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Challenges to Manage the Risk of Water Scarcity and Climate Change in the Mediterranean

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Abstract The Mediterranean region is undergoing rapid local and global social and environmental changes. All indicators point to an increase in environmental and water scarcity problems with negative implications towards current and future sustainability. Water management in Mediterranean countries is challenged these pressures and needs to evolve to reach the target of increasing population with reliable access to freshwater established by the Millennium Development Goals. This paper first reviews and evaluates current and future social and environmental pressures on water resources, including climate change. The results show that pressures are not homogeneous across the region and sectors of water use. Second the paper evaluates the adaptation strategies to cope with water scarcity, including technology, use of strategic groundwater, and management. Finally, the paper proposes a framework for managing the risk of water scarcity based on preparedness rather than a crisis approach. The importance of local management at the basin level is emphasized, but the potential benefits depend on the appropriate multi-institutional and multi-stakeholder coordination.

Key words water scarcity · climate change · risk management · Mediterranean

1 Pressures on Water Resources in the Mediterranean

Mediterranean countries are diverse from the point of view of socio-economic development, climate, water availability and infrastructure, and the social and ecological

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pressures on water resources (Figure 1). The region is undergoing rapid social and environmental changes with negative implications towards current and future sustainability. Pressures and impacts of water scarcity often result in conflicts among users and with an apparent lack of policy response towards sustainable management, due to the complex institutional structure and legislation (Garrote et al. 2005; Iglesias and Moneo 2005; Garrido and Llamas 2006).

Water resource managers face the dilemma of ensuring future sustainability of water resources while maintaining the strategic agricultural, social and environmental targets. The average annual potential water availability per capita considering the total freshwater resources in southern Mediterranean countries is less than 1,000 m^3 per capita and year (Table I). The aim of the Millennium Development Goals (MDGs) is to halve by 2015 the proportion of people who suffer from hunger and do not have access to safe drinking water. These goals are a set of quantified objectives with concrete target times that arise form the Millennium Declaration, that have been adopted by all members of the United Nations (September 2000).

1.1 Environmental Pressures

Usable water resources are always less than potential water resources in all countries. For example in Spain real available water resources are less than half of the total freshwater resources (Iglesias et al. 2006) and the potential use of surface water under natural regime is only 7% (Garrote et al. 1999). In Egypt, Israel, and Libya, and many areas in the rest of the countries, demand is above the available resources, and water scarcity crisis is common (Table I). The difficulty in forecasting the highly variable seasonal and inter-annual rainfall is an impediment for advanced decision in water management.

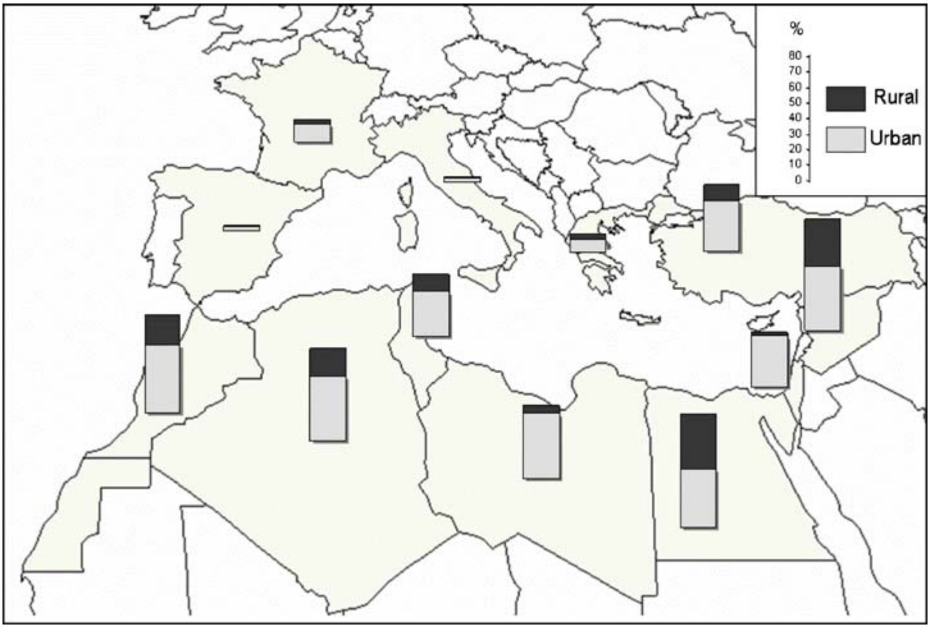

Figure 1 Mediterranean countries and population increase projections for 2025. Data source: FAO 2005.

Table I Water resource indicators: Total freshwater resources, available resources, use, and water availability in selected Mediterranean countries

Country	Total area ($\times 10^3$ km2)	Population (million)	Rainfall (mm/yr)	Internal usable water resources (km^3/yr)[a]	Usable water resources (km^3/yr)[b]	Internal groundwater (km^3/yr)[c]	Total water use (km^3/yr)	Total water use (% renewable)	Potential total usable water resources per capita (m^3/capita per year)
Algeria	2,382	32	89	13.90	14.32	1.70	5.74	40	473
Egypt	1,001	72	51	1.80	58.30	1.30	61.70	106	859
France	552	60	867	178.50	203.70	100.00	35.63	17	3,439
Greece	132	11	652	58.00	74.25	10.30	7.99	11	6,998
Israel	22	6.5	435	0.75	1.67	0.5	1.63	103	254
Italy	301	57	832	182.50	191.30	43.00	43.04	22	3,325
Libyan Arab J.	1,770	6	56	0.60	0.60	0.50	5.73	954	113
Morocco	447	31	346	29.00	29.00	10.00	12.23	42	971
Spain	506	41	636	111.20	111.50	29.90	35.90	32	2,794
Syrian Arab R.	180	18	252	7	26.26	4.2	20.6	100	1,403
Tunisia	164	10	313	4.15	4.56	1.45	2.58	57	482
Turkey	770	71	593	227	213	69	37	18	2,800

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

[b] These values include transboundary water. See also Wolfe, 1999.

[c] A proportion of these values is included in the total renewable water resources.

Source of data: FAO, 2005 (data of 2004).

Recurrent drought episodes in the region further increase the complexity of water scarcity management. Drought events in the Mediterranean have been more frequent after 1970 (Figure 2; Iglesias and Moneo 2005; Hisdal et al. 2001; Vogt and Somma 2000; Wilhite and Vanyarkho 2000). The economic damage caused by drought in the Mediterranean during the last 20 years is about five times more than in the entire United States (CRED 2005), and in Spain the major drought of the mid 1990s affected over six million people and had severe effects on the agricultural economy (CRED 2005). These examples reveal the vulnerability of the Mediterranean region to predict the climate conditions and the increasing demands.

Figure 2 shows the time series of aggregated precipitation in Morocco and the corresponding widely used drought index SPI calculated at 24 month intervals. Drought 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). The Figure shows at least two periods with different precipitation trends and variability patterns. Precipitation after the 1970s has clearly followed a decreasing trend and provoked further water deficit in many areas in the country (Ouassou and Ameziane 2005; Skees et al. 2001).

1.2 Social Pressures

Irrigated agriculture is the main consumer of water in the Mediterranean (Figure 3). The evolution of irrigation in all Mediterranean countries has been remarkable over the last half

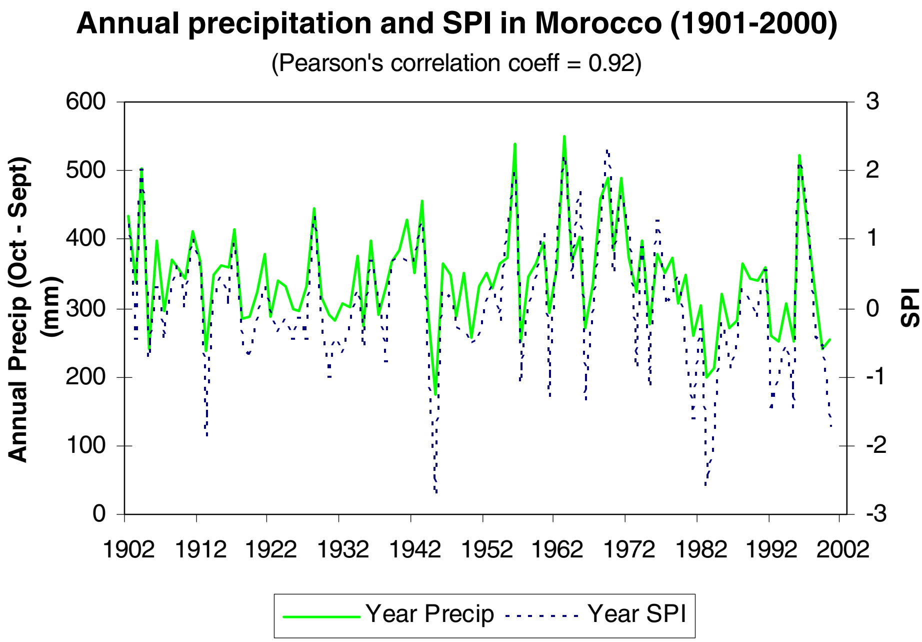

Figure 2 Time series of aggregated annual precipitation and SPI values (12 month time scale) in Morocco. (Data source: The Tyndall Center database TYN CY 1.1; Mitchell et al. 2001).

century, although northern and southern Mediterranean countries differ in relation to the rate of expanding their irrigated land and irrigation technologies used (Garrido and Iglesias 2006). In general, there is little development of new irrigation areas and the investments focus on rehabilitation of existing schemes, and improvement of irrigation technologies. But, nevertheless there is a rapid increase in the water demands in all countries as a result of the increase of economic and social activities together with the increasing demand for tourism and for the ecosystems.

Currently there is an increasing pressure on water resources in Mediterranean countries, derived from population dynamics, upgraded standard of living, economic and social development, and the use of water consuming technologies. Population growth in many southern Mediterranean countries is the major factor affecting water resources, reducing the water availability per capita (Figure 1 and Table I). Urbanization increases urban demands, which are of high-priority and intensifies conflicts among users. Tourist population in the Mediterranean is very significant, and tourist water consumption is about three times higher than local demands (EEA 2000). The number of international tourist arrivals increases every year; in Spain, Greece, and France; the number exceeds total countries' population by about one third (World Tourist Organization 2005). Tourist consumption is highly seasonal, but the industry increases permanent water demand for facilities and leisure structures. Particularly Spain is experiencing a tourist and second-home boom all across the

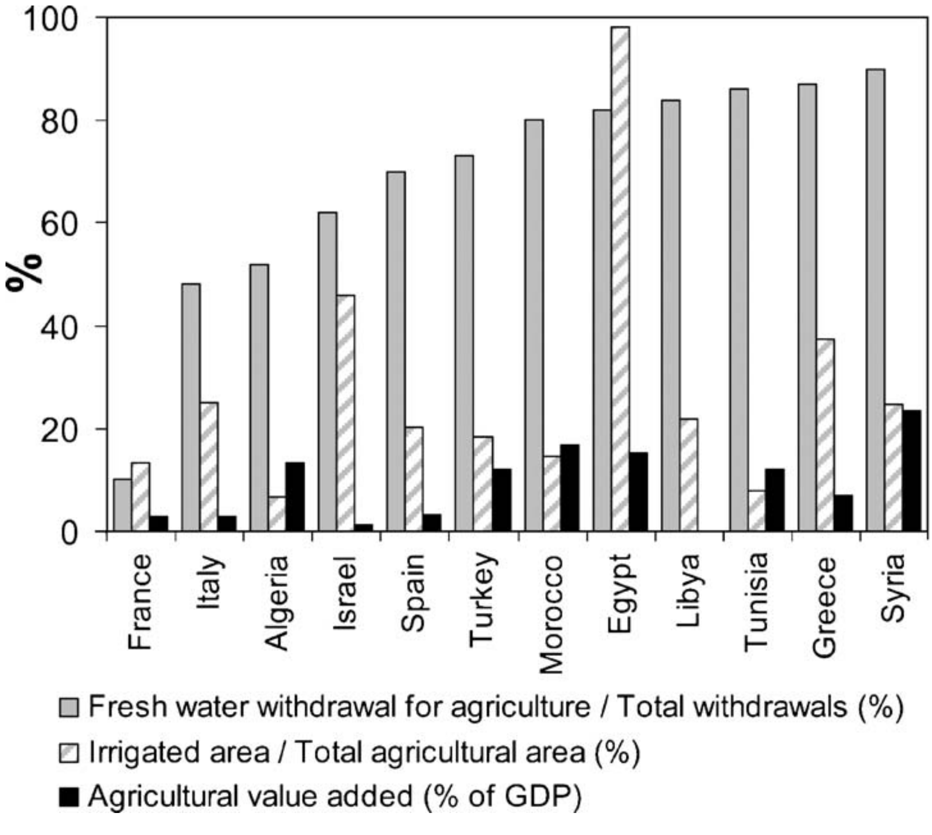

Figure 3 Water use for irrigation and irrigated agricultural areas in selected Mediterranean countries. Source of data: FAO 2005.

Mediterranean coast and together with the 275 golf courses (75 more are on project only along the Mediterranean coast), represent a demand increase of about 30 million m^3. This demand is a small fraction of agricultural demand at the country or regional level (for example in Cyprus tourist demand represents 5% of total contrasting with about 70% of agricultural demand), but at the local level in key tourist destinations it is the main demand (for example in Majorca, Spain; Essex et al. 2004).

1.3 Water Quality

Water management problems are not an exclusive matter of water quantity but also of water quality. The environmental impacts human activities cause on water resources, have gained increased interest in recent years and water pollution has become a high priority issue for the protection of the quantity and the quality of the surface water and groundwater resources.

Degradation of the groundwater quality is a common problem in the Mediterranean region due to multiple pressures on the aquifers: excessive pumping in relation to average natural recharge, return flow from irrigation water with intense use of agrochemicals, leakage from urban areas, land fills, septic tanks, sewers, mine tailings, among others (Barraque 1998; Fornes et al. 2005). Also irrigated agriculture in semiarid regions, although increases crop productivity and economic stability, however, it is one of the major diffuse source contributors to the contamination of surface and groundwater bodies, mainly from pesticides and fertilisers. Control of pesticides and optimization of fertilisation with crop uptake are essential management strategies for better control of irrigated agriculture. Drought episodes also contribute to the degradation of groundwater quality (Iglesias and Moneo 2005) as a result of the overuse of aquifers. An important number of Mediterranean wetlands are affected by irrigation activities since their ecosystems depend to a significant degree on the sustainability of agro-ecosystems. Habitats' conservation and agriculture have in many cases irreconcilable interests (Hellegers and van Ierland 2003).

Many aquifer systems that naturally contain vast quantities of brackish water, have limited possibilities for exploitation for human or agricultural uses, imposing so, additional demand stress to neighbouring aquifers with higher water quality. Also saline intrusion is an important concern in aquifers, especially in the Mediterranean region, where as a result of the high seasonal water demand, mainly for tourism, they have been over pumped.

1.4 Climate Change

Climate change projections for the region derived from global climate model driven by socio-economic scenarios (Intergovernmental Panel on Climate Change, 2001; Iglesias et al. 2000) result in an increase of temperature (1.5 to 3.6°C in the 2050s) and precipitation decreases in most of the territory (about 10 to 20% decreases, depending on the season in the 2050s). Climate change projections also indicate an increased likelihood of droughts (Kerr 2005) and variability of precipitation – in time, space, and intensity – that would 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, with further impact on the ecosystems. Under all climate change scenarios in the Mediterranean region, available water resources decrease while irrigation demand increases (El-Shaer et al. 1997; Iglesias 2002; Iglesias et al. 2006).

Under current conditions all Mediterranean countries also face significant problems due to the unbalanced distribution of water resources, conflicts among users, and between countries and it seems most 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 (Intergovernmental Panel on Climate Change, 2001; Iglesias et al. 2002). If climate change results in intensification of drought, available water resources in the Mediterranean region may become increasingly unstable and vulnerable. Drought management in both regulated and unregulated systems will have to adapt to the slow evolution of climate. The human dimension of climate change in the Mediterranean may not stop at the country' boundaries, since there is the potential for more pronounced water conflicts with neighbouring regions (i.e., transboundary issues in the Nile and in many shared aquifers).

The management of the decreasing water resources, as a result of the climatic changes within the Mediterranean region, is challenged in particular, as climate change coincides with high development pressures, increasing populations, and high agricultural demands. Evidence for limited capacity to cope with socio-economic and agricultural demands in the Mediterranean region can be documented in recent history. For example, water reserves were not able to cope with extensive droughts in the late 1990s in Spain, Morocco and Tunisia, causing many irrigation dependent agricultural systems to cease production. Effective measures to cope with long-term drought and water scarcity are limited and difficult to implement due to the variety of stakeholders involved and the lack of adequate means to negotiate new policies.

1.5 Shared Water

Almost one half of the Earth's land surface is covered by trans-boundary river basins and freshwater scarcity problems are becoming more frequent. Water can lead to political hostilities and many regions with political conflicts are sharing water resources. International Organizations need to address cooperation among nations in order to solve conflicts. Most Mediterranean freshwater and groundwater resources are shared among countries (Wolfe 1999), the Nile River being a key global example. Within the Mediterranean countries, water shared between administrative regions is also common. Disputes exist, especially during drought conditions, which will probably increase as a result of imbalance distribution of water resources among the regions. Policies of central government or single basin management cannot resolve issues over shared water bodies, and local interests are likely to diverge. International Institutions can play a key role as official and independent mechanisms to deal with water related conflicts between the regions.

2 Current Adaptation Strategies

2.1 Drought Management

Water scarcity and drought have multidimensional implications for society and therefore no single management action, legislation or policy can respond to all aspects and demand objectives (Table II). Mediterranean countries have developed legislation with different perspectives and levels of integration into the overall water management policy. When water is managed at the river basin level and the institutional responsibilities are clearly defined, drought legislation is more effectively applied. Nevertheless, a characteristic of all countries in the region is the weak cooperation among different institutions, and the fragmented roles of the State, the administrative regions and the river basin authorities, that often results in conflicts and impediments for implementation of existing legislation.

The European Water Framework Directive (2000/60/EC) is an example of recent efforts to develop coherent water management legislation, promote creation of institutions responsible for planning, management and control of water resources at the basin level. 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 integrate the stakeholders in the decision process. However, the implementation of the Directive leads to difficulties, especially in transboundry basins – between countries or administrative regions of a country – where institutional coordination is required. Neither the current legislation nor the aforeseen implementation of the Directive, provide explicit regulations for the ecological quality of water bodies or the quality of the discharges in drought situations. This important issue is being left to the discretion and responsibility of the various River Authorities.

Drought management needs to be integrated into the long-term strategies for water management incorporating improved early warning and monitoring systems (Wilhite 2005). The development of specific drought contingency plans is at early stage in most countries. Example of detailed and operational plan is provided by the urban water supplier CYII that manages water for the metropolitan area of Madrid (Cubillo and Ibanez 2003). The plan is based on the comprehensive understanding of the demands of the system, the strategic

Table II Summary of the drought management actions in the Mediterranean

Concept	Cyprus	Greece	Italy	Morocco	Tunisia	Spain
Water law	Includes drought	Includes drought	Includes drought	Includes drought	Includes drought	Includes drought
River basin authorities	Managed at central level Developed	Developed	Developed	Development	Partially developed	Developed
Relation among institutions	High	Low	Low	Medium	High	Medium
Public participation in water management	Low	Medium	High	Low	Low	High
Drought contingency plan	Developed	In development	Sub-national	In development	National	River basin
Drought monitoring system	Partially developed	Partially developed	River basin	National	National	River basin
Surface Water ownership	Public	Public	Public	Public	Public	Public
Groundwater ownership	Public	Public	Public	Partially private	Public	Partially private

National: developed at country level. Sub-national: developed at a level smaller than the country, such as a province or district. River basin level: refers to the portion of the river basin within the country.

Source of data: Iglesias and Moneo (2005).

reserves of the stored volume and the level of guarantee for the water supply. It is surprising that international initiatives such as The United Nations Convention to Combat Desertification (UNCCD 2002) that provides the global framework for implementing drought mitigation strategies, and the United Nations International Strategy for Disaster Reduction (UNISDR 2002) that establishes a protocol for drought risk analysis, have not been taken into account for the preparation of the local drought management plans.

Water saving is a key strategy for overall reduction of societal vulnerability to drought. Water reuse and desalinization technologies at market rates and wide scale are recent but are developing fast, with significant efficiency gains, placing the cost at about 0.22 €/m3 and 0.48 €/m3 for brackish and sea waters, respectively (Garrido and Iglesias 2006). Irrigation technology is increasing water and land productivity with outstanding savings and benefits to ecosystems (Garrido and Iglesias 2006). The adoption of water saving measures requires education and participation of the users.

Real public participation in water management is difficult to quantify, since participation in all countries is mainly theoretical. The data presented in the table is based in a comparative evaluation of the institutional analysis performed with a common methodology. It is difficult to compare results with other individual studies. For example Barreira (2003) carefully analysed the implications of the EU WFD for the Iberian peninsula, concluding low public participation, but does not provide a scale to compare with other Mediterranean countries. The level of participation evaluated in Table II reflects the proportion of stakeholders legally represented in water management bodies in each country. The ownership of surface and groundwater results to complications for the application of legislation and other aspects of water management. Common aspects of the region is the public ownership of surface water and the partially private ownership of groundwater, as well as the intensive groundwater use without restrictions or legal rights. Groundwater reserves have been and continue to be the largest buffer in water scarcity situations, but a large range of negative effects has been documented for its overuse (Llamas and Martinez-Santos 2005).

Finally, economic instruments contribute to the design of effective management but alone are ineffective (Garrido and Calatrava 2005). Water markets, tariffication, and reallocation of rights with financial compensation, may be adequate in some cases (Garrido et al. 2005). For example, data show that water markets or water transfer exchanging mechanisms are effective instruments during water shortages in Italy, Greece, Tunisia and Morocco, but in contrast water tariffication in Greece and Italy, and in Tunisia via incentives, is not adequate during water shortage periods (Garrido et al. 2005).

2.2 Strategic Resources and Technology

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 and Iglesias 2006; Llamas 2000; Llamas and Martinez-Santos 2005). Although groundwater has been used historically, the technology to use groundwater intensively has been developed in the last 50 years, and used intensively in arid and semi-arid countries to satisfy the demands for water supply and irrigation. The pressure on groundwater resources in the last decades partially arises from the intensive development of intensive irrigated agricultural areas. Global examples include the developments in India, Pakistan, Yemen, Eritrea, and Egypt, among others (Moench et al. 2003). Custodio and Llamas (2001) compile tens of studies in, which the role of groundwater is highlighted and its social importance emphasised. 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. The main challenge to sustainable groundwater is to maintain its social and strategic value (Garrido and Iglesias 2006). In most cases, almost all groundwater abstracted is used for irrigation (Fornes et al. 2005). As Table I shows, groundwater provides a significant part of irrigation water to the farm sector in Algeria, Morocco, Egypt, Turkey and Tunisia. Spain and Italy rely heavily on groundwater as well. Conjunctive use of surface-groundwater resources has been around for decades. For example, the urban supply system of Madrid and more than 100 of municipalities (pop. 5.5 mill) depends on groundwater to face scarcity situations of moderate to severe level (Cubillo and Ibanez 2003).

Technology for desalination, reuse and use of brackish waters has evolved significantly in recent years (Calatrava and Sayadi 2005; Bazzani et al. 2005; Saadi and Ouazzani 2004) and many users in the Mediterranean region can today use these waters at affordable prices (Garrido and Iglesias 2006). However the alternative of desalinized water as a massive supply, for example in agriculture it is still non-sustainable.

3 A Framework for Risk Management of Water Scarcity

This section describes a framework for risk management of water scarcity based on the analysis of the current adaptation strategies to water scarcity in Mediterranean countries that provides a systematic approach to prevent and/or minimize the impacts of drought on people. The framework is developed in the context of current drought vulnerability, legislation, management, and technologies (see previous section) and intends to be broad enough to incorporate new criteria for establishing priorities as societies change or as scientific and technological aspects of drought management improve. The framework includes the following components:

1. *Data*. Evaluate the data and information relevant to characterization (i.e., precipitation) and impacts (i.e., reservoir levels) of water scarcity that conform the monitoring and early warning systems and may be used to produce trigger indicators.
2. *Institutions*. Describe the institutional and legal frameworks that have direct or indirect inflows on drought preparedness and management, and the hierarchical relations among them.
3. *Stakeholders*. Identify the stakeholders affected by the decisions of each institution and the mechanism of participation in the decision process.
4. *Validation*. Validate the interactions among institutions, legislation and stakeholders with concrete historical examples.
5. *Risk*. Define thresholds of acceptable risk for a range of water scarcity situations and the indicators used to identify the risk level.
6. *Measures*. Describe Elaborate the measures that synthesise the process.

In most basins, measures grouped according to different severity levels. A commonly used ranking describes three levels of severity (i.e., can be named pre-alarm, alarm, and emergency). It is extremely important to also define the “normal” situation, since the plan is optimally developed at this stage. The management plan is considered a pro-active measure that defines a protocol for implementing reactive measures when the water scarcity situation occurs. The severity levels are determined by established thresholds of indicators that trigger groups of measures in response to the objective of each level (Table III). There are many examples that validate this framework over the past decades in Mediterranean

Table III Summary of a planning framework for risk management of water scarcity

	Preparedness	Pre-alert	Alert	Emergency
Monitoring indicators	Indicators show a normal situation	Indicators show initial stage of danger; no observed impacts (meteorological drought)	Drought is occurring and impacts will occur if measures are not taken (meteorological and hydrological drought)	Drought is persistent and impacts have occurred; water supply is not guaranteed (socio-economic drought)
Objective of the plan in each stage	To ensure that a preparedness and early warning plan is in place	To ensure acceptance of measures to be taken in case of alarm or emergency by raising awareness of the danger of drought	To overcome the drought situation and to guarantee water supply while emergency measures can be put in place	To minimize damage, the priority is drinking water
Measures	•Development of a management plan and strategy for revision and review	•Low cost, indirect, voluntary	•Low cost, direct, coercive, direct impact on consumption costs	•High cost, direct, restrictive, approved as general interest actions
	•Implementation of a monitoring and early warning system	•Non structural directed to influence water demand and avoid worse situations	•Non structural directed to specific water use groups	•Structural, new infrastructure, intra-basin, inter-basin and transboundary transfers
	•Integration with development and land use policies	•Focus on communication and awareness	•Water restrictions for uses that do not affect drinking water	•Non structural, such as permission for new groundwater abstraction points
		•Intensification of monitoring and evaluation of worse case scenarios	•Changes in management	•Water restrictions for all users, including urban demand
			•Revision of tariffs •Rights exchanging centres	

countries, especially in the pre-alarm and alarm levels. In the emergency level, the main priority is to satisfy drinking water demands and all structural and non-structural measures of high economic, social, or environmental cost are designed and taken in order to minimised water restrictions for urban demand.

Monitoring and early warning of potential water quality and quantity is a key component of the plan (Wilhite 2005; Wilhite 1996). Continuous improvements of technology in instrumental monitoring devices (i.e., gauges, piezometers, etc) play a key role for accounting of resources. Drought indices adequately calibrated represent local features of the water resources system of the basin they can be used as auxiliary tools for drought monitoring and forecasting (Wilhite 2005). Realistic models appropriate for water management need to be incorporated in monitoring and early warning system (Rossi et al. 2003; Cancelliere et al. 2006). Finally, scientific advances in understanding variations of the climate system offer an opportunity to develop prediction methods.

In the Mediterranean, 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 (i.e., developing a drought management plan, and coherent resource management). 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.

The drought management is implemented by the water management responsible authorities, in general at the basin level. These planning bodies develop and use management plans that incorporate: demand and supply analysis and projections, contingency and preparedness plans, and scenario analysis for drought. In an optimal situation, permanent monitoring provides indicators that can trigger specific drought management actions. These indicators ideally include: hydrological, socio-economic, and environmental aspects. In general, drought management plans include measures that respond to different drought severity levels.

4 Conclusions

The Mediterranean region is undergoing rapid socio-economic and technological changes that increase the pressure on its already structural water deficit and question the ability to maintain the current management philosophy. In addition, climate change projections indicate an increased likelihood of droughts. Institutions in the region are evolving to respond to these pressures and to ensure more sustainable water resources management. There is an ongoing progress in many of these countries, which is favoured by the increasing regional cooperation, a better monitoring and management systems, and above all by the awareness of governments. The adoption of emerging technologies for using fresh or unconventional water resources more effectively is crucial for water management. Drought management measures need to be integrated into the long-term strategies for water and land uses and overall development strategies. When water resources are managed at the river basin level, there is an opportunity to respond directly to policy decisions and to the needs and problems of the natural hydrological system. Monitoring and early warning systems continue to improve and are being incorporated into the planning processes. Lastly, strengthened regional cooperation and better understanding of the resource's dynamics and social dimension, and more efficient monitoring systems give hope for alleviating the present pressures on the water resources in the next decades.

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References

Barraque B (1998) Groundwater management in Europe: regulatory, organisational and institutional change. In: Hilding-Rydevik T and Johansson I (eds) How to cope with degrading groundwater quality in Europe. Stockholm

Barreira A (2003) Public Participation in the WFD: Implications for the Iberian Peninsula. Proceedings of the III Congreso Ibérico sobre Gestión y Planificación del Agua. Spain: Institución Fernando el Católico (in Spanish)

Bazzani G, Di Pasqualeb M, Gallerani V, Morganti S, Raggib M, Viaggi D (2005) The sustainability of irrigated agricultural systems under the Water Framework Directive: first results. Environ Model Softw 20:165–175

Calatrava J, Sayadi S (2005) Economic valuation of water and "willingness to pay" analysis with respect to tropical fruit production in southeastern Spain. Spanish Journal of Agricultural Research 3:25–33

Cancelliere A, Di Mauro G, Bonaccorso B, Rossi G (2006) Drought forecast through the Standardized Precipitation Index. Water Resour Manag (in press)

CRED, Center for Research on the Epidemiology of Disasters (2005) University of Louvain and the United Nations Department of Humanitarian Affairs. International Disasters Data Base (EM-DAT) http://www.cred.be/ Cited 15 June 2005

Cubillo F, Ibanez JC (2003) Manual of water supply. Canal de Isabel II. 169 pp

Custodio E, Llamas R (eds) (2001) Intensive use of groundwater: challenges and opportunities. Balkema, Amsterdam

EEA, European Environment Agency (2000) Europe's environment: the third assessment. Copenhagen

El-Shaer HM, Rosenzweig C, Iglesias A, Eid MH, Hillel D (1997) Impact of climate change on possible scenarios for Egyptian agriculture in the future. Mitig Adapt Strategies Glob Chang 1(3):233–250

Essex S, Kent M, Newnham R (2004) Tourism development in Majorca: is water supply a constraint? J Sustain Tour 12(1):4–28

FAO, Food and Agriculture Organisation of the United Nations (2005) Databases. FAO's global information system of water and agriculture. http://www.fao.org/

Fornes JM, de la Hera A, Llamas MR (2005) The silent revolution in groundwater intensive use and its influence in Spain. Water Policy 10:1–16

Garrido A, Calatrava J (2005) Recent and future trends in water charging and water markets. In: Garrido A, Llamas MR (eds) Water policy in Spain, Resources for the Future, Washington, DC (in press)

Garrido A, Iglesias A (2006) Groundwater's role in managing water scarcity in the Mediterranean region. In: International Groundwater Sustainability, International Groundwater Association (in press)

Garrido A, Llamas MR (eds) (2006) Water policy in Spain, Resources for the Future, Washington, DC (in press)

Garrido A, Gomez-Ramos A, Iglesias A (2005) Economic Instruments and Evaluations of Drought Policies. MEDROPLAN Report, Hamammet

Garrote L, Rodríguez I, Estrada F (1999) Una evaluación de la capacidad de regulación de las cuencas de la España peninsular. VI Jornadas Españolas de Presas. Libro de actas, pp 645–656

Garrote L, Flores F, Carrasco FJ (2003) The hydrologic regime of the Tagus basin in the last 60 years. IWRA Congress. October 2003, Madrid

Garrote L, Flores F, Iglesias A (2005) Linking drought indicators to policy. The case of the Tagus basin drought plan. Water Resour Manag (in press)

Hellegers P, van Ierland E (2003) Policy instruments for groundwater management in The Netherlands. Environ Resour Econ 26:163–172

Hisdal H, Stahl K, Tallaksen LM, Demuth S (2001) Have streamflow droughts in Europe become more severe or frequent?. Int J Climatol 21(3):317–333

Iglesias A (2002) Climate changes in the Mediterranean: physical aspects and effects on agriculture. In: Bolle HJ (ed) Mediterranean climate. Springer, Berlin Heidelberg New York

Iglesias A, Moneo M (eds) (2005) Drought preparedness and mitigation in the Mediterranean: Analysis of the Organizations and Institutions. Opions Méditerranéenness, CIHEAM, Centre international de Hautes Etudes Agronomiques Méditerranéennes, Paris. 2005

Iglesias A, Rosenzweig C, Pereira D (2000) Prediction spatial impacts of climate in agriculture in Spain. Glob Environ Change 10:69–80

Iglesias A, Ward MN, Menendez, M, Rosenzweig C (2002) Water availability for agriculture under climate change: understanding adaptation strategies in the Mediterranean. In: Giupponi C, Shechter M (eds) Climate change and the Mediterranean: socioeconomic perspectives of impacts, vulnerability and adaptation. Edward Elgar, Milan
Iglesias A, Moneo M, Garrote L, Flores F (2006) Drought and water scarcity: current and future vulnerability and risk. In: Garrido A, Llamas MR (eds) Water policy in Spain, resources for the future, Washington, DC (in press)
Intergovernmental Panel on Climate Change (IPCC) (2001) Climate change 2001: impacts, adaptation and vulnerability. Contribution of working Group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
Kerr RA (2005) Confronting the bogeyman of the climate system. Science 310:432–433
Llamas MR (2000) Some lessons learned during the drought of 1991–1995 in Spain. In: Vogt JV, Somma F (eds) Drought and drought mitigation in Europe. Kluwer, Dordrecht, pp 253–264
Llamas MR, Martinez-Santos P (2005) Intensive groundwater use: silent revolution and potential source of social conflicts. J Water Resour Plan Manag 131:337
Mitchell TD, Hulme M, New M (2001) Climate data for political areas. Tyndall Centre for Climate Change Research. Observations 109–112
Moench M, Burke J, Moench Y (2003) Rethinking the approach to groundwater and food security. FAO Water Reports 24, Rome
Ouassou A, Ameziane T (2005) In: Iglesias A, Moneo M (eds) Drought preparedness and mitigation in the Mediterranean: analysis of the organizations and institutions. Opions Méditerranéenness, CIHEAM, Centre international de Hautes Etudes Agronomiques Méditerranéennes, Paris
Rossi G, Cacelliere A Pereira LS, Oweis T, Shataniawi M, Zairi A (eds) (2003) Tools for drought mitigation in Mediterranean Regions. Kluver Academic , The Netherlands. 357 p
Saadi A, Ouazzani N (2004) Perspectives of desalination of brackish water for valorisation in arid regions of Morocco. Desalination 1:165, 81
Skees J, Gober S, Varangis P, Lester R, Kalavakonda V (2001) Developing rainfall – based index insurance in Morocco. Policy Research working paper 2577, World Bank, Washington DC
UNCCD, United Nations Convention to Combat Desertification (2002) Convention adopted in Paris on 17 June 1994 and opened for signature there on 14–15 October 1994; entered into force on 26 December 1996. 179 countries were Parties as at March 2002. http://www.unccd.int Cited 15 June 2005
UNISDR, United Nations International Strategy for Disaster Reduction (2002) Drought living with risk: an integrated approach to reducing societal vulnerability to drought. Ad Hoc Discussion Group on Drought. Geneva
Vogt JV, Somma F (eds) (2000) Drought and drought mitigation in Europe. Kluwer, Dordrecht, 336 pp
Wilhite DA (1996) A Methodology for Drought Preparedness. Natural Hazards, 13: 229–252. Kluwer, The Netherlands
Wilhite DA (ed) (2005) Drought and water crises. CRC, London
Wilhite DA, Vanyarkho O (2000) Drought: pervasive impacts of a creeping phenomenon. In: Wilhite DA (ed) Drought: a global assessment (Vol. I, Ch. 18). Routledge, London
Wolfe A (1999) The transboundary freshwater dispute database project. Water Int 24(2):160–163
World Tourist Organization (2005) http://www.world-tourism.org/ Cited on 15 June 2005