Application of the drought management guidelines in Spain [Part 2. Examples of application]

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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 373-406

Chapter 20. Application of the Drought Management Guidelines in Spain

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SUMMARY – The Spanish case study presents the drought planning process carried in the Tagus Basin. The presentation is structured in four parts: organizational, methodological, operational and public review components. The organizational component presents the framework and specific legislations and the organizations and institutions in Spain that work on drought preparedness and mitigation. The methodological component presents the analytical techniques used for drought risk analysis and management. The operational component describes the proposed structure for the drought management plan and presents the specific actions that are contemplated in it. The process review component identifies stakeholders that are involved in the decision making process and presents their views on the process.

Key words: Tagus Basin, regulated systems, water supply, agricultural, urban, probabilistic, deterministic.

Organizational component

Legal framework

Embid Irujo (2003) recognizes two main legal sources of the Spanish water codes and statutes: derived from the Spanish Constitution and from the European Union Water Framework Directive. These two legal bodies are on top of the hierarchy of laws and statutes pertained to water and droughts. Three instrumental laws are identified as the main precursors of drought preparedness and planning: The Water Law, the Law of the National Hydrological Plan and the Agricultural Insurance Law.

The Water Law (WL) was approved in 1985, reformed in 1999, and consolidated in 2001 in a Royal Decree (Real Decreto Legislativo 1/2001, 20 July 2001) with slight amendments with respect to the 1999 version. The Spanish Water Law can be considered a modern and comprehensive water code, covering all issues and aspects related to water policies, organization, procedures, finance, civil works, planning, and public participation. Among the key Water Law provisions that pertain to droughts are:

(i) Water-rights holders can make use of their rights insofar Basin Authorities approve them and issue concrete management plans detailing all possible uses for the current hydrological year (Articles 55 and 58).

(ii) Water use plans and reservoir release decisions are taken by the Basin Authorities, as proposed by the Reservoir Release Commissions and Management Boards (Articles 32 and 33). Droughts are considered exceptional circumstances.

(iii) The formal declaration of a "drought" allows the Government to initiate any project, work, or action under fast track approval procedures.

(iv) Right-holders are allowed to freely exchange their water use rights, but the transfer requires approval of the Basin Authority and is subject to various regulatory provisions (Articles 67-70). Works and projects needed to solve emergent scarcity problems are considered works that promote the general interest (Article 46), and as such, their approval procedures and financing enjoy preferential treatment.

(v) Basin Authorities can create Water Exchanging Centres, through which right holders can offer or demand use rights in periods of droughts or severe water scarcity situations (Article 71). The initiative to create these Centres must be proposed by the Environment Ministry and be approved by the Ministerial Cabinet. If the exchanges centres or the water rights transfers involve two different basins they must be explicitly approved by the Environment Ministry.

All Spanish Hydrological Basin Plans were approved by the Royal Decree 1664/1998 (Real Decreto 1664/1998, of July 24th). In compliance with Article 60 of the Water Law, reliability criteria were established that guarantee minimum allowances for the irrigation and urban sectors for the medium and long term. The criteria are specified by a range of probabilities of supply failure during one, two, or ten consecutive drought years.

The Law of the National Hydrological Plan (Ley 10/2001, of July 5th, de Plan Hidrológico Nacional) consolidates all planning decrees pertained to each of the inter-regional basins, and lays down the basic principles of the Water Planning at the national level. Droughts are explicitly mentioned in Article 27 establishing:

(i) The Environment Ministry will establish a system of hydrological indicators to support the formal declaration of alert situation and droughts by Basin Authorities.

(ii) Basin Authorities should develop special action plans for alert situation and droughts, including the management rules and the programme of measures to be applied on the water public domain under these situations.

(iii) All public administrations that are responsible of supplying urban water services to cities with more than 20,000 inhabitants must develop an Emergency Plan. This Plan must be approved by the relevant Basin Authority and take into account the special action plans mentioned in the previous point.

The Agricultural Insurance Law (Ley 87/1978, 28 December 1978, de Seguros Agrarios Combinados) lays the framework and institutional organization of the Spanish system of agricultural insurance policy. Droughts are mentioned among the risks recognized in the law to be covered by the insurance policies (Article 3). The specific development of various insurance policies covering yield losses caused by droughts (and other abnormal natural events) has given rise to a menu of options that are currently available to most crops grown under dry-land regimes. Some of these will be described below.

In addition to the above, there is also extensive legislation and normative related to water management and water policy. In general the laws, statutes, and norms focus on reactive drought management, providing conditions for emergency actions. In the case of the insurance normative, the laws from 2001 to present have a pro-active character.

Institutions involved in water and drought management

River Basin Authorities

The administrative body that is responsible for providing public service regarding water management in the basin is the Basin Authority, with competence on inland water and groundwater. The Basin Authority is an autonomous public organization that depends from the Ministry of the Environment. The River Basin Authority structure is the following:

Chairman, appointed by the Council of Ministers at the proposal of Ministry of Environment, for inter-regional basins, and at the proposal of the Autonomic Communities the when is an intra-regional basin.

Management Board ("Junta de Gobierno"). Headed by the Chairman, includes representatives of the Ministries of Environment, Agriculture, and Energy; and regional governments whose territories are part of the basin and users (at least 33% of the board members). It is in charge of: financial matters, general action plan, definition of aquifer depletion and groundwater protection, and drought by creating an ad-hoc Permanent Committee.

Operation Boards ("Juntas de Explotación"). Co-ordinate the management of hydraulic works and water resources in specific areas. The Waters Act establishes composition of the Board according to the importance of each user group in the basin, but it includes the administration, public and private water supply companies, irrigation associations, hydropower companies, and industrial users.

Assembly of Users ("Asamblea de Usuarios"). Headed by the Chairman, includes all users that are part of the Operation Boards. Co-ordinates the management of hydraulic works and water resources throughout the basin.

Dam Water Releases Commission ("Comisión de Desembalse"). Headed by the Chairman, and members selected by the Assembly of Users. Responsible for proposing the system for releasing water from reservoirs, and flood measures (through the creation of a special Permanent Committee).

Water Basin Council ("Consejo del Agua de Cuenca"). Headed by the Chairman, and includes representatives the central and regional governments, technical services, and users including NGOs and professionals (at least 33%). It approves the Basin Hydrological Plan, which is then referred to the central Government.

Hydrological Planning Office ("Oficina de Planificación"). Defines, monitors, and reviews the Hydrological Basin Plan, and provides technical support to the Water Basin Council.

Other institutions

The Ministry of Agriculture is responsible for irrigation planning, the implementation of publicly funded water schemes and the development of irrigation improvement schemes.

The Agricultural Insurance Agency (ENESA), that has the character of an Autonomous Agency dependent on the Ministry of Agriculture, Fisheries and Food through the Under-Secretariat of the Department, acts like a coordination organization and link on behalf of the Administration for the development of Agricultural Insurances. The Institution is headed by the Undersecretary of the Ministry of Agriculture, Fisheries and Food and has a Director that is designated by the Minister of Agriculture, Fisheries and Food.

The Insurance Compensation Consortium acts as an essential re-insurer of the system and has been entrusted the monitoring of the consultancies and taking on the percentage of co-insurance not covered by the insurance institutions.

The Permanent Office for Adverse Climate and Environmental Situations depends from the Ministry of Agriculture, Fishing and Food, General Secretariat of Agriculture and Food. It is directed to an agricultural environment, and acts through the generation, execution and monitoring of measures undertaken to mitigate drought effects.

Methodological component: Drought characterization and risk analysis

Challenge to water management in Spain

Water resources in Spain are limited, scarce, and difficult to predict from year to year. The average annual potential water availability per capita considering the total freshwater resources is 2,700 m^3 compared to 3,807 m^3 in the EU-15 and 7,000 m^3 worldwide (Aquastat, 2005), but some Spanish regions have less than 1000 m^3 per capita and year, such as the Southeast regions and the Islands. In addition, real available water resources in Spain are less than half of the total freshwater resources.

Regulated water resources account for 40% of the total natural resources, compared with 8% worldwide, since the potential use of surface water under natural regime is only 7% (Garrote *et al.*, 1999). Groundwater use is intensive in many areas of the country contributing to an additional 10% of the total available resources. With limited and scarce water resources and demand rising due to demographic shifts, economic development and lifestyle changes, water management problems are significant even without drought events, due to the imbalance between availability and demand. Water use in the country is mainly for agriculture (irrigation accounts for 68% of the water demand), nevertheless the other economic and social water demands are rapidly increasing, such as tourism (current urban demand is 13%) and ecosystem services (Aquastat, 2005).

Storage and regulation by reservoirs do not always solve the problem of water scarcity in areas where dry periods are particularly damaging to the natural and human wellbeing. Eutrophication is a major problem in southern areas of Spain, where 40% of the reservoirs show biological oxygen demand, conductivity, and nitrogen and phosphorus concentrations well outside the adequate range (Estrela *et al.*, 1995). These water quality parameters usually get worse during dry periods due to the depletion of reservoir storage. This factor may play a significant role during crises since water from certain reservoirs may not be acceptable for human consumption.

In Spain, 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, 2002). 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. Direct use of groundwater in Spain is currently estimated at 5 km^3/year, mainly for irrigation use (80%), but the water quality is easily deteriorated due to point-source pollution or diffuse pollution caused by agricultural and livestock activities (Estrela *et al.,* 1995).

Wetland area in Spain has decreased from over 1200 km^2 in the 1970s to less than 800 km^2 in the present time (excluding the Guadalquivir marshlands). This decrease may be in part related to recurrent drought episodes and surface water scarcity, and amplified by the excessive groundwater pumping to compensate for these problems.

The case study: Tagus Basin

The Tagus Basin is located in the central part of the Iberian Peninsula. The main river runs on east-west direction, with a contributing area of 83,678 km^2, of which 55,870 km^2 are located in Spain and the rest in Portugal. Due to the transboundary nature of the basin, a certain amount of water has to reach the river in Portugal, determined by the Albufeira agreement. The Tagus Basin also supplies water to the Segura Basin, a water scarce basin in eastern Mediterranean area of Spain. Table 1 outlines the water balance of the Tagus Basin.

Table 1. Hydrological balance in the Tagus Basin

Water balance	Water use	Sector	Mm^3/year	Mm^3/year
Total available water resources				12180
Demands				5780
	Inside the basin	Urban	740	
		Irrigation	1780	
		Refrigeration	1390	
		Environmental	1440	
	Outside the basin	Transfer to the Segura Basin	430	
Losses	Consumption		1650	2210
	Evaporation		560	
Water leaving the system	Transfer to the Segura Basin			430
	Water to Portugal			9540

Water resources in the Tagus Basin are dominated by irregularities of the hydrologic regime that originate frequent and severe drought episodes. There is a long tradition of water use in the Basin, with 12 main water supply systems equipped with well-developed infrastructure for regulation, transportation and distribution of water resources (Table 2). In some of these systems, water demand is a large fraction of average resources. Due to the imbalance between water availability and demand in drought years, there is an extensive experience in hydrological management, but recent drought events have questioned the capacity of some systems to meet increasing demands with the available water resources.

Table 2. Characteristics of the main water supply systems in the Tagus Basin

System	Mean flow (Mm^3/yr)	Coeff. of Variation	Min. flow (Mm^3/yr)	Storage (Mm^3)	Demand (Mm^3/yr)
Cabecera	1200	0.48	350	2400	980
Tajuña	51	0.59	12	68	30
Henares	150	0.56	15	240	110
Sorbe	170	0.46	20	53	50
Madrid	750	0.42	200	900	500
Alberche	650	0.51	110	250	180
Toledo	62	0.73	1	32	12
Tiétar	900	0.52	155	115	170
Alagón	1300	0.48	312	911	510
Árrago	267	0.51	45	125	110
Salor	32	0.66	0.57	14	11
Trujillo	6.4	0.59	0	1.5	1.5

Streamflow regulation in the Basin

The diverse characteristics of regulation systems in the Tagus basin are illustrated in Fig. 1. The figure presents the simulated time evolution of water storage in three systems under current conditions of demand and infrastructure for the period 1940-1993: Alberche, Madrid and Cabecera. The Alberche system consists of two main reservoirs with maximum storage capacity of 250 Mm^3. The system supplies a local demand of 180 Mm^3/yr with average inflows of 650 Mm^3/yr, with a coefficient of variation of 0.51 and a minimum of 110 Mm^3/yr. It also supplies a maximum of 120 Mm^3/yr to Madrid in drought periods.

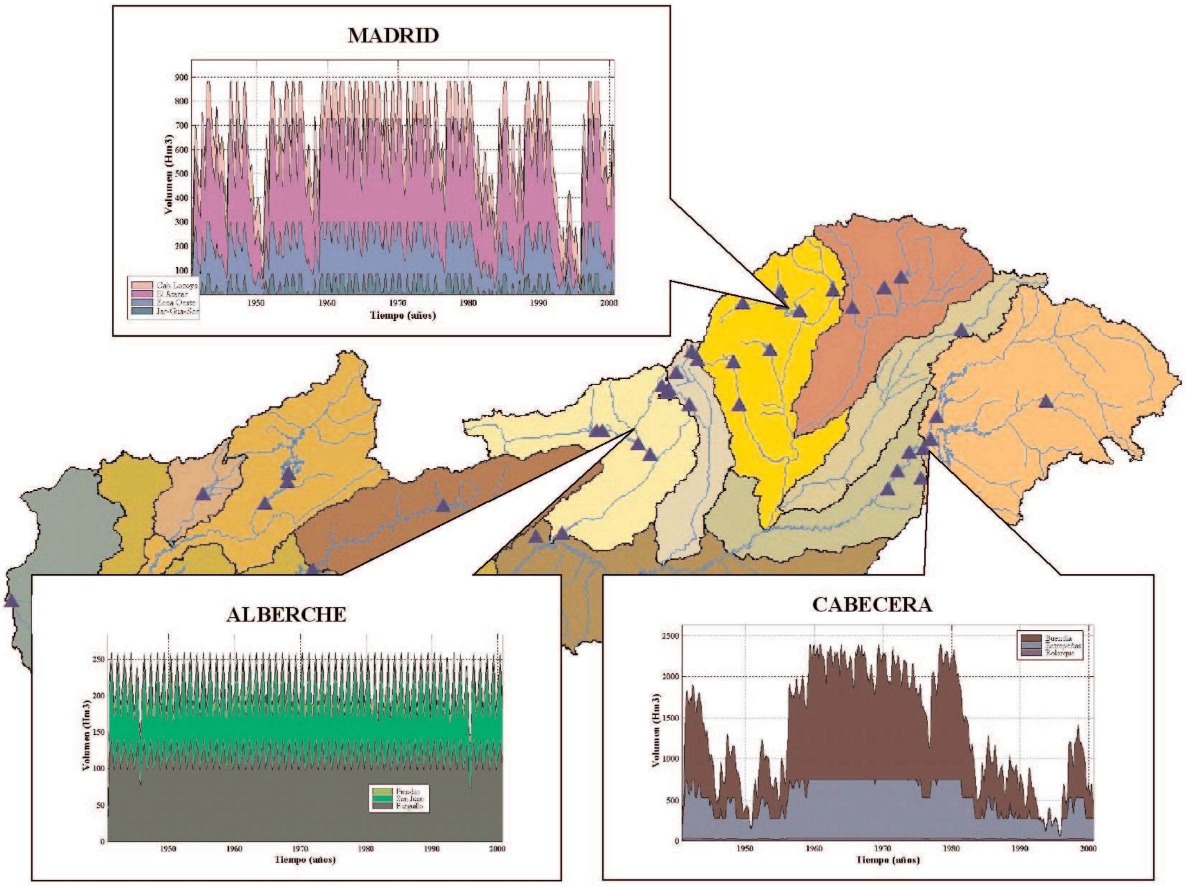

Fig. 1. Different regulation systems in the Tagus Basin.

Regulation in the Alberche system is based on an annual cycle. Storage is depleted significantly only in very dry years, and it usually returns to normal levels in the following year. The Madrid water supply system consists of 17 reservoirs in the Jarama and Guadarrama basins with total storage capacity of 900 Mm^3. The average inflow to the reservoirs is 750 Mm^3/yr, the coefficient of variation is 0.42 and the minimum of the historic series is 200 Mm^3/yr. Regulated surface waters supply an urban demand in Madrid of 500 Mm^3/yr, although the system has other alternative sources, such as groundwater or transfer from the Alberche basin. The regulation cycle in Madrid is normally annual, but persistent droughts can affect reservoir levels during two or three consecutive years. The Cabecera regulation system consists of two reservoirs with total storage capacity of 2,400 Mm^3. Mean annual flow is 1,200 Mm^3/yr, with a coefficient of variation of 0.48 and a historic minimum of 350 Mm^3/yr. In this system, the regulation cycle is hiperannual, with long dry and wet periods. Over-the-year storage is crucial to supply demands in dry periods, which may last one decade or more.

Meteorological and hydrological drought

No single indicator or index can identify drought. Many efforts have been made to characterize drought by using a range of indices (Rossi *et al.*, 2003; Wilhite, 2000, Vogt and Somma, 2000). Classical drought indices, such as the Standardized Precipitation Index (SPI), (Hayes *et al.*, 1999) or the Palmer Drought Index (Palmer, 1965), 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 (Flores-Montoya *et al.*, 2003). Many of the more complex indices that take storage and management into account are not easily interpreted across regions and cannot be validated with the data available over wide geographical areas. Therefore, managers of water resources tend to rely on precipitation and streamflow variables to determine the onset of drought.

Figure 2 shows the time series of aggregated precipitation in 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 alert 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). The Figure also shows the extremely large variability characteristic of Spanish precipitation and the recurrent multi-year drought episodes. The Figure 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.

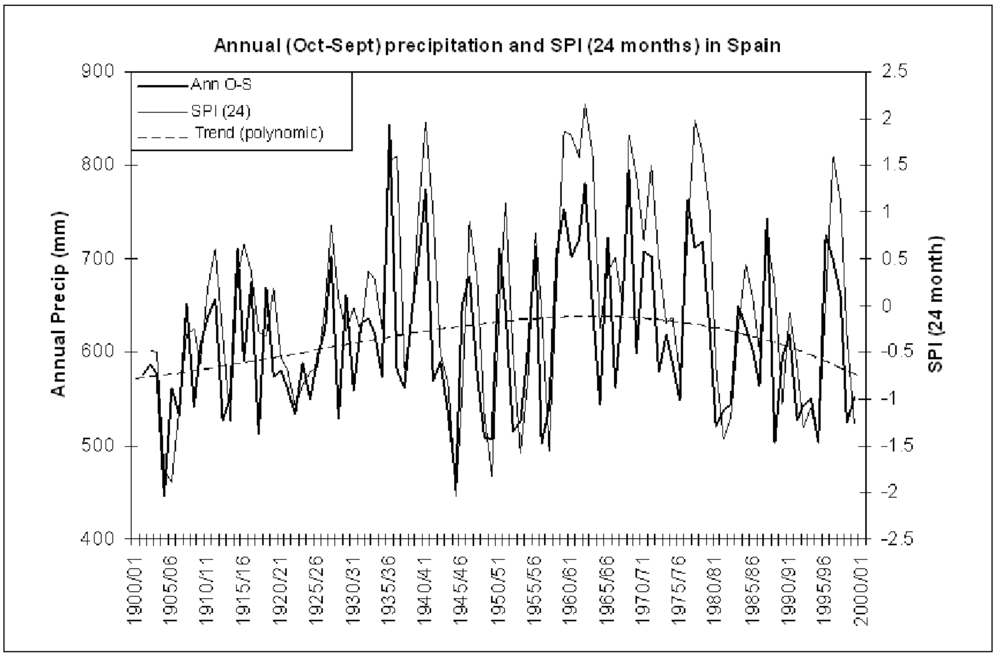

Fig. 2. Time series of aggregated annual precipitation and SPI values (24 month time scale) in Spain. (Data source: The Tyndall Center database TYN CY 1.1).

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. During these droughts, besides the collapse of irrigation water supply, urban water supply series were affected significantly.

Drought characterization in highly regulated systems is complex and calls for multiple indicators. The slope of accumulated deviation of precipitation from the mean (Fig. 3) is an indicator that highlights drought patterns relevant to hydrological management. The Figure highlights the recurrent multi-year characteristic of drought periods in Spain and the value of continuous monitoring for preparedness. Also, this indicator is related to other variables that are more difficult to monitor, such as groundwater levels.

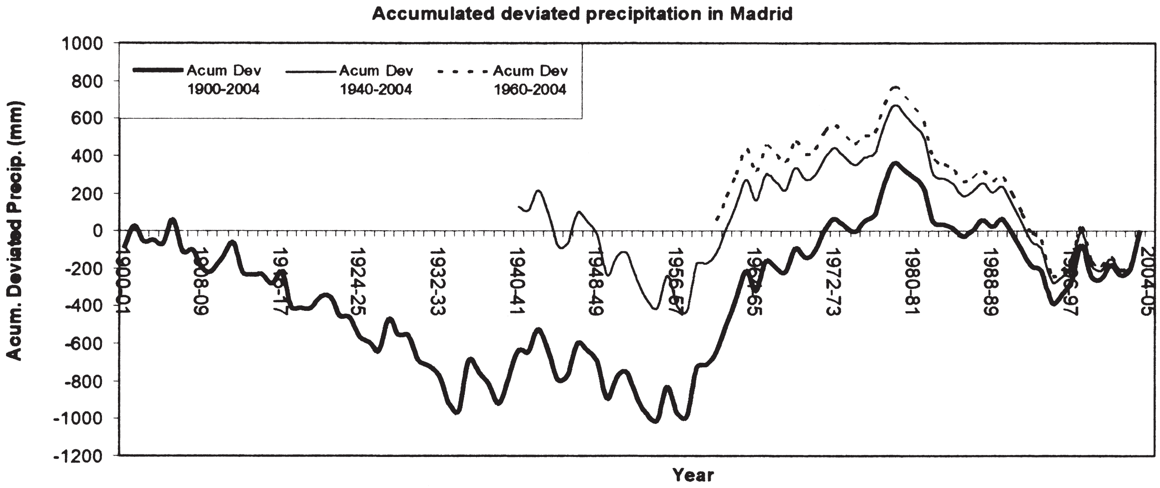

Fig. 3. Accumulated desviated precipitation in Madrid. (Data source: Tagus River Basin Authority).

Components of hydrological drought monitoring systems

The basis of any drought management plan is a robust system of indicators that can identify and diagnose anomalies in water availability and can provide the basis for early detection of drought episodes. A comprehensive study of hydro-meteorological time series and drought indices in the Basin (Flores-Montoya *et al.*, 2003) led to the definition of a drought indicators system. The system is in continuous revision, taking into consideration the availability of new information and the progress in knowledge of the hydrologic behaviour of the Basin.

Variables used as early warning levels to predict droughts are grouped in two categories: informative and executive. Informative variables provide information on the development of the drought, and are used as a monitorization tool. Executive variables are objective indicators that are used to trigger specific actions in an operational context.

Drought is a complex phenomenon that evolves slowly in time and may affect different regions with varying levels of intensity. No single indicator can encompass the complexity of drought development (Hisdal and Tallaksen, 2000). Effectiveness is greatly enhanced if multiple indicators are used to describe drought extension and severity. Values used in the Tagus Basin are: significant departure from normal values in cumulative precipitation or streamflow during the hydrologic year in representative rain and stream gauges, reservoir levels, classical drought indices, like the Standardized Precipitation Index or the Surface Water Supply Index (Garen, 1993), abnormal thickness of snow pack during winter months and depletion of piezometric levels in aquifers.

The combination of the above indices and indicators can provide decision makers with enough information to understand the drought phenomenon and estimate its effect. Although these informative indicators are very useful to understand and characterize droughts, management of a multidimensional array of indicators can limit the effectiveness of decision making. In the drought management plan, the monitoring system should be linked to specific actions through a limited set of indicators that can be used as triggers of drought mitigation measures. For this reason, a subset of indicators has been selected as executive variables, which are used as thresholds to trigger specific actions.

Water managers are ultimately concerned by drought if it affects water supply. A robust indicator of hydrological drought is reservoir storage. Figure 4 shows the time series of inflow in Bolarque, a reservoir near Madrid with a contributing area of 7,420 km^2. The behaviour of this series appears to be non-stationary, or, at least, highly variable with a period between wet and dry spells clearly beyond the possibilities of regulation for water supply (Flores-Montoya *et al.*, 2003). Data show a possible intensification of drought conditions in recent years, during the decades of 1980's and 1990's. If a linear trend is fitted to the data, the slope is clearly negative, with a decrease of more than 8 Mm3/yr every year.

However, since droughts were also important during the 1940's and 1950's, the question arises as to whether recent droughts are a consequence of man-induced climate change or there is a multi-annual cycle of wet and dry conditions with a period of about 40 years over the time period analyzed. Classical drought indices, such as the SPI, have limitations for analyzing regulated systems. Although the correlation between streamflow and SPI over the time series is 0.54, the SPI threshold of -1 does not capture severe water shortages such as the one of the mid 1990s that led to emergency actions (see below: Supporting legislation).

The variability of streamflow at Bolarque reservoir in the high course of the Tagus Basin was not completely understood when a water-transfer facility was planned. The Tajo-Segura aqueduct diverts water from the Tagus river at Bolarque and transports it to South-East Spain. The aqueduct was designed during the wet period using data that, at that time, seemed to be reliable, but the subsequent evolution of streamflow showed a significant reduction of mean flows and forced a change in the planned exploitation of the infrastructure. The Bolarque example also represents the complexity of the indicators that need to be included in a drought characterization system. In the case of water for irrigation, indicators for drought risk extend to water allocation options (Gomez-Ramos and Garrido, 2005).

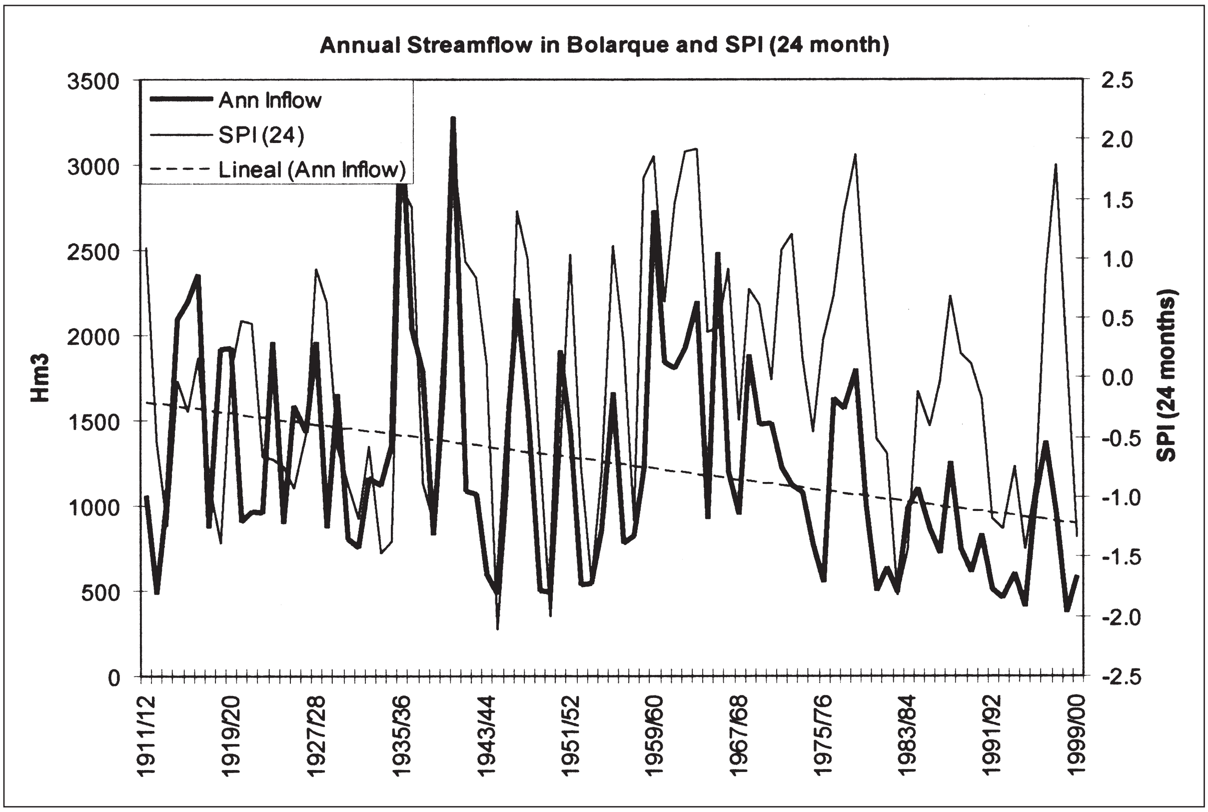

Fig. 4. Time series of inflow in Bolarque and SPI calculated for a 24 month time sale in Madrid (data source: Tagus River Basin Authority).

In some cases, the indicators do not reflect the real impact of drought. Figure 5 shows results from the simulation model used in the Tagus Hydrological Plan for the Henares Basin (sub-basin of the Tagus Basin, east of Madrid), compared to SPI index in the Basin. Shortages of water supplied to the demands of the Henares Basin are poorly correlated with SPI due to the effect of reservoir storage. The fact that the system has enough regulation capacity to supply the demand with high reliability and relatively scarce failures is probably one of the reasons for this low correlation. When the demand exceeds the available water resources, as in Southern Spain, drought episodes may result in failures in demand supplied (del Moral and Giansante, 2000).

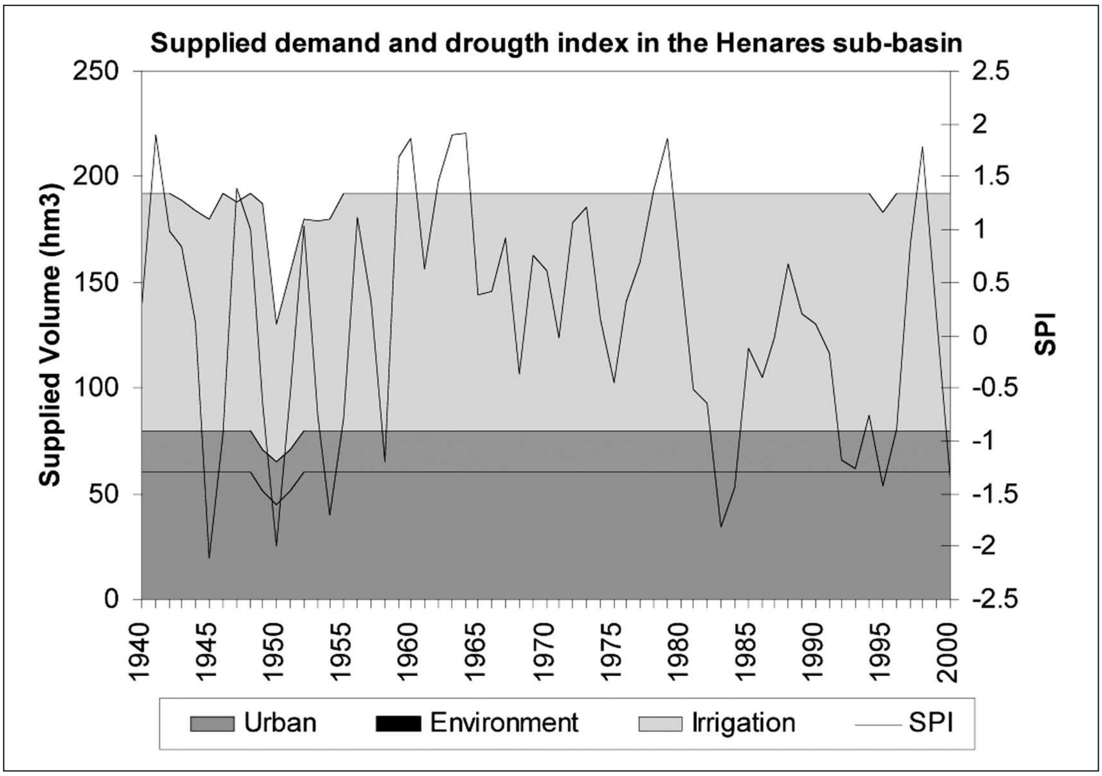

Fig. 5. Demand supplied in the Henares Sub-basin (Tagus Basin) and historical droughts calculated with the SPI.

The value that best describes water scarcity in regulated systems is the reduction of water stored in strategic reservoirs below critical levels. Whenever the development of a meteorological drought is being discussed, water managers check for stored water in the reservoirs in order to decide whether there is a significant risk of water deficit. Reservoir storage complies with most of the requirements proposed by (Steinmann *et al*., 2005) for drought indicators and triggers and are ideal for decision making, because they can be interpreted in terms of risk of failure of the systems.

Therefore, from the operational perspective, the executive set of variables that have been selected to link with actions in the drought plans are the sum of volumes stored in the reservoirs in every system. These values are readily available through the hydrographic service, and are of public domain, so users can have easy access to them.

Hydrological risk analysis

The proposed methodology for hydrological risk analysis is based on two main requirements: objectivity and simplicity. Objectivity is unavoidable, since drought management actions affecting users rights will be based on the results of the analysis. The requirement for simplicity is justified by the necessity to submit the results of the analysis to discussion and approval by all stakeholders in the Basin Water Council. Complex models based on sophisticated analyses are difficult to understand and may not be trusted by affected users. It is expected that once the drought plan is approved and put into operation, the simplicity requirement may be relaxed progressively, as users become more familiar with the methodology.

Probabilistic analysis

The objective of the analysis is to define the thresholds for the declaration of the pre-alert, alert and emergency scenarios. Since future reservoir inflows are uncertain, these thresholds should be formulated in probabilistic terms. Thresholds are defined as the available storage in the system, S, that is required to satisfy a fraction, f, of the demand in a time horizon, h, with a given probability, p. Values of f, h and p are model parameters that should be fixed though discussion with stakeholders. They depend on several factors: The type of the demand in the system (urban, irrigation, hydropower, etc.), the reliability of the current water supply system, the alternative management strategies that can be applied during droughts, the vulnerability of the demand to deficits of a certain magnitude, etc.

The basic tool is the development of a simplified model of the water resources system. The model considers only a single reservoir, with storage capacity equal to the sum of all reservoirs in the system. Inputs to the system are the regulated flows, which are flows in the contributing basin to the reservoirs, and non-regulated flows, which enter the system downstream of the reservoirs. The model simulates the operation of the reservoir considering losses to evaporation and restrictions imposed by environmental constraints.

The model was initially used to estimate the volume that is required every month to satisfy 100% of the demand during different time horizons. The results for the three representative systems in the basin (Alberche, Madrid and Cabecera) are shown in Fig. 6. These results show the different nature of regulation in the three systems, although the hydrologic regime of natural resources is similar in all of them. Droughts in the Alberche have impacts during more than one year only occasionally. In the Madrid water supply system the effects are seen during three and even four years. In the Cabecera system the effects of droughts have longer persistence, spanning several years. Variations in demand and reservoir volume compared to natural resources explain these differences.

By analyzing the results produced by the model, graphs like those presented in Fig. 7 can be obtained. The graphs on the left show the cumulative probability distribution for every month of required storage volumes to supply 100% of the demand during a time horizon of 1 year with a given amount of storage. In a probabilistic sense, these may allow to estimate the probability of satisfying 100% of the demand during 1 year given the volume stored in the reservoir in a certain month. The graphs shown on the right represent the required storage volumes corresponding to different quantiles (0.5, 0.75, 0.9, 0.95 and 1).

The graphs shown in Fig. 7 and similar graphs generated by changing model parameters (the time horizon or the fraction of the demand that is satisfied) may be used as a basis to declare pre-alert, alert and emergency scenarios.

The definition of parameter values to declare drought scenarios in every system is currently under discussion. There are two main factors to be considered in this discussion: The vulnerability of demands and the effects of drought declaration.

The characteristics of demands in every system are the first factor to assign values to model parameters. Demands having only one single source of supply are more vulnerable and require stricter parameter values than those having alternative sources. In this group, demands having such sources available exclusively to themselves are less vulnerable than those sharing them with other demands. The Alberche system provides water supply for urban, irrigation, hydropower, and recreational uses, and is the major source of emergency water supply to Madrid. Although local demands in the Alberche system have good reliability, the drought situation in Madrid can affect all uses in the Alberche system significantly.

The expected effects of drought declaration should also be balanced versus drought risk. In systems where demands are close to average natural resources, like, for instance, the urban water supply to Madrid, there is little margin for action, and drought declaration may have very important social and economic impacts. Most emergency measures for Madrid imply having to alter existing

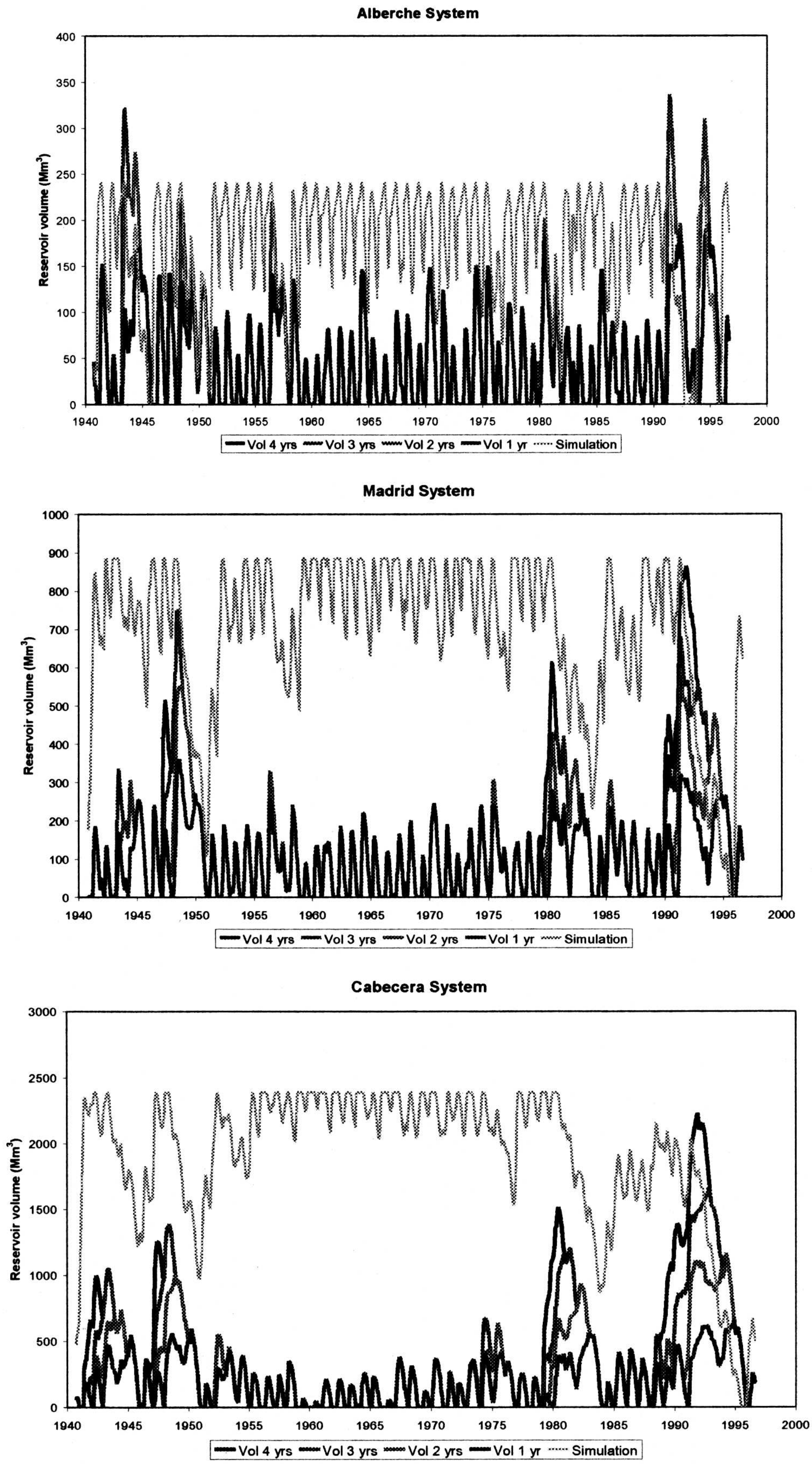

Fig. 6. Required storage volumes to supply 100% of the demand compared to simulated storage for the three representative systems of the Tagus Basin.

water rights, face the development of new transport or storage facilities under great social pressure or impose stronger rules and penalties and more strict control. If the drought situations are declared very frequently, the global effects may be even worse than the no-action approach.

One of the issues raised by technical staff in charge of water resources management in the Basin Authority was the situation of regulated systems for irrigation use at the end of the hydrological year. Normal operation of irrigation systems usually depletes reservoir storage at the end the irrigation campaign. This is a normal feature of annual regulation systems. However, according to the graphs shown in Fig. 7, there is a significant probability of not being able to satisfy demands during the next year if reservoirs are almost empty in October. But declaring drought in November is not perceived as a good management policy. If the following autumn and winter are normal, the reservoirs will fill again, and there will not be a scarcity situation. If autumn and winter are dry, farmers cannot do anything to react to drought until spring. So for these systems based on annual regulation for irrigation use, declaration of drought might only make sense at the beginning of the irrigation campaign, when farmers are making decisions regarding their crops.

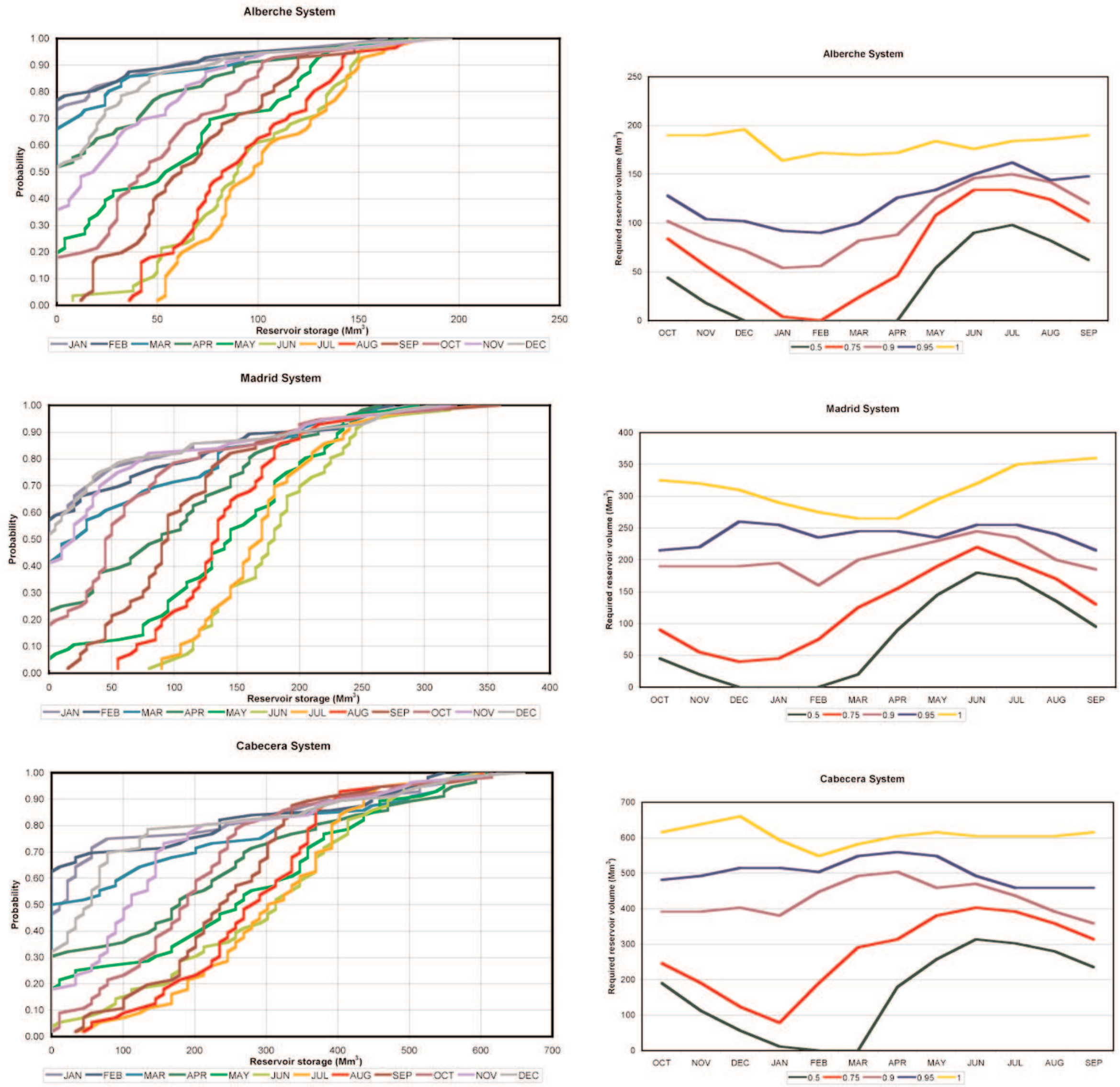

Fig. 7. Cumulative probability distribution of required reservoir storage to supply 100% of the demand for 1 year and monthly distribution for selected quantiles in the three representative systems of the Tabus Basin.

Deterministic analysis

The probabilistic analysis presented in the previous section is a good approach for decision making within the Basin Authority. However, from the perspective of user involvement in the process, the presentation of probabilistic results is always faced with reluctance. Unless they have a formal education in water resources engineering, users are not willing to accept restrictions based on a probability of failure, especially if that probability is not close to one. Implementation of measures usually takes time, and if the activation of the drought situation is delayed until there is almost a certainty of deficit, it is very difficult to avoid important impacts. For that reason, a simplified version of the procedure was developed for the purpose of dissemination and negotiation with users. Rather than using a probability distribution of required storage volumes, the decisions are based on a set of droughts, which are selected as representative of droughts of different severity occurred in the past in the system. The methodology is structured in three phases, which are described as follows.

The process begins by the characterization of the distribution of annual and monthly flows and the evaluation of the minimum values in historic record for different lengths of time, obtaining sample deciles and fitting the sample values to a theoretical probability distribution. In most systems the normal probability distribution provided an acceptable fit, while in others the gamma probability distribution was selected. The characteristic drought is defined by an annual volume and a monthly distribution. The annual volume is selected from the fitted distribution of annual flows, considering a probability of exceedance depending on the nature of the demand of the system. The monthly distribution of the annual volume was taken from the deciles of the sample monthly distributions, using a probability of exceedance equal to that of the annual volume.

The second step is the definition of the values of reservoir storage that are associated to every drought scenario. The simplified system model was used to estimate the storage volumes that are required to supply a given percent of total demand for a certain period of time during the characteristic drought. Different values of demand percentage, length of time period and probability of occurrence of the characteristic drought were used in every system. The figures finally adopted were the result of a feedback process with system managers during the validation phase.

The final step is the validation of the model. System behaviour was simulated with the simplified model for the period of historic record, implementing a set of measures in every drought scenario. The measures were simplified assuming a reduction of a fraction of the demand in every drought scenario. This reduction means either a real demand reduction by water conservation measures, or the activation of an additional supply source that supplies water to a fraction of total demand. Values were fitted by trial and error with the goal of avoiding complete depletion of reservoir storage and considering the possibilities of demand reduction and resource mobilization in the system.

This scheme was applied to all systems in the basin, adapting parameter values to the particular circumstances in every system. To illustrate the process, results obtained for the Alberche system are presented in Figs. 8 to 11. The cumulative distribution of annual flows in the system is shown in Fig. 8. The sample has been fitted to a normal probability distribution. The characteristic drought was chosen as the minimum value in historic record, 117.91 Mm^3/yr, which corresponds to a probability of exceedance in the normal fit of 95%. Threshold values for the pre-alert, alert and emergency drought scenarios are shown in Fig. 9, together with the maximum conservation volume in the reservoirs of the system, which is limited by hydropower and flood control. Threshold values were obtained as the reservoir storage that is required to supply the following fractions of the demand during the characteristic drought:

(i) Pre-alert scenario: 90% of the urban water supply demand and 80% of the irrigation demand during at least 1 year.

(ii) Alert scenario: 80% of the urban water supply demand and 60% of the irrigation demand during at least 1 year.

(iii) Emergency: 70% of the urban water supply demand and 40% of the irrigation demand during at least 1 year.

Model validation was performed by simulating the system with and without the implementation of drought management rules. The results of system simulation without rules are shown in Fig. 10. There are three severe drought episodes in the historic record in which the reservoirs of the system are

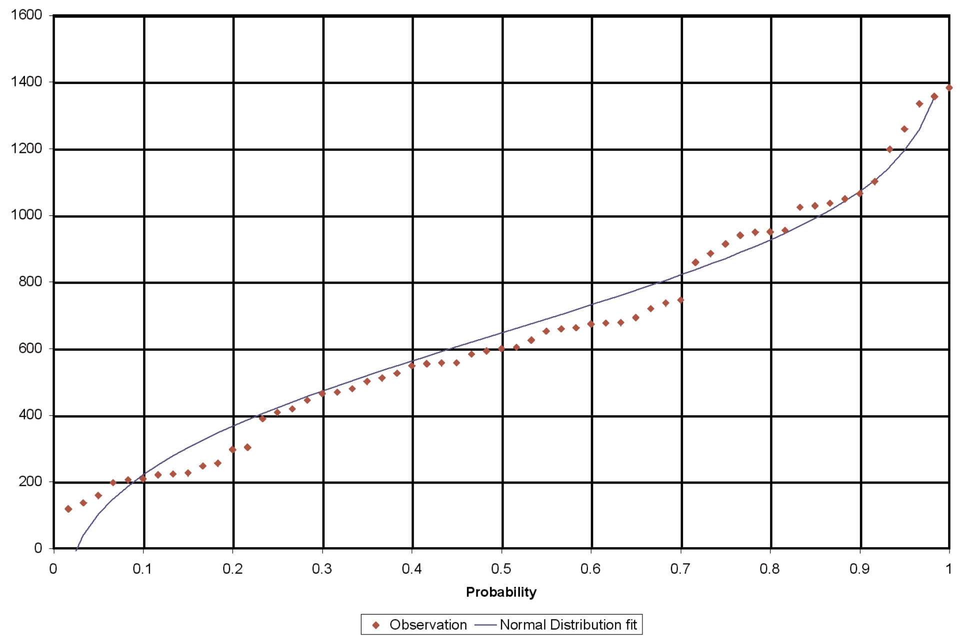

Fig. 8. Distribution of annual flow values in the Alberche system.

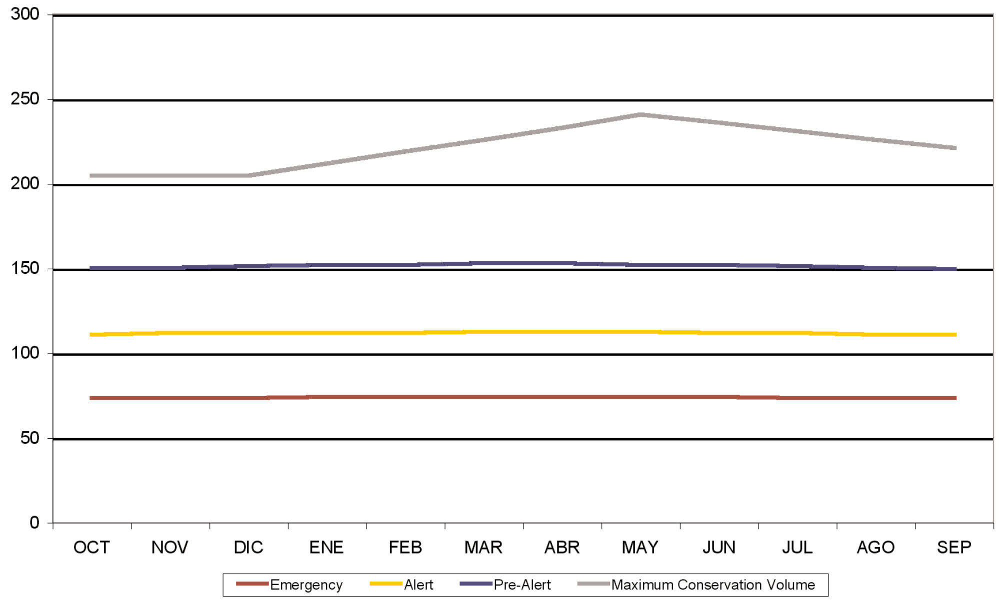

Fig. 9. Drought definition thresholds in the Alberche system.

completely empty, and there is a deficit of 100% of the demand during several months. This situation is catastrophic, and should be avoided by defining drought management rules that conserve water in the system. As a first approximation, these rules have been simulated as reductions of the demand supplied by the system in every drought scenario. These rules are defined as follows:

(i) Pre-alert scenario: no specific demand reductions. Only awareness measures are contemplated.

(ii) Alert scenario: reduction of 15% of the demand, which corresponds to a reduction of 35% in supply to irrigation and no reduction in supply to urban demand. Irrigation can be supplied using waters from the nearby Tagus River, although farmers do not want this option, due to the lower quality and the pumping costs.

(iii) Emergency scenario: reduction of 50% of the demand, which corresponds to no supply to irrigation and 15% reduction in supply to urban demand. Urban demand can use alternative water supplies, like in the case of the cities of Madrid, Talavera and Toledo, but this possibility depends on the situation of their own water supply systems.

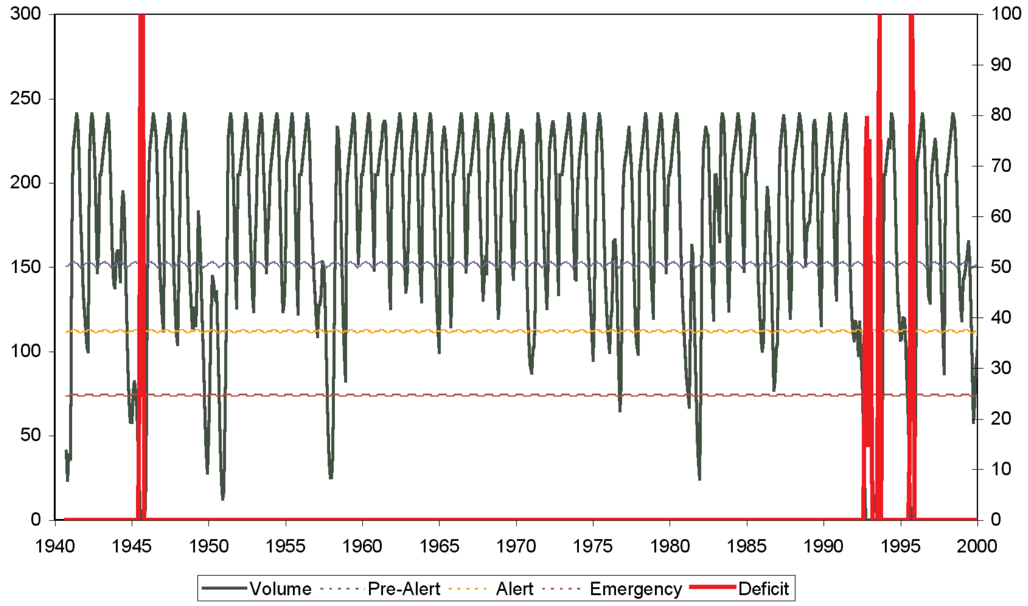

Fig. 10. Simulation of the Alberche system without implementing drought management rules.

Results of this simulation are shown in Fig. 11. The proposed rules can reduce maximum deficit in the system to 50% of total demand, but at the cost of more frequent restrictions. There is always this trade-off between water conservation measures and drought risk. Early response to drought risk implies producing restrictions that could have been avoided, but it can also avoid important deficits of catastrophic consequences.

The results of the simulation can be analyzed to assess the frequency of drought declarations. A comparison of drought thresholds and the cumulative distribution of simulated reservoir storage is shown in Fig. 12. The probability of reservoir storage being below the drought thresholds in the Alberche system is presented in Table 3. These values are relatively higher for the autumn and winter months. This is due to the fact that autumn and winter flows are much higher than spring and summer flows. Dry winters can fill the reservoir, while even the wettest of summers cannot contribute much to reservoir storage. This feature of the methodology is currently under discussion, and will probably be revised before the plan is implemented.

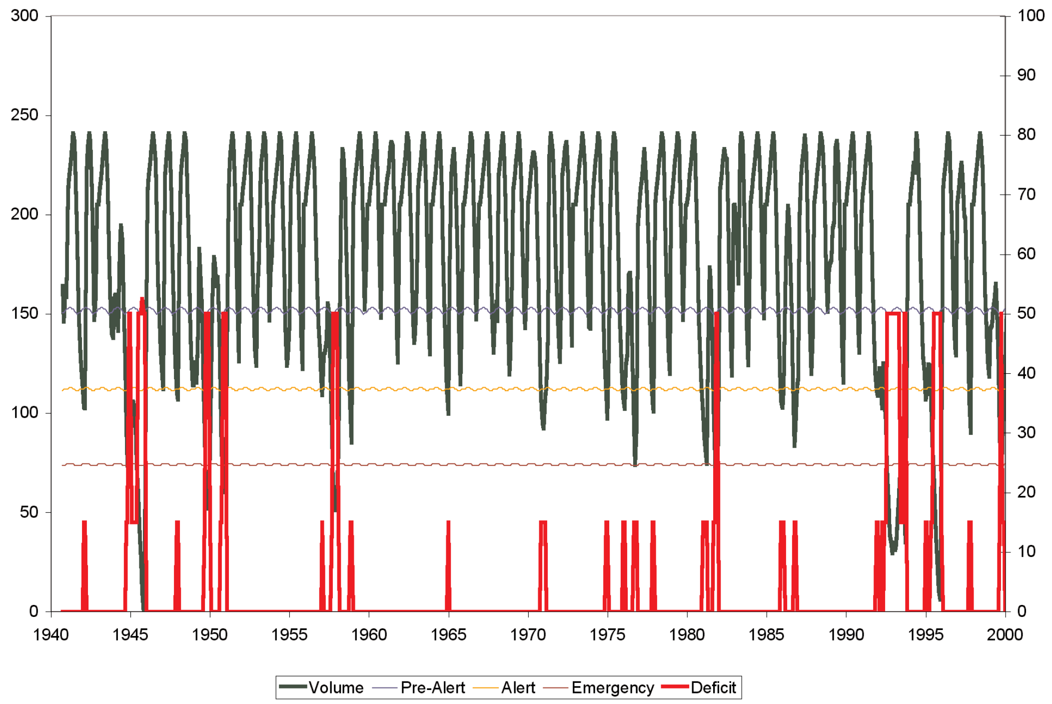

Fig. 11. Simulation of the Alberche system alter implementing drought management rules.

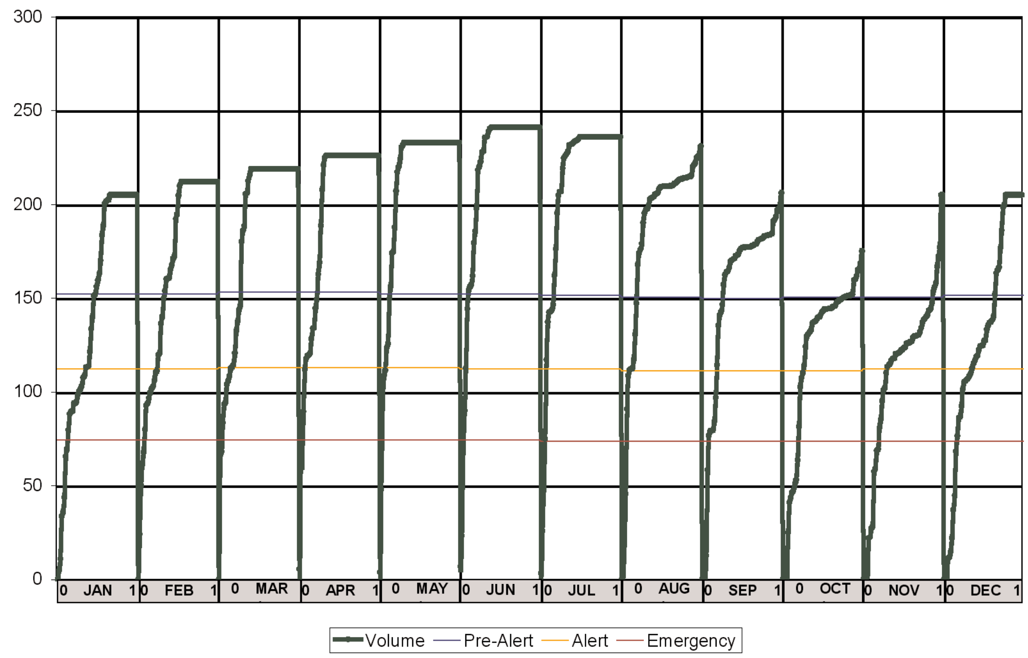

Fig. 12. Monthly cumulative probability distribution of reservoir storage in the Alberche Basin.

Table 3. Probability that the reservoir storage is below the drought thresholds in the Alberche system

Month	Pre-alert	Alert	Emergency
October	0.77	0.25	0.20
November	0.87	0.28	0.20
December	0.63	0.35	0.15
January	0.48	0.35	0.12
February	0.33	0.23	0.07
March	0.28	0.15	0.05
April	0.22	0.08	0.05
May	0.13	0.07	0.03
June	0.10	0.07	0.05
July	0.17	0.07	0.05
August	0.20	0.10	0.07
September	0.27	0.18	0.08

Operational component

Proactive measures

The institutional process and the context of the pro-active responses to hydrological and water scarcity drought is mapped in Fig. 13. Triggers and motivations include general trends of the economy, demographics, environment, or land planning policies. Pro-active responses may also be motivated by force of complying with National and European Union legislation. In this situation the River Basin Authorities operate at three levels: Governing Bodies, Management Bodies and Planning Bodies (Stage 1), who draft the Basin Hydrological Plan (Stage 2). The decision process follows the phases of proposal, consultation, revision and submission to the Ministry of the Environment (Stage 3). The Ministry of the Environment can approve or reject the proposed Basin Hydrological Plan. If the Plan is rejected, the decision process is reinitiated (Stages 4 and 5).

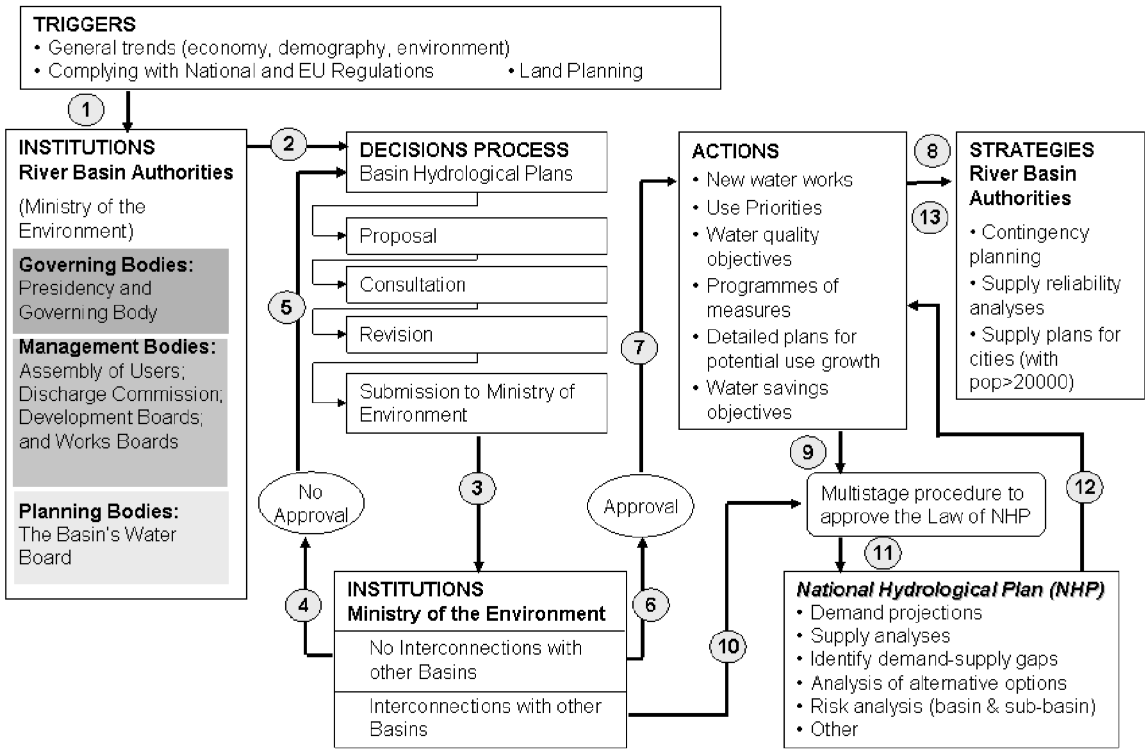

Fig. 13. Processes and institutional linkages in the pro-active responses to hydrological drought and water scarcity in Spain.

If the plan is approved, two alternative roadmaps follow, depending on whether or not the Plan envisions any inter-basin transfer, according to the following structure:

(i) If the Plan does not foresee connections with other basins, it is approved (Stage 6). In this case, a few of the included measures can be qualified as pro-active, such as new water works, defining use priorities, water quality objectives, programmes of measures to solve scarcity issues, setting water conservation targets, and detailed plans for potential use growth (Stage 7). From this action some strategies to mitigate drought are derived which are related to contingency plans, supply plans for cities or supply reliability analyses (Stage 8). Finally, these actions and strategies are included in a multistage (Stage 9) that will likely integrate some of the proposed actions, measures, works and policies included in the Basin Plan (Stage 11).

(ii) If the Plan envisions inter-basin transfers (from or towards other basins), strategies are designed and drafted within the multistage procedure to approve the Law of National Hydrological Plan (NHP) (Stage 10). These plans take into account some outcomes from the NHP like demand projections, supply analyses, identify demand-supply gaps, and analysis of alternative options and risk analysis (basin and sub-basin) (Stage 11). From this procedure final actions and strategies return to the Basin Plan for development and execution (Stages 12 and 13).

Reactive measures

Figure 14 summarises the institutional reactive responses to hydrological drought or water scarcity. As a result of permanent monitoring, some indicators of scarcity such as reservoir levels, low water tables in groundwater, or low runoffs may be warning signs to River Basin Authorities (Stage 1), whose response will depend on the relative severity of the perceived risks. Under non-emergency conditions, the Reservoir Release Commission will meet in ordinary session (Stage 2) and will define some actions relative to reservoir management, onset of Right Exchanging Centres, revision of ecological flows and ground water abstraction and definition of precautionary water allocation schemes (Stage 3). All these measures affect farmers, hydropower units, environment, urban users, and others.

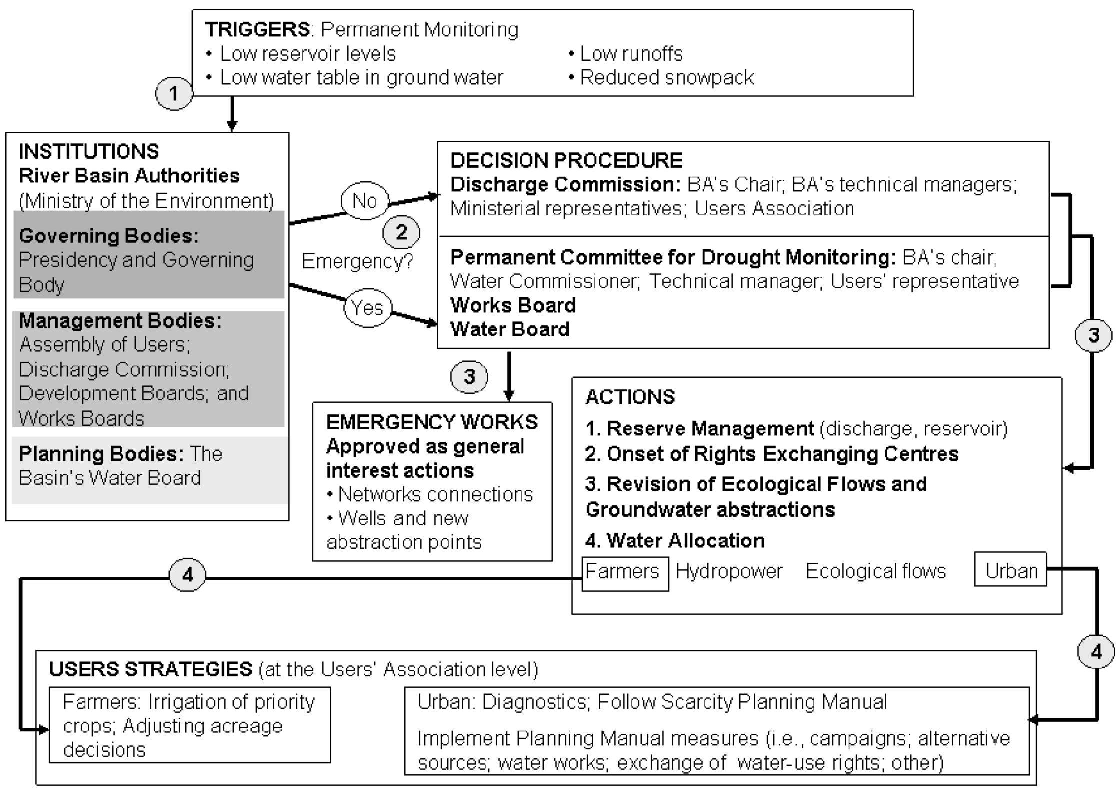

Fig. 14. Processes and institutional linkages in the pro-active responses to hydrological drought and water scarcity in Spain.

If the monitored indices worsen, entering a pre-emergency stage, a Permanent Committee is established within the Basin Authority for drought monitoring. This committee can adopt exceptional measures such as extraordinary releases or establishing special strategic reserves in the Basin's reservoirs. In this situation the Works Board and the Water Board, in addition, can file applications to have emergency works approved as "initiatives of general interest action" (networks connections, wells and new abstraction points) (also Stage 3).

Based on these River Basin Authority initiatives and in coordination with them, users strategies will be planned and carried out. These responses are usually drafted and decided by water users associations. For instance, irrigators can consider priority crops to be irrigated or perform exchanges of water use (Stage 4). Urban users in turn will follow their Water Scarcity Planning manuals or protocols, implementing measures like saving campaigns, alternative uses, water works, exchanges of water use, demand management provisions and so on. In general, these reactive responses will be applied only during drought periods. Examples of these are the revision of ecological flows and a better coordination of releases for hydropower generation with the timely demands for consumptive uses, such as irrigation.

Meteorological and agricultural drought

Pro-active responses

The degree of development of the Spanish agricultural insurance, as it covers most climate risks, stands out as the main pro-active response to droughts. Being a major drought policy in Spain, and one that complements other types of policies, it deserves specific attention. Therefore, we first concentrate on the institutional landscape of the agricultural insurance policies, since this is a guide for describing the institutional framework of the other reactive responses. The institutional mapping of meteorological and agricultural droughts is completed with the description of the reactive responses to drought risks.

Figure 15 describes the institutional process of the agricultural insurance system to illustrate a key pro-active response to drought in Spain. The Figure illustrates the framework for developing new agricultural insurance premia as a result of emerging risks. This process includes seven key stages (1 to 7 in Fig. 15).

The trigger (Stage 1) is the realization that a new potential insurable risk(s) is sufficiently concrete and specific, so that demand to develop new premia to cover it is expressed by formal and informal means. In some cases, the result is coverage expansion of premia already in the market based on past and accumulated experience for increased risk. In others cases, farmers associations demand that certain risks should be covered. Occasionally, local and regional political pressures take on sufficient strength so that the Ministry of Agriculture elects to initialize new studies, and provide the required research and development (R&D) funds.

Under Stage 2 budget is allocated and approved for concrete research and development activities to analyze the new product. A research team is formed, which tentatively includes officials from ENESA (The Spanish State Insurance Agency), representatives of farmer associations, insurance companies, and external research institutes. If the research and development results recommend to generate marketable premia, all its details are defined in Stage 3, including rates, geographical scope, and other technical characteristics. Under Stage 4, the Finance Ministry, and the Reinsurance public agency will review the proposed new premia, and approve or reject them. In this process, the pool of insurance companies is consulted. Their approval is necessary to continue the process.

Stage 5 gives rise to final marketable policies that are added to the menu of insurance premia and are commercially offered to eligible farmers. In addition, the level of rate subsidization requires the approval of the Ministry of Agriculture, which also makes budgetary allocations (Stage 6). The process ends in a standard feed-back relation, described by Stage 7. New and old premia are permanently evaluated, giving rise to amendments, removals, or impulse to broaden existent insurance lines.

In conclusion, the institutional framework encompasses all sectors –from farmers to insurance companies– and various Administrative branches. In the past 25 years (i.e., from the declaration of the Agricultural Insurance Law mentioned above) this process has given rise to a wide and broad set of insurance policies, being the ones covering drought risks the most important from the point of view of farmers' responses and agricultural areas covered.

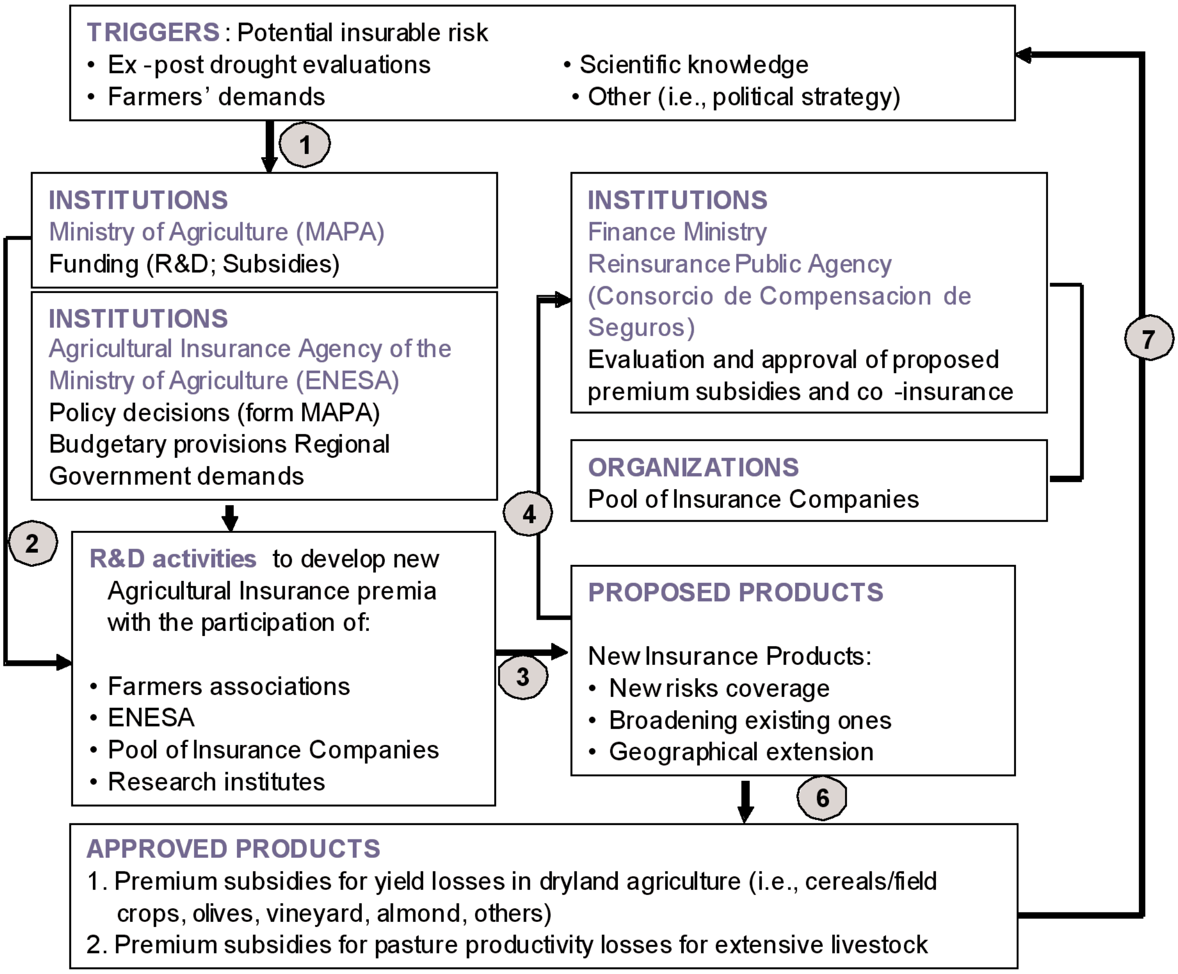

Fig. 15. Processes and institutional linkages in the pro-active responses to drought in the agricultural sector in Spain.

Reactive responses

Figure 16 illustrates the reactive responses to meteorological and agricultural drought, outlining the organizations and institutions involved in the processes, their hierarchical linkages, and the sequential time stages of the process. This process complements the pro-active responses described above. In general, the triggers of the reactive responses are dispersed and diffused: social tensions, social unrest, or warning signals that originate from regional and local Governments (Stage 1). These triggers originate primarily from the agricultural sector, particularly from dry-land farmers and extensive livestock farms.

In Stage 2, the Ministry of Agriculture calls for a meeting of the Permanent Office for Drought (entirely composed by officials serving in the Ministry). In Stage 3 the Permanent Office analyses the situation focusing almost exclusively on the risks for which no insurance was available. Among the most vulnerable sub-sectors subject to non-insurable risks are a few marginal crops, such as saffron or nuts orchards, and animals raised under extensive husbandry threatened by drinking water scarcity.

Under Stage 4, the Permanent Office will table specific proposals to alleviate the drought effects on the identified vulnerable sectors. These proposals are translated into the final programme measures to be developed and approved (Stage 6). The programme includes taxation abatements or deferrals and requires the approval of the Ministry of Finance (Stage 5), agricultural policy, agricultural insurance, and water policy. The EU Commission may also take measures to help farmers hit hard by droughts, bringing forward direct CAP payments or permitting cattle to graze on set-aside land. The most common response in water policy is a reactive response related to the authorization for drilling wells for animal drinking and it has to be approved and financed by the River Basin Authorities with urgent character (Stage 7).

The most salient characteristics of this mapping are: (a) that it focuses explicitly in the agricultural sector; (b) that the executive committee is formed only by officials of the Ministry of Agriculture; and (c) that its scope and concerns are limited to the vulnerable sectors or sub-sectors whose risks are not insured.

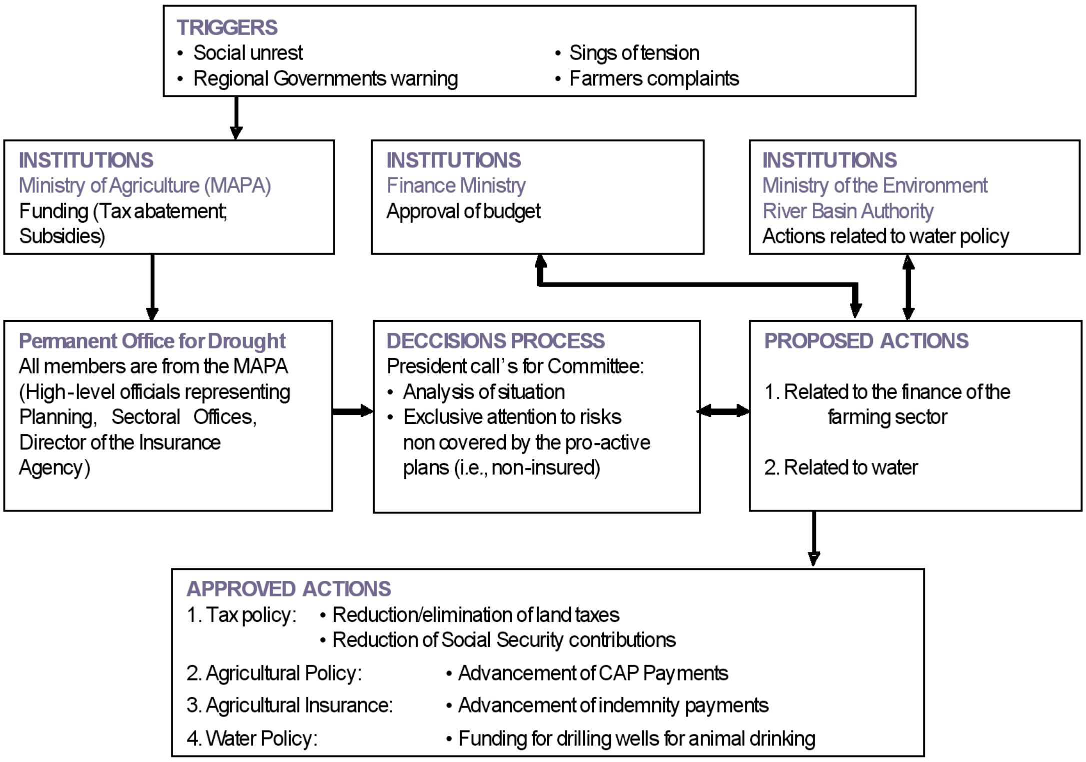

Fig. 16. Processes and institutional linkages in the reactive responses to drought in the agricultural sector in Spain.

Conceptual model for drought management

Specific drought management plans have been developed at different administrative levels. Figure 17 shows a conceptual model elaborated from the range of operational management actions observed and supported by the institutional and legal framework existing in Spain.

Possible operational actions

The Basin drought policy can be summarized as a list of possible actions to be taken in case of drought. The catalogue of possible actions is restricted by the legal competences that are attributed to the organism, but the resulting list includes a great number of actions of very diverse nature, like the examples presented in the following categories.

Internal operation: Within the Basin Authority, most frequent measures include intensification of monitoring, inspection of facilities to prevent leaks or revision of rules for the operation of infrastructure.

Water uses: Regarding water uses, demand management measures include: information dissemination and user involvement, promotion or enforcement of water savings, prohibition of certain uses, temporary exemption of environmental obligations, etc.

Water resources: Regarding the water resources, drought measures focus on conservation and protection of stored resources, activation of additional resources or monitorization of indicators of water quality.

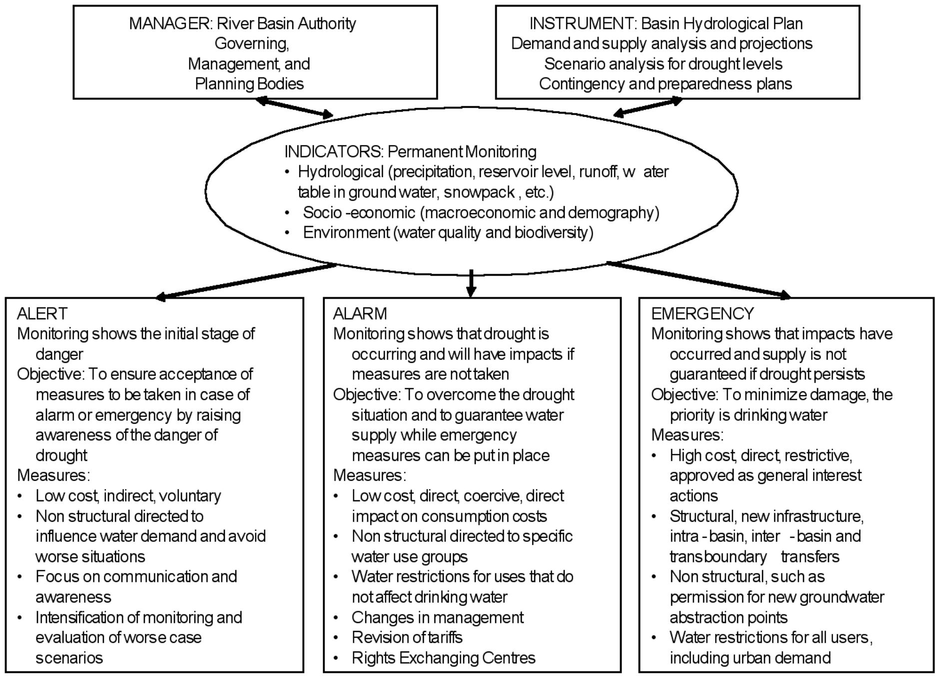

Fig. 17. Drought management at the basin level: Indicators and measures for different levels of drought intensity.

Institutional: From the institutional perspective, the President of the Basin Authority may appoint committees or task forces to address specific issues, usually in conjunction with affected users, or enhance cooperation with other organizations or stakeholders.

Legal: In the legal framework, there are a number of legislative measures that can be adopted, ranging from the official declaration of emergency due to drought, to a long list of possible palliative measures with different objectives: subsidy, restrictions, emergency works, etc.

These options are very diverse in nature, have different effectiveness and imply multiple economic and social impacts (Wilhite, 1997). In every practical case, only a number of measures are feasible and potentially effective at a reasonable cost.

Drought severity levels

The operational effectiveness of the drought management plan is greatly enhanced if the selected measures for every system are grouped in packets, which are applied if certain conditions are met. In the Tagus Basin Plan (BOE, 1999), drought management strategies are grouped in three scenarios, corresponding to increasing levels of severity: Pre-alert, alert, and emergency scenarios.

Pre-alert scenario

The pre-alert scenario is declared when monitoring shows the initial stage of drought development, which corresponds to moderate risk (i.e. greater than 10%) of consuming all water stored in the system and not being able to meet water demands. The management objective in the pre-alert scenario is to prepare for the possibility of a drought. This means to ensure public acceptance of measures to be taken if drought intensity increases by raising awareness of the possibility of societal impacts due to drought. The kinds of measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily by stakeholders and are usually of low cost. The goal is to prepare the organism and the stakeholders for future actions. Regarding the Basin Authority, main actions are intensification of monitoring, usually through the creation or activation of drought committees, and evaluation of future scenarios, with special attention to worst case scenarios. Regarding the stakeholders, the focus is communication and awareness. Generally, non structural measures are taken, aimed to reduce water demand with the purpose of avoiding alert or emergency situations.

Alert scenario

The alert scenario is declared when monitoring shows that drought is occurring and will probably have impacts in the future if measures are not taken immediately. There is a significant probability (i.e. greater than 30%) having water deficits in the time horizon. The management objective in the alert situation is to overcome the drought avoiding the emergency situation by enacting water conservation policies and mobilizing additional water supplies. These measures should guarantee water supply at least during the time span necessary to activate and implement emergency measures. The kind of measures that are taken in the alert situation are generally of direct nature, are coercive to stakeholders and are generally of low to medium implementation cost, although they may have significant impacts on stakeholders' economies. Most measures are non structural, and are directed to specific water use groups. Demand management measures include partial restrictions for water uses that do not affect drinking water, or water exchange between uses. This may be a potential source of conflict because user rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses.

Emergency scenario

The emergency scenario is declared when drought indicators show that impacts have occurred and supply is not guaranteed if drought persists. The management objective is to mitigate impacts and minimize damage. The priority is satisfying the minimum requirements for drinking water and crops. Measures adopted in emergency are of high economic and social cost, and they should be direct and restrictive. Usually there has to be some special legal coverage for exceptional measures, which are approved as general interest actions under drought emergency conditions. The nature of the exceptional measures could be non structural, such as water restrictions for all users (including urban demand), subsidies and low-interest loans, or structural, like new infrastructure, permission for new groundwater abstraction points and water transfers.

Examples of response actions in historical droughts

Pro-active plans: Insurance policies for winter crops

Upon the approval of the Law of Agricultural Insurance in Spain in 1978, the initial policies offered to farmers for winter crops covered only fire and hailstorm risks. Since then, these crop producers have been given an increasingly broad choice to cover all natural risks in a broad range of crops, including droughts. For the fiscal year 2003-04, growers of rainfed winter crops can select one of the insurance premia listed in Table 4.

Table 4. Summary of the insurance premia for winter crops (2003-2004) in Spain

Premia	Hailstorm	Fire	Freeze	Drought	Wind	Rain	Floods	Pests & diseases	Climatic Adversities
Integral	x	x	x	x	x	x	x	x	
Combined	x	x				x	x		
Yield	x	x	x	x	x	x	x		x

During the period 1993-2001, insurance uptake has ranged from a low of 59% of all eligible land to a maximum of 78%. Presently, about 75% of the eligible land is covered by an insurance policy. In 2001, 42% of the total insured production was covered by integral, 18% under the combined premia and 12% with yield premia. Purchasing insurance represents a small cost percentage for the growers. The most expensive premia represent about 4% of all direct production costs, whereas the least expensive policies represent about 0.5% of direct crop production costs.

Total premia subsidies of insurance lines applicable to winter crops amount to €18 million in year 2001 year, which represents about 1.4% of the value of the insured crops. Subsidies range from 35 to 42 percent of the market rates for integral insurance and yield insurance respectively. These extremely large values data demonstrate that the Government policy aims to induce farmers to purchase insurance with the largest risk coverage.

Yield insurance is the latest addition to the choices, and it was offered for the first time in 2000. Individual risk premia for yield was developed by using historical records of individual farmers' yields. During drought years, the individual yields are adjusted according to the records of yield loss caused by drought (other hazards are also included in the database). Individual risk premia and loss adjusting is possible because ENESA (The Spanish State Insurance Agency) has kept and updated a database of 160,057 individual farmers, with 12 years of yield data.

The 20-year experience of insuring rainfed extensive crops has made a significant progress in facing drought risks in about 45% of all Spanish agricultural land. In addition, the cumulative results of years of Research and Development, ex-post evaluation and data collection and analysis, ensures that each farmer idiosyncratic risks can be evaluated, so that premia can be tailored to each farmer at actuarially fair prices.

An indirect by-product of the insurance process is the research opportunities that ENESA's databases and experience offer to carry out risks analyses. Unfortunately, very little academic work has been conducted in this area. The evaluations carried out so far indicate that:

(i) Farmers tend to develop habits regarding their insurance strategies. The ones at greater risk tend to insure more often than those characterized as being expose to lesser risks.

(ii) Yields respond positively to higher than expected prices and to lower than expected prices variance. As a result of this and the previous findings, price support mechanisms seem to provide clearer incentives to increase cereal yields than the various insurance policies available for Spanish cereal growers during the 1990 to 1998 seasons.

Reactive plans: Actions at the Tagus Basin Authority

All relevant pro-active responses fall within the planning and administrative institutions. There are several examples that document the reactive actions taken during critical drought conditions with the aim of increasing water resources availability, such as new wells, conduits for water transfer, and desalination plants, or for reducing water losses in conveyance and distribution network. Here we document, as example, the actions taken in the Tagus River Basin that involved the agreement of four key stakeholders: Two partners in MEDROPLAN –the CYII and the Tagus Basin Authority (CHT)–, a hydropower company (Unión Fenosa) and an association of irrigation farmers (Comunidad de Regantes del Alberche).

During 1991 to 1993, prolonged meteorological drought resulted in hydrological drought, and the regulated water storage systems that serve Madrid Metropolitan Area (over 5 million people) were under critical conditions. As response to the situation a number of emergency measures were taken. One of the actions was to establish an agreement to use water from the river Alberche for water supply in Madrid. An emergency work was constructed to link the source (San Juan dam in the Alberche River) to the urban distribution system in Madrid. The water supply service provider for Madrid, CYII (Canal de Isabel II), did not hold a permit to use water from the Alberche for urban water supply in Madrid at that time. Water use priorities in the San Juan dam were and continue to be, recreation and ecological services, and water in the Albeche river was legally allocated to hydropower and irrigation. The hydropower company was entitled to turbine freely while the water level at the San Juan reservoir was above a certain minimum required to satisfy the irrigation demand. Since there was a drought situation, water in the San Juan reservoir was below the minimum level for hydropower operation. The irrigation association of the Alberche river was affected by the decision to derive water for Madrid. The agreement among the irrigation association and CYII was reached after legally changing the priorities of water use in the San Juan dam to allow for urban use in Madrid. In exchange for the loss of water rights, the irrigation association was given the right to irrigate with water from the nearby Tagus River. A pumping station was built to pump water from the Tagus River to the Alberche irrigation canal. The State Administration (CHT) paid for the facility, and CYII paid for the energy costs of the action. As a side effect, irrigators complained that water from the Tagus River had worse quality than that from the Alberche River and could contaminate the aquifer that was used for urban water supply to several municipalities. An existing water supply line, used for the nearby city of Talavera, was used to supply water for three municipalities at risk of contamination. Eventually, all problems were solved, and water from the Alberche could finally reach Madrid, although the critical drought conditions were already over.

It is remarkable to note that, although this infrastructure was built under pressure due to the emergency conditions, it has been used ever since to supply water for Madrid. A legal action had to be taken to concede a permanent water use permit to CYII to divert the Alberche water. The negotiations involved the agreement with the hydropower company to establish an economic compensation for the loss of hydropower production, to be paid by CYII. This action highlights the implicit value of some of the emergency works during severe drought in the cases that drought is the detonating point to undertake a structural work that was necessary for the system. Nevertheless, structural works undertaken under emergency conditions often result in a higher total cost than if they were planned with sufficient time.

Combination of reactive and pro-active plans: Programme for improving urban water use efficiency in Zaragoza

Background. The impact of drought in 1991-1995 in Spain stimulated Fundación Ecología y Desarrollo (ECODES), to develop a pilot project focused on improving urban water use efficiency. Spanish water use efficiency in cities has a great potential for improvement as documented by the World Water Council. ECODES launched a program of actions in Zaragoza (Zaragoza: The Water Saving City) that is outlined in Fig. 18.

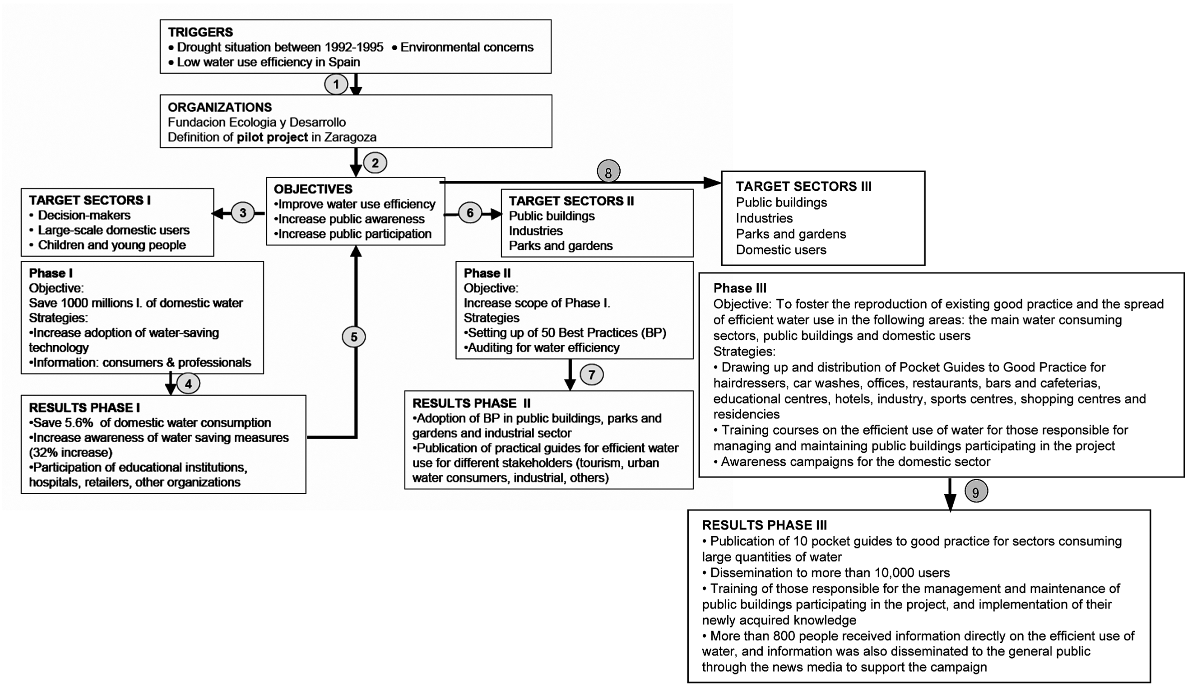

Fig. 18. Summary of the NGO Fundación Ecología y Desarrollo (ECODES) program to save water in the city of Zaragoza, Spain.

Objective and strategies. The main strategy was to save 1 million m^3 of domestic water per year.

This objective was met by:

(i) promoting demand for water-saving technology among consumers;

(ii) stimulating water-saving technology markets; and

(iii) training and informing professionals in this sector.

Specific actions were directed to:

(i) professionals linked to domestic water use (i.e. manufacturers, distributors, retailers, plumbers);

(ii) large-scale domestic users (i.e. hotels, restaurants, gymnasiums, etc.);

(iii) young people; and

(iv) the general public.

The program took place in parallel to other initiatives taken by the city, the Regional Government, the River Basin Authority, and the National Government.

Results. The results were positive and 1.176 million m^3 of water were saved (5.6% of annual domestic consumption). The number of people aware of water-saving measures increased (from 40% to 72%). The participation in the project was large: 69% of educational centres; 65% of health care centres; and 150 diverse organizations that collaborated by disseminating information about water savings.

Although the results were positive, it was considered necessary to extend the scope of action of the project. A new objective was the development of 50 best practices for efficient water use in public buildings, industries, and parks and gardens. A program of free audits was created and implemented in voluntary centres willing to adopt the best practices guides. These pilot centres served and continue to serve as role model for others in the city.

In this second phase, the main results of the project include:

(i) participation by 100% of the city's nurseries and garden centres;

(ii) adoption of best practices in public buildings, in parks and gardens and in the industrial sector; and

(iii) publication of practical guides for efficient water use. These guides include: practical eco-audit guides for hotels, offices, industry, hospitals and educational institutions; practical guide to dryland gardening; and practical guide to water-saving technology for households and public services.

The third phase of the project centered on the spread of good practice to sectors consuming large quantities of water. To this end Pocket Guides to Good Practice were produced for hairdressers, car-washes, offices, restaurants, bars and cafeterias, educational centres, hotels, industry, sports centres, shopping centres and residencies, and these were delivered to more than 10,000 users.

The Guides contain information on Good Practices identified during the previous phase of the project in the sector in question, and resulting from contacts made with institutions and companies. The guides also include a section of general information concerning habits and technologies for the efficient use of water in the sector. Agreements have also been drawn up with professional associations in each sector to ensure their collaboration in the distribution process of guides to their members.

The aim of the guides is to ensure the same type of consumers can benefit from experience gained from each good practice identified in the project. For example, using experience gained from one shopping centre in all the other shopping centres in the city. The goal is to ensure the reproduction of existing good practices and the spread of efficient water use. The involvement of professional associations linked to the range of sectors means the message reaches the professionals concerned through a medium they are familiar with and with which they identify because of their professional activity.

During the third phase specific activities were also carried out to foster efficient water use in the public sector. For example, training courses in efficient water use for those responsible for the management and maintenance of public buildings participating in the project, or for the general public, such as a public awareness campaign use and on efficient water saving technologies undertaken in a shopping centre in the city. Water saving devices were on offer at a subsidized price for washbasins (aerators) and water meters were given away with them so savings achieved in comparison to traditional taps could be checked. Those interested could also receive information free on other savings options explained in the Good Practice Guides on the Efficient Use of Water at Home, drawn up in the previous phase of the project.

A new phase began in November 2006 the objective of which is to obtain *100,000 commitments* from at least *25,000 citizens and organizations* to save water and consume it efficiently. The commitments will then be put on display at the *Zaragoza International Exhibition 2008.*

The commitments concern actions taken to save water and/or to spread the word, which citizens or organizations declare publicly as already underway or soon to be implemented. Savings actions include all those day-to-day activities that result in major water savings. Spreading the word refers to actions that foster good practice and water saving in others.

The above-mentioned aims are however ambitious and can only be achieved if thousands of citizens actively participate by undertaking savings actions and consuming water efficiently in their homes, at work, at school, in common sectors of consumption (shopping centres, leisure centres) and in public areas (libraries, civic centres, administrative buildings, etc.).

Public review component: Stakeholder participation

This section identifies stakeholders whom have been and are involved in the decision making process. The primary stakeholder is the Tagus Basin Authority that has competences for water management at the national, regional and local levels by implementing the Basin Hydrological Plan. The River Basin Authority includes users groups and representatives of different central and regional government bodies. The Basin Authority defines the Basin Hydrologic Plan, controls the public water domain, designs, develops and manages the hydraulic works, granting of licenses and permits for the use of water resources and the public water domain and hydrological monitoring (gauging, floods, quality). The responsibility of the Hydrological Planning Office (Oficina de Planificación) is to define, monitor, and review the Hydrological Basin Plan, and to provide technical support to the Water Basin Council.

Historically, three groups of users have been in conflict over water use in the Tagus basin: the urban water supply companies, the irrigators and the hydropower companies. They compete for their established rights to water use within the framework established by national, regional and local authorities. Recently, environmental groups are playing an important role in protecting the natural resources. The conflicts are solved within the Assembly of Users of the Tagus Basin Authority.

Stakeholder validation and proposals

Six key stakeholders have been interviewed to validate the mental model and to enhance the understanding of droughts and water scarcity problems in the country. This Section includes an outline of the information provided by them relevant to model validation.

Tagus River Basin Authority

The River Tagus is the longest river on the Iberian Peninsula and the third with regards to total contributing area (about one ninth of Spain) and in amount of water carried (about one tenth of Spain). The Tagus Basin is the one that has the largest population weight in Spain and in the Iberian peninsula (over 6 million people). The volume of water that provides to other basins is a concern, since the Tagus is the one that provides the largest share to other basins. The Tagus Basin is the most regulated one (about one fourth of the regulated water in Spain is from the Tagus Basin). Drought is viewed as a situation in which available resources are insufficient to meet regular demands, or when tensions arise attempting to meet the system's demands. Meteorological droughts are considered secondary events, as they affect soil moisture and runoff coefficients. As a result, meteorological droughts increase the left tails of the probability distribution of runoffs as they feed the systems reservoirs. Basin Authorities take decisions in collective bodies, although the executive responsibility is held by the Chairman of the Basin's Authority. Reservoir Release Commissions are responsible for the continuous management of reservoirs. Under severe scarcity conditions, a Permanent Committee is appointed to manage the situation. As in any other River Basin Authority, the planning process is exposed to public scrutiny. Concerned individuals and social or political groups can make allegations that affect the planners' decisions. The drought mitigation measures considered take into account all economic and social costs, at the regional and local levels. At the present time, the exchange of water rights may not be the most adequate strategy in many areas of the Basin. The main impediment is that some water right holders do not exhaust their current rights, and therefore if they are offered an interesting price, they will sell their rights to buyers who would put the purchased waters into use, deteriorating the Basin's water balance. Some of the current water concessions could be revised and reduced if evidence of under-utilization is found. A fundamental issue that determines the actions related to risk management in a large basin arises from the available data series. In general data series are too short to consider accurately extreme events, such as droughts or floods. This may be partially solved by the use of synthetic series.

Ebro River Basin Authority

The Ebro Basin provides in general sufficient water for its users, although conflicts are manifested in certain years and/or locations. Nevertheless, the basin includes several areas of endemic drought where supply is not enough and others where there is a recurrent problem but not endemic. Eighty percent of the water use is for irrigation and the future of it is linked to the future water scenarios and Common Agricultural Policies of the European Union. The data provided by the extensive data system SAIH (Sistema Automático de Infomación Hidrológica) in real time, and water extractions metering are an essential tool in the planning process. Spain is a Pilot experiment for the use of these data. Agricultural water use data are provided by farmers willing to collaborate; at the moment 15 irrigation districts are already engaged in an experiment that monitors real time data on agricultural water use. The Ebro River Basin Authority provides these data on-line. The legal framework for the planning process is complete. However, the Basin Authority may benefit from a fuller capacity of decision during crisis situations. At the present time the Basin Authorities depend on the Council of Ministries for drought declaration and water rights revisions. It is important to highlight that planning for drought should be performed during non-crisis times. Drought impacts appear in the Basin under certain conditions. When irrigation supply is below 90%, conflict among users in the basin arises. This may even give rise to additional conflicts between users of other basins if inter-basin water exchanges occur. Full cost recovery in the farming community cannot assume the cost of improved irrigation structures, part of these costs may have to be assumed by the State if they are recognized as positive for Basin's conditions and for other users along the Basin. Information, water allocation, and allocation of priorities are essential components of adequate management. Participation is consolidated in the Management Board. The meetings of the Board have incorporated a large number of stakeholders to conciliate interests. The Pilot projects with farmers have shown positive results. Priorities in water allocation should be, as established in the Water Law, for domestic water supply. In many cases conflicts arise with water permits of the farmers. In case of crisis, it is necessary to agree on economic compensations to the water rights holders in exchange for their rights. In general this was not necessary in the Ebro Basin as stakeholders reach agreement without compensations. In the agricultural sector the priority is irrigation of orchards since the lack of water causes long term effects.

National Association of the Water Supply Companies

The National Association of Water Supply Companies (AEAS) includes the most relevant companies that supply urban water. The interviewed believes that water supply companies are passive actors for most possible pro-active responses since they are severely constrained. A main constraint is that the companies are not responsible for reservoir management, therefore it is difficult, if not impossible, to take an active role in reducing water scarcity risks. An exception is the water company of Madrid (Canal de Isabel II, a partner in MEDROPLAN), which has a protocol for both reactive and pro-active responses to water scarcity risks. An additional constraint is the regulatory regime for Local Governments ("Real Decreto legislativo 781/1986, de 18 de Abril por el que se aprueba el Texto refundido de las Disposiciones legales vigentes en materia de Régimen Local") that limits the water companies in the scope of actions to obtain new tariffs approval based on the costs of implementing future contingency plans. A final constraint is the non-accumulative nature of technical efficiency improvements, from the abstraction point to the customer connection. As a result, improvements on the leakage ratio, or the unaccounted losses have an incremental effect that cannot be accounted for in long-term planning, unless the reduced demands can be maintained and projected in the future. Therefore improvement of technical efficiencies, demand management, and other measures taken by water companies, may not be as effective to reduce water scarcity risks. In contrast, the interviewed expressed that water companies have a role in reactive planning and must also coordinate actions and initiatives with the Basin Authorities and local Governments. Contingency plans and stable agreements (i.e., for water allowances exchange) are perceived as critical elements for effective performance in case of drought. Nonetheless, market arrangements for sharing water use rights must be agreed through negotiations, with the mediation of the Basin Authority.

Water Supply System

The CYII (Canal de Isabel II) is responsible for water supply to 5 million people and is the most important user of the water in the Tagus River Basin. The company has a comprehensive Manual of Water Supply. The manual has had significant public relevance and its aim is to provide rational arguments and rigorous risk analysis of actions before, during or after water scarcity situations. By rationalizing all processes and strategies, the company seeks to shelter itself from mismanaged allegations and uninformed public scrutiny. The main concern of CYII is the frequency or probability associated with each level of insufficient supply to meet water demands. In the view of the interviewed, droughts cannot be controlled, but water scarcity can be controlled to a certain extent. The CYII does not establish priorities among users during water scarcity, reflecting a political choice of free decision of the users. The Manual provides a special water levy for water scarcity situations, and it is systematically used in operations with preventive character. In real situations, water scarcity affects the environment and agriculture in the first place. The water company has a prevalent position within the River Basin Authority (Tagus) and an influential role among other competing users. Drought policies are included in long term planning, but are also dependent of the short term (i.e., operational) planning. In the long term, planning for scarcity consists of defining scenarios, evaluating probabilities and identifying effects and strategies, and in general these actions are not influenced by political or media pressures. Sources of uncertainty for future planning arise from:

(i) The uncertainty of the climate patterns;

(ii) land and urban development; and

(iii) changing demand factors, such as seasonality or consumption patterns.

The main challenge is to maintain current reliability levels, despite the significant changes appearing from demographic and socio-cultural change (i.e., expansion to the peri-urban space, and single family homes). The measures include:

(i) Water metering;

(ii) full cost recovery rates;

(iii) demand management; and

(iv) water right exchanges with irrigators, making use of the provisions of the 1999 Water Law amendment. The CYII considers that the water rights are sufficiently clear and envisions purchasing water rights currently in the hands of irrigators, as one possible strategy to meet moderate risks of water scarcity.

Economic instruments are viewed as a main tool for implementing measures. Reasonable expectations are based on market allocation mechanisms, by which water companies can acquire permanently or temporarily use rights currently in the hand of the farmers. If these measures result in cost increases, the company would pass them on to its final consumer.

Agricultural Insurance

ENESA is an autonomous body under the umbrella of the Ministry of Agriculture. The General Director of ENESA is also a member of the Permanent Office for Drought. The interviewed expressed that meteorological and agricultural drought risks are perceived as identical. The Permanent Office for Drought meets when the signs of stress or difficulties arisen from meteorological droughts are perceived by affected groups. No particular index or set of indices of droughts are used to set off alert signs or justified a call for a Permanent Office meeting. All members are Senior Officials of the Ministry of Agriculture. In crisis situations, attention is focused on the agricultural sub-sectors with no agricultural insurance available that experience difficulties related to crop water stress or unavailability of animal drinking water. Alleviation measures include tax reductions or subsidies for wells construction for animal drinking. The Permanent Office is also concerned with insurable production inasmuch financial support can be secured by advancing insurance indemnities payments, Common Agricultural Policy subsides, and occasionally filling applications to the Finance Ministry to condone land taxes or social securities contributions.

Non Governmental Organization

The Fundación Ecología y Desarrollo is an NGO that plays a role in public water saving programs in urban environments. The interviewed considers drought a recurrent process that depends mainly on management actions. In his view, man can anticipate drought and be prepared to minimize its impacts. The identified roles of NGO's in water management are: (i) to mobilize and rise awareness; and (ii) to force Public Administrations to introduce some topics in the political agenda that otherwise will not be attended. Through these actions, FED has contributed to raise awareness in society of the need of rational water use together with implementation of actions targeted to reduce consumption using best available technology. The program started in a pilot experience in households, and has expanded to the commercial sector. FED has introduced and developed a set of ideas for improving Water Management, including:

(i) Demand management versus supply management. Modifications in the current legal framework to increase flexibility at crisis time (i.e., revision of water permits) and establishment of different crisis levels with measures target to each level. Increased participation in the River Basin Authority, since environmentalists, consumers, neighbourhood associations are currently under-represented.

(ii) Include Better Water Management in the political agenda by increasing efficiency in the system (i.e., reforms in the sewage system, water metering, etc.), and by incorporating anticipatory measures (i.e., pro-active management).

(iii) Promote cultural changes that will result in water use reductions (i.e., Mediterranean gardens with lower water consumption plants).

Lessons learned

Meteorological and agricultural droughts

The mapping for reactive responses shows that triggers originate from widespread and diffused signs that reach the Ministry of Agriculture. The call of a meeting of the Permanent Office for Drought is the origin of all reactive responses for drought alleviation. However, the types of signs and collected evidence are based on costs, damages, and difficulties, as they are already occurring across the agricultural regions.

By limiting their attention to non-insured risks, the Permanent Office assumes that insured risks do not deserve concern. The implication is that the drought effects that go beyond the farm gate are properly handled by agricultural markets, both of inputs and outputs. As a result of this, the spanning chain of effects that droughts create in related industries and perhaps in the urban areas is mostly disregarded. As a result, the whole family of indirect effects beyond the farm gate is left unattended in the institutional mappings.

Consider of a severe drought, and the supply reductions of many basic commodities. Eventually, consumer prices will start rising, affecting the Consumer Price Index and the economy as a whole. This example, and many others that could be thought of, illustrates the reductionists concerns of the competences of the Permanent Office

Some of the consequences resulting from this view are:

(i) That drought indirect effects are not considered, nor corrected.

(ii) Many vulnerable farms do not purchase insurance.

(iii) Risks associated with water supply could also be insured against, provided they are based on natural and objectively measurable indices, such as runoffs or precipitation indices.

(iv) While the agricultural insurance system is quite complete and innovative, some of the policies that are based on satellites images, such as the pastures drought insurance, are purchased by a very limited number of farmers.

The above points indicate that there are significant gaps both in terms of geographical scope and in the number drought vulnerable sectors and productive activities that may not receive sufficient attention.

Hydrological droughts and water scarcity

The development and revision of Basin Hydrological Plans are slow processes, constrained by legal formalities, and some data or results may become outdated in the process. In addition, the Plans will have to be amended to comply with the EU Water Framework Directive, especially with the new notions enshrined in this European legislation.

At the basin levels, contingency planning is still in very early and immature stages. Groundwater resources, as a strategic supply source, is not sufficiently controlled and valued. It is also a source of conflicting views among Basin agencies and water suppliers that rely on them for very specific situations.

Water quality deterioration is threatening the regulation capacity of eutrophic reservoirs to service urban customers. This reflects that proactive measures should include water quality issues in order to preserve the adequacy of current water supply sources.

Although users' and public participation is secured within the various bodies of the Basin Authorities, risk analyses performed by executive bodies may encroach the rights of the lowest value users.

Public awareness of the value of secure water sources at the basin level is extremely limited. While most users across the basin are largely dependent on the Basin Authority reactive and pro-active plans, the general public may disregard this fact and assume that their water supply security is managed by the retailers that service the water. This is the most uncommon case, except for the urban water supply to Madrid.

The water market and exchanging options, as envisioned in the Water Law, is perhaps too naïve to facilitate the kinds of agreements that water companies are interested in reaching with the irrigation sector. In particular, sharing mechanisms that are based on objectively measurable conditions may have a more promising future than the rights lease-out contracts that are defined in the law.

With reference to the previous point, water companies are demanding legal security and enforceable long-term contracts with irrigators. These will significantly reduce the negotiation costs that impede and retard lease-out contracts sometimes needed urgently.

Strengths and weaknesses of current drought plans

In this section we identify the strengths and weaknesses of the institutional mappings that have been described in the Organizational Component Section, contrasted by personal interviews and validated in our discussion in the previous part of this section. The section is organized in coherence with our previous structure, focusing first on agricultural and meteorological droughts, and then on hydrological droughts and water scarcity risks.

Meteorological and agricultural droughts

The main strengths of the Spanish institutional framework that stand out from the above analyses are:

(i) The Spanish agricultural insurance system has solid bases, and grows year by year expanding its coverage and new premia specifically targeted to cover drought risks. This has given rise to an important capital of knowledge regarding site-specific drought risks and the development of premia individually tailored to all eligible farmers.

(ii) In some rainfed crops, such as cereals, olive trees and other field crops grown, farmers can elect from a wide menu of insurance premia, that cover an increasingly range of risks from fire and hailstorms all the way to yield losses caused by any natural event.

(iii) In addition to the well-developed and dynamic agricultural insurance system, there exists a Permanent Office with clear missions and means to address stressful situations caused by droughts and other climatic and environmental hazards. The Permanent Office members are appointed in advance, and its president can call for a meeting whenever signs of stress are received. All Permanent Office members are senior officials of the Ministry of Agriculture, and are likely to be especially receptive to agricultural strains. The Office's attention is primarily focused on the agricultural sub-sectors and farmers, which are not eligible for any of the agricultural insurance premia.

The main weaknesses are the following:

(i) The combination of all eligible productions for insurance and the non-insurable areas or production is far from complete. In some products and production systems, the subscription rates are below 20%. This includes premia for pastures, olive trees and vineyards which in total make up more than 4 million hectares. The fact the Permanent Office does not address drought hazards as they affect insurable production results in significant area and sector gaps, which the present insurance framework does not cover.

(ii) Fundamental problems hinder the prospects for higher subscription insurance rates. This is because many agricultural areas are subject to significant risks, which the insurance system can cover only with unaffordable premium rates for the farmers. This is not going to be solved by the insurance system, and does not seem to be properly addressed either by the Permanent Office's services.

(iii) The Permanent Office's primary attentions do not go beyond the agricultural sectors, nor does it pay attention to indirect effects of the vulnerable agricultural sectors. This implies that non-agricultural effects are basically disregarded and left to be attended by other income-smoothing and counter-cyclical instruments such as the tax and social security systems.

(iv) The Permanent Office does not use currently drought indicators or any other scientific objective indices to call for crisis situations.

(v) As a risk reducing strategy, insuring irrigated crops is presently disregarded on the basis of potential moral hazard and adverse selection problems. While there are unquestionable difficulties in developing insurance premia that are based on human-made decisions, such as water allocation among sectors and crops, index rates could be developed that are based on runoffs or other fully natural events/variables. This possibility is fully disregarded, though does not differ dramatically from other policies that are already in the market, such as pastures insurance based on indices computed from satellite images.

Hydrological droughts and water scarcity risks

The main strengths of the Spanish institutional setting are:

(i) Basin agencies are experienced organizations in managing basins' water resources. They have adopted modern technologies to monitor all systems in real time and are capable of collecting and processing hydrological data and analyze it for risk analyses and projects' evaluations.

(ii) Basin agencies, albeit public institutions, encompass by statute all users, governmental branches and stakeholders in all decision bodies both for pro-active and reactive responses. It is customary to favour their active participation and influence most decisions in planning and managing tasks.

(iii) Entities responsible of retailing water to final customers participate actively in the basin agencies' decisions and have seats in their planning and executive bodies. In times of scarcity, water is assigned through collective decisions taking into account the priorities enshrined in the approved Hydrological Plans or, by default, as the Water Law dictates. The allocation process is transparent, at least with regards to the most immediate consequences as they result in costs and benefits accruing on water right holders.

(iv) The Spanish Water Law is modern, well adapted to the country's water conditions, and fairly well enforced in most basins for surface resources. The 1999 Law amendment foresees water rights lease-out contracts and water banking schemes, as a means to mobilize valuable resources to be made available for demanding agents through voluntary responses.

(v) Planning documents both at basins' and national levels are legally approved, detailing priorities, specific plans, works and actions. These plans have gone through multi-layered consultation processes, and been subject to very thorough scrutiny by the political parties, various administrations, the general public, the media and the scientific community.

(vi) As a legal mandate, Basin agencies must develop contingency plans for drought situations and develop strategic plans for cities with 20,000 population or larger.

(vii) Lessons drawn during recent drought experiences have been incorporated and used to shift the focus on pro-active responses and preparedness capacity. The Madrid Water company is currently in its second generation "strategic contingent planning" and has specific staff devoted to these tasks working on risk analyses.

Some of the main weaknesses of the institutional framework to face hydrological droughts and water scarcity are the following:

(i) Although the Planning documents described above result from intense consultations, scrutiny and analyses, they may lack the flexibility to be amended to accommodate social, environmental and economic trends. In particular, the planning concept and the programmes of measures as they are conceived in the EU Water Framework Directive represent a significant departure from the traditional planning techniques as they have been practiced by basin agencies in the past. Among the most significant difference is perhaps the focus on the "ecological status of the heavily modified water bodies", and how restoring the ecological water quality is integrated in the planning strategies.

(ii) While Basin agencies, in coordination with the Environment Ministry, are adapting their methodologies, objectives and constraints at a reasonable speed, the needed changes are far from simple and direct. So it remains to be seen how Spanish Basins manage to comply with these new challenges.

(iii) The Water Law enforcement levels show a number of grey areas, particularly in the area of groundwater resources. Although key water suppliers internalize them as key strategic supply sources, the Basin agencies are in charge of managing and controlling its use and exploitation regimes. Inconsistencies in these are have been identified, showing that much more is needed to protect these key resources and secure accessibility when they are urgently needed.

(iv) The steps taken to let economic incentives allocate scarce resources during stressful situations are laid down in the Law, yet they have to be put into practice under real conditions. In particular, while these market arrangements to mobilize water resources and transfer them to highly valued uses are recognized by urban suppliers as promising, at the Basin agencies level there is much more scepticism. This gives rise to some inconsistencies between the drafters of the 1999 Law amendment, the expectations of some of the active parts of these market agreements, and the reluctance and reserves expressed by those Basin agencies' officials, who act as notaries and controllers of such agreements.

(v) Water quality problems endanger strategic resources and threaten the quality of high water quality sources. These problems evolve slowly and silently, but are not properly framed in the menu of pro-active measures.

(vi) Emergency actions, mainly in the from of works approved and built under urgent conditions, often take much larger costs and efforts than would be the case had they been planned for regular time frames. Occasionally, these works become operative when scarcity is no longer a problem, although they are certainly available for subsequent drought periods.

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