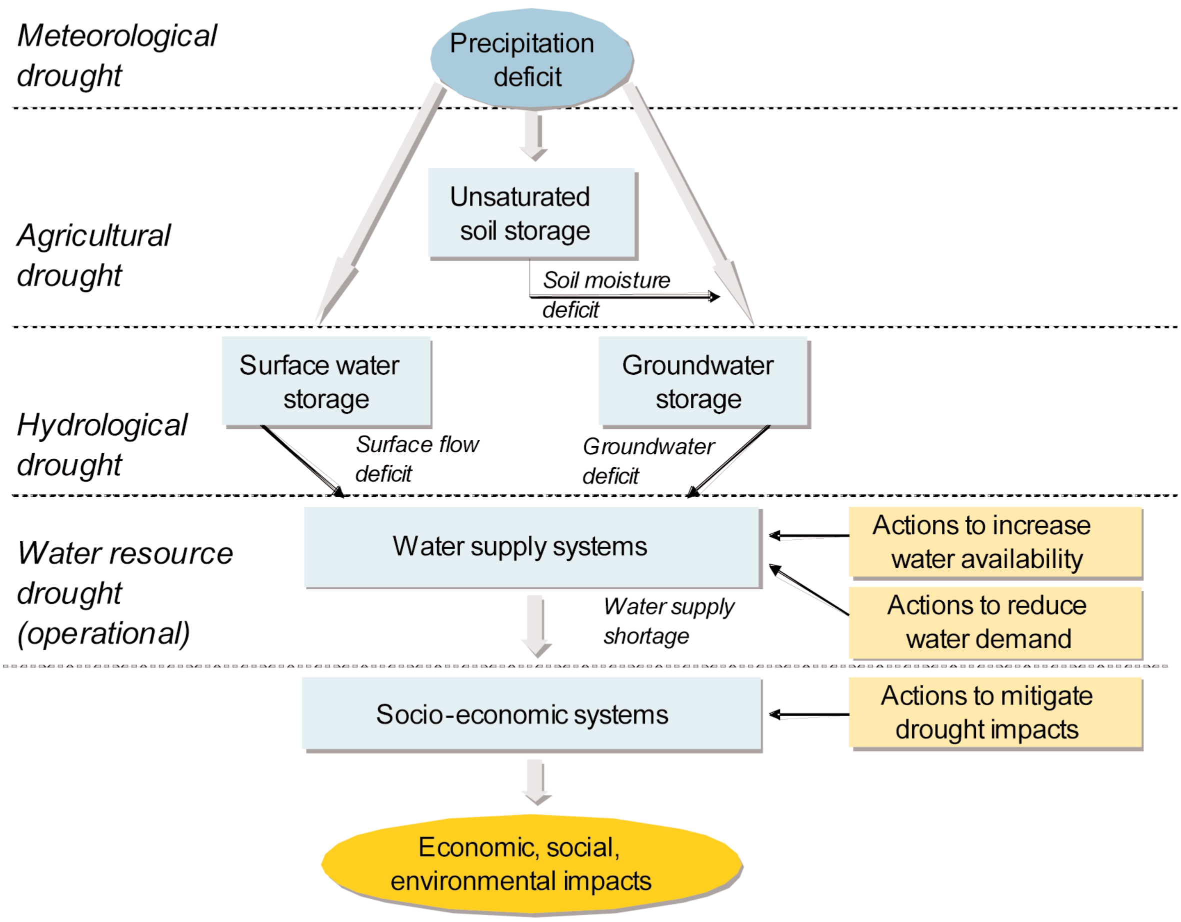


Fig. 3. Drought phenomenon and role of drought mitigation measures (adapted form Rossi, 2005).

Sometimes, the definition of *socio-economic drought* is also used to indicate impacts of water shortage on population and economy. Hereafter, the latter will be examined in terms of economic, environmental and social impacts produced by a drought.

Defining the drought management approaches

Drought management actions can be applied at different time scales, with different objectives and at different points of the system. All these aspects are to be taken into account and defined throughout the management plan so that timeframes and responsibilities are clear enough to ensure the adequate application of the management plan.

Drought management timeframe

A *reactive approach* is based on the implementation of measures and actions after a drought event has started and is perceived; this approach is taken in emergency situations. This approach often results in inefficient technical and economic solutions since actions are taken with little time for evaluating optimal actions and stakeholder participation is very limited.

A *proactive or preventive approach* includes all the measures designed in advance, with appropriate planning tools and stakeholder participation. The proactive approach provides both short term and long term measures and includes monitoring systems for a timely warning of drought conditions. It also includes a contingency plan for emergency situations. It can be considered an approach to "manage risk". Water and agricultural managers in USA and Australia have promoted the proactive approach for decades. Table 1 summarises the characteristics of these two approaches.

Table 1. Characteristics of the approaches to drought management

Approaches to drought management	Characteristics	Limitations
Reactive approach	Based on the implementation of actions after a drought event has occurred and is perceived Taken in emergency situations but not based in a contingency plan	Often results in inefficient technical and economic solutions since actions are taken with little time for evaluating optimal actions Limited stakeholder participation
Proactive or preventive approach	Actions designed in advance, with appropriate planning tools Includes stakeholder participation Provides both short and long term measures and includes early warning systems Includes a contingency plan for emergency situations	The ineffective coordination and cooperation among institutions and the lack of policy to support and revise the proactive plan may result in obsolete and inadequate planning

Figure 3 shows the theoretical sequential evolution of drought, the consequences of intensified drought events and the potential management actions that can be applied to mitigate the effects of drought in a water supply system. In the figure we can appreciate the different time steps followed by drought, affecting in the first place to rainfed agricultural systems, evolving to affect components of the hydrological system, such as surface or groundwater storage and deriving into affection to water supply systems, either for urban or irrigation purposes. In relation to this sequence, the objectives and the timeframe of application of management actions vary from preventive actions oriented to modify supply or demand before or during the drought event, to other actions oriented to minimize the potential impact of drought in combination with the previous actions or when these ones have not been successful.

Assignment of responsibilities for drought management

The implementation of a proactive approach implies drafting plans in which the mitigation measures are clearly defined together with the instructions for their implementation. At this end, a clear assignment of competences among the different involved institutions appears to be a key issue; therefore a legislative act which defines the responsibilities is necessary in each country. Such act could be part of national water resources policy and/or strategy to fight desertification (within the U.N. convention).

Other important aspects to take into account are:

(i) Stakeholders' participation.

(ii) Management and changes in water rights legislation allowing water exchange during droughts.

(iii) Definition of standards of efficiency to foster water saving and sanctions for who does not respect them.

The need for drought management plans in Mediterranean countries

Climate is an essential component of the natural capital in the Mediterranean Basin. Different from other environmental assets, climate is subject to a great degree of natural variation. Mediterranean climates are among the most variable of the world and recurrent drought problems often affect entire countries over multi-year periods and often result in serious social problems, such as water scarcity stress and low quality of water. The intensive demand of water for agriculture contributes to the conflicts among water users. Over the last three decades spring rainfall has decreased in many areas of the region exacerbating the severe problems associated with drought. Fresh water has undergone increasing pressures and has also suffered quality degradation in many regions limiting options for sustainable development.

Mediterranean Region's development is strongly dependent on water resources availability. A main element for the development of social-economic activities is to ensure that water will be always available; the uncertainty derived form drought leads, without doubt, to a condition of underdevelopment and degradation. The purpose of developing drought management guidelines is to contribute to formulate comprehensive water management plans that take into account the probabilistic nature of the drought phenomena, encouraging a risk based rather than a crisis based approach. The MEDOPLAN Guidelines respond to the analysis of the current resources and dynamic social and environmental pressures.

Mediterranean countries are diverse from the point of view of climate and water infrastructure (Table 2). Rainfall and water resources are limited, scarce, and difficult to predict from year to year. The average annual potential water availability per capita considering the total freshwater resources in southern Mediterranean countries is less than 1000 m^3 per capita and year. In addition, real available water resources are always less than potential water resources in all cases. For example in Spain real available water resources are less than half of the total freshwater resources (Iglesias *et al.*, 2005) and the potential use of surface water under natural regime is only 7% (Garrote *et al.*, 1999). In the areas where demand is above the available resources, drought usually results in crisis. Due to the current imbalance between availability and demand, water management problems are significant even without drought events.

In all countries, demand is raising due to demographic shifts, economic development and lifestyle changes. The remarkable demographic increase (population in the Mediterranean areas, especially in the south and east areas, increased three times in few dozens of years), the rising level of life style, the industrialization, the ongoing climatic change, are all together causing a continuous reduction in water availability and quality often causing many emergencies, nearly everywhere.

Water use in the region is mainly for agriculture, accounting for over 50% of total water use in all countries except France where water used in agriculture is only a 10% of the total use, nevertheless the other economic and social water demands are rapidly increasing, such as tourism and ecosystem services (Aquastat, 2005). There is a clear difference in the proportion of water usage in the different sectors between northern countries, where industrial use shows a larger share than domestic use, and southern countries, where agriculture is the main use followed by domestic and finally industrial use.

Drought events in the Mediterranean have been frequent after 1970 (Iglesias and Moneo, 2005; Hisdal *et al.*, 2001; Vogt and Somma, 2000) and have had serious effects on the economy, the environment, and on the population's well being. The economic damage caused by drought in the Mediterranean during the last twenty years is about five times more than in the entire United States (CRED, 2005). Drought events affect water supplies for irrigation, urban, and industrial use, ecosystem's health, and give rise to conflicts among users that limit coherent integrated water resource management. For example, the major drought of the mid 1990s affected over 6 million people in the region and had severe effects on the agricultural economy of southern Mediterranean countries (Iglesias and Moneo, 2005).

Drought impacts are generally non-structural and also difficult to quantify (UNISDR, 2002). This is especially significant in regions where economic resources and technology can buffer the effect of negative environmental changes (insurance, public support). Therefore, characterization of drought episodes is complex, and includes both physical aspects and social consequences.

Agriculture in the Mediterranean is both the main use of the land in terms of area and the principal water-consuming sector. Therefore the adverse effects of drought are perceived to be associated with agricultural activities, leading to conflicts over the use of resources with other sectors. These conflicts especially affect ecosystem sustainability and imply the need to incorporate substantial changes in current water management.

Groundwater resources play a vital role in meeting water demands, not only as regards quality and quantity, but also in space and time, and are of vital importance for alleviating the effects of drought. (Garrido *et al.*, 2000; Llamas, 2000). However, groundwater pumping should be controlled because excessive use of the aquifers can cause overexploitation problems with the consequent negative environmental, social and economic impact.

Most Mediterranean freshwater and groundwater resources are shared among countries (Wolfe, 1999), being the Nile river a key global example. Within the countries, shared water among administrative units is also common in the Mediterranean. Disputes exist, especially during drought

Table 2. Total freshwater resources, available resources, use, and water availability in selected Mediterranean countries

Country	Total area (km^2) [Population (million)] †	Rainfall (mm/yr) ††	Internal renewable water resources (km^3/yr) †††	Renew-able water resources (km^3/yr)	Internal groundwater (km^3/yr)	Total water use (km^3/yr)	Total water use (km^3/yr) (% Renew -able)	Potential total renewable water resources per capita (m^3/capita per year)
Algeria	2.381,740 [30]	89	13.90	14.32	1.70	5.74	40	473
Egypt	1.001,450 [68]	51	1.80	58.30	1.30	61.70	106	859
Libya	1.759,540 [5]	56	0.60	0.60	0.50	5.73	954	113
Morocco	446,550 [30]	346	29.00	29.00	10.00	12.23	42	971
Tunisia	163,610 [9]	313	4.15	4.56	1.45	2.58	57	482
France	551,500 [59]	867	178.50	203.70	100.00	35.63	17	3439
Greece	131,960 [11]	652	58.00	74.25	10.30	7.99	11	6998
Italy	301,340 [58]	832	182.50	191.30	43.00	43.04	22	3325
Portugal	91,980 [10]	855	38.00	68.70	4.00	7.40	11	6859
Spain	505,990 [44]	636	111.20	111.50	29.90	35.90	32	2794

† The values refer to both regulated and unregulated water. Real available water resources in all cases are a fraction of these values.

†† These values include transboundary water. See also Wolfe, 1999.

††† A proportion of these values is included in the total renewable water resources.

Source of data: Aquastat, 2005.

conditions, and potentially will increase due to the increasing water imbalances. Policies of a single government or basin unit cannot resolve issues over shared water bodies, and local interests are likely to diverge. International Institutions play a key role as formal mechanisms to deal with water related conflicts in the region.

Drought characterisation in the Mediterranean

Characterization of drought episodes provides the adequate framework for developing indicators of risk. Drought indicators may be used to evaluate the levels of drought risk, linking science to policy.

Droughts differ from other natural hazards in several important ways: (i) no universal definition exists; (ii) its spatial extent is usually very large; (iii) slow-development that makes difficult to determine the onset and end of the event; and (iv) its duration may range from months to years.

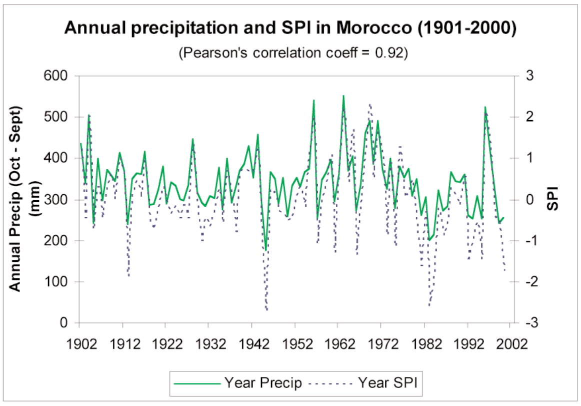
Drought occurs in most climatic regimes, and is often described as a natural hazard. It is a temporary anomaly, unlike aridity, which is a permanent feature of the climate. Defining drought is therefore difficult; it depends on differences in regions, needs, and disciplinary perspectives (Wilhite, 2005; Iglesias and Moneo, 2005). Meteorological drought is caused by a deficit in precipitation and hydrological drought is caused by the decrease or deficiency in ground water and reservoir levels when the meteorological drought is very intense or persistent. Whatever the definition, it is clear that drought cannot be viewed solely as a physical phenomenon, as its severity depends on the impact on people or ecosystems and their ability to cope and recover. Although drought may cause water scarcity –the extent to which demand exceeds available resources– human actions such as population growth or water mismanagement may also be the cause.

The impacts of drought in agriculture result directly from decreased precipitation (in dryland crop production) and from decreased water storage (in irrigated agriculture). It is therefore important to distinguish between meteorological and hydrological drought for a correct analysis.

Drought characterization in highly regulated systems is complex and calls for multiple indicators. Classical drought indices, such as the Standardized Precipitation Index or the Palmer Drought Index, are widely used to characterize meteorological drought. These indices do not correlate well with hydrological drought periods or historical drought impacts, due to the effect of storage (Garrote *et al.*, 2003). Many of the more complex indices that take storage and management into account are not easily interpreted across the regions and cannot be validated with the data available over wide geographical areas (Rossi *et al.*, 2003). Therefore, managers of water resources tend to rely on precipitation and streamflow variables to determine the onset of alarm, alarm, and emergency situations (see below: Current strategies for drought management).

Figure 4 shows the time series of aggregated precipitation in Morocco and Spain defining meteorological drought episodes, and the SPI calculated at 24 month intervals, defining hydrological drought. The two variables are correlated (correlation coefficient = 0.75) and a threshold value of the SPI index of -1.0 may be taken as an alarm indicator of drought (Hayes *et al.*, 1999). Many studies have characterized comparable precipitation patterns at different geographical scales (De Luis *et al.*, 2000; Estrela *et al.*, 2000). Figure 4 also shows the extremely large variability characteristic of Spanish precipitation and the recurrent multi-year drought episodes.

Figure 4 shows at least two periods with different precipitation trends, highlighting the importance of choosing the adequate reference period for developing indicators for management. Precipitation in the latest period, from the 1960s has clearly decreased. The very low precipitation of the 1940s defined the historical drought during that period, with severe consequences for the economy. The structural water deficit of many areas in the country has been aggravated during three severe drought episodes (1975-76, 1981-82, and 1992-95), each more severe than the previous one (Fig. 4). During these droughts, besides the collapse of irrigation water supply, urban water supply series were affected significantly.



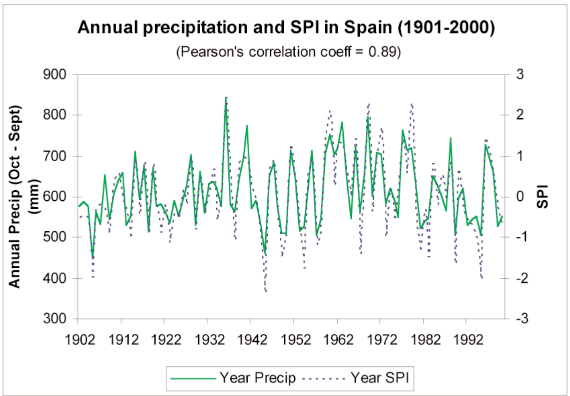


Fig. 4. Time series of aggregated annual precipitation and SPI values (12 month time scale) in Morocco and Spain. (Data source: The Tyndall Center database TYN CY 1.1; Mitchell *et al.*, 2002).

Current drought management

The national governments and the local authorities have responded to extreme drought vigorously, taking emergency measures, but so far the responses have focused on the effects of drought ex post, rather than on anticipatory measures ex ante. In general, these efforts have neglected to build the capacity needed to deal with similar situations in the future. Information on possible longer-term climate forecasts and/or development of plausible scenarios has not yet been incorporated into any specific action plans.

No single management action, legislation or policy can respond to all the aspects and achieve all goals for the effective drought management. Multiple collaborative efforts are needed to integrate the multidimensional effects of drought on society. The United Nations Convention to Combat Desertification (UNCCD, 2000) provides the global framework for implementing drought mitigation strategies. The United Nations International Strategy for Disaster Reduction (UNISDR, 2002) establishes a protocol for drought risk analysis.

Current legislation on water and drought management shows different development stages for the Mediterranean countries that lead to important differences in the way droughts can be faced. While some of the countries have a stable and long tradition legislative framework with functional river basin authorities and clearly defined responsibilities, others are still developing institutions and organizations that take care of water management issues.

A common characteristic of the countries in the region is the weak cooperation among the different institutions related to water management, and the fragmented roles of the State, the administrative regions and the river basin authorities, that result in administrative conflicts that are an impediment for adequate water management (Iglesias and Moneo, 2005). The key issue of transboundary water management is included in drought management plans. Other Mediterranean countries, especially in the southern basin, share a significant portion of groundwater, but the regulation during drought needs to be further developed.

In general, decisions related to drought are taken in the context of formal legal system. There are legal provisions for emergency actions in case of crisis situations, such as extreme drought. Informal customs may evolve into formal decisions, for example, historical users of groundwater without formal rights may be legalized. The legislation does not provide explicit regulations about how to calculate the ecological discharge during drought situations; this important question is being left to the discretion and responsibility of the various river authorities.

A main advantage of the explicit linkage of legislation and management to the basin level is the opportunity to address directly the needs and problems of the natural hydrological system and the stakeholders represented in management board of the river basin. Water managers can establish priority of users or right holders, or can approve emergency works and projects according to each level of risk. In contrast, when water resources management is linked to administrative units, responses to drought tend to be "crisis based" rather than "preparedness based".

Historically, policy-makers with competence in agriculture at the national and sub-national levels have been responsible for both natural and economic resource management. These agricultural managers already use short-term weather forecasts in irrigation scheduling with success, since cropping systems must be matched with seasonal water supply, a major component of risk for farmers (Iglesias *et al.*, 2000; Wilhite and Vanyarkho, 2000; Wilhite, 1996). These managers, therefore, have already incorporated quantitative estimates of probabilistic climate conditions and modelling output into their decision-making process. It is reasonable to expect that this current situation may lead to an effective dialog among resource managers and scientists on methods of quantitative assessment, therefore paving the way for improving the development of adaptation strategies for longer-term climate change.

The structural water deficit of many Mediterranean countries has been aggravated during the drought episodes in the last thirty years. Since the 1990s, Mediterranean countries have improved drought preparedness strategies but have also experienced severe drought impacts. Drought indicators, although imperfect, contribute to understand the temporal characteristics of drought and to define alarm situations. Past efforts to manage drought have built capacity to deal with similar situations, but have failed to solve the conflict among users, especially with the environment.

Drought management needs to be integrated into the long-term strategies for water management. When water resources are managed at the basin level, there is an opportunity to respond directly to the needs and problems of the natural hydrological system with policy decisions. Monitoring and early warning systems continue to improve and are being incorporated into the planning processes.

Drought planning with future uncertainties

Drought management in both regulated and unregulated systems will have to adapt to the slow evolution of water supply and demand. The combination of temperature increase and changes in the hydrological cycle, limit some of the current adaptation measures, such as the increase of the volume of irrigation water. The human dimension of drought management in the Mediterranean might not stop at the regions' boundaries. There is the potential for more pronounced water conflicts with neighbouring regions (i.e. transboundary issues in shared surface waters and aquifers) and demographic shifts due to the collapse of agricultural activities in some areas.

Although scientific projections of future climate evolution are highly uncertain and subject to numerous hypotheses, there is a growing concern among the scientific community about the impacts of climate change on drought magnitude and frequency in the Mediterranean region (IPCC, 2001). The combination of long-term change (e.g. warmer average temperatures) and greater extremes (e.g., droughts) can have decisive impacts on water demand, limiting further ecosystem services. If climate change intensifies drought impacts, current Mediterranean water management plans may become increasingly unstable and vulnerable. Water managers may find planning more difficult. Current water management strategies based on changes in mean climate variables should be revised to account for the potential increase in anomalous events.

Uncertainties and opportunities for the future

Historically, policy-makers with competence in agriculture at the national and sub-national levels have been responsible for both natural and economic resource management. These agricultural managers already use short-term weather forecasts in irrigation scheduling with success, since cropping systems must be matched with seasonal water supply, a major component of risk for farmers (Iglesias *et al.*, 2000; El-Shaer *et al.*, 1997; Wilhite and Vanyarkho, 2000; Wilhite, 1996). These managers, therefore, have already incorporated quantitative estimates of probabilistic climate conditions and modelling output into their decision-making process. It is reasonable to expect that this current situation may lead to an effective dialog among resource managers and scientists on methods of quantitative assessment, therefore paving the way for improving the development of adaptation strategies for longer-term climate change.

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Climate change projections indicate an increased likelihood of droughts. Variability of precipitation –in time, space, and intensity– can directly influence water resources availability. The combination of long-term change (e.g. warmer average temperatures) and greater extremes (e.g. droughts) can have decisive impacts on water demand, limiting further ecosystem services. If climate change intensifies drought impacts, Spanish water delivery systems and control may become increasingly unstable and vulnerable. Water managers may find planning more difficult. Current water management strategies based on changes in mean climate variables should be revised to account for the potential increase in anomalous events.

Climate change

Climate change scenarios for the region are derived by using the Magicc Scengen software of the University of East Anglia (UK) with input data form the HadCM3 global climate model driven by the A1 and B2 SRES socio-economic scenarios (IPCC, 2001; Eid *et al*., 2001). The scenarios result in an increase of temperature (1.5°C for the B2 scenario and 3.6°C for the A1 scenario) and precipitation decreases in most of the territory (about 10 to 20% decreases, depending on the season).

Agriculture in the Mediterranean is both the main use of the land in terms of area and the principal water-consuming sector (see above). Therefore the adverse effects of climate change are perceived to be associated with agricultural activities, leading to conflicts over the use of resources with other sectors. Under all climate change scenarios, water supplies decrease and irrigation demand increase in the Mediterranean region (El Shaher *et al*., 1997; Minguez and Iglesias, 1995; Iglesias and Minguez, 1997; Iglesias *et al*., 2005; Mougou *et al*., 2005). These results will affect ecosystem sustainability, implying substantial future changes in water management.

Under current conditions all Mediterranean countries face significant problems due to the unbalanced distribution of water resources, conflicts among users, and between countries and it seems likely that climate change will lead to an intensification of these problems. The effects of sea level rise in North Africa, especially on the coast of the Delta region of Egypt, would impose additional constraints to the use of resources (IPCC, 2001).

Northern Africa's adaptation capacity is challenged in particular, as climate change comes in conjunction with high development pressure, increasing populations, water management that is already regulating most of available water resources, and agricultural systems that are often not adapted (any more) to local conditions. Evidence for limits to adaptation of socio-economic and agricultural systems in the Mediterranean and North African region can be documented in recent history. For example, water reserves were not able to cope with sustained droughts in the late 1990's in Morocco and Tunisia, causing many irrigation dependent agricultural systems to cease production. In addition, effective measures to cope with long-term drought and water scarcity are limited and difficult to implement due to the variety of the stakeholders involved and the lack of adequate means to negotiate new policies.

The human dimension of climate change impacts in Northern Africa might not stop at the regions' boundaries. There is the potential for more pronounced water conflicts with neighbouring regions (i.e. transboundary issues in the Nile and in many shared aquifers). There is the risk of climate change induced refugee flows to Europe from the region.

Although scientific projections of future climate evolution are highly uncertain and subject to numerous hypotheses, there is a growing concern among the scientific community about the impacts of climate change on drought magnitude and frequency. Global increases in temperature and changes in the hydrological cycle are expected to have a major impact on drought in the Mediterranean region (IPCC, 2001). Future risk assessments require the development of environmental change scenarios at different time-scales. These scenarios should include estimates not only of changes in the climatic baseline, but also estimates of possible future changes in socio-economics.