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European Commission - EuropeAid Co-operation Office
Euro-Mediterranean Regional Programme for Local Water Management (MEDA Water)
Mediterranean Drought Preparedness and Mitigation Planning (MEDROPLAN)

Drought Management Guidelines

Examples of application in Mediterranean countries

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MEDROPLAN

MEDA Water

1. Cyprus

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 15: Application of the Drought Management Guidelines in Cyprus

The Planning Framework

Societal response to drought

Droughts in Cyprus are becoming more frequent events with adverse impacts on the economy, social life and on the environment. During the period 1990-2005 Cyprus suffered from three meteorological drought events, one in the period 1990-1992, one in the period 1997-2000 and one in the period 2004-2006. The first two meteorological droughts were followed by acute water shortage and affected the total population of the area under the control of the Government of the Republic of Cyprus, whereas the third did not develop into hydrological drought because the precedent years were relatively wet and the surface reservoirs were filled with water. Drought events affected water supplies which were rationed both in the domestic and the agricultural sectors, whereas in the case of industries, measures were taken to reduce consumption without affecting productivity. Water quality both for domestic use and for agriculture have deteriorated because marginal quality water was used to augment scarce water supplies and the environment was partly neglected because of the inability of the water supply systems to provide satisfactory water quantities for their needs.

The water in the surface water reservoirs was used with adverse effects on the ecology and biodiversity, and the groundwater was overpumped causing reduction of the phreatic water level, and deterioration of the water quality due to seawater intrusion in the coastal aquifers and due to depletion in the inland aquifers. The total consumption of water in Cyprus is estimated at 280 Mm^3 out of which 210 Mm^3 are used for irrigation (75%) and the remaining 70 Mm^3 of water are used for domestic and industrial needs (25%).

Cyprus has been implementing Integrated Water Resources Management processes since the 1970s. Water demand management is widely applied, especially in agriculture where water distribution and on-farm systems are using efficient modern pressurized systems, all water supplies are metered and charged, water saving equipments are used, the use of lower quality water in towns (local groundwater or on-spot recycled grey water) is promoted through subsidies for garden irrigation and for toilet flushing, and water consumption auditing for big consumers is carried out and water saving measures are suggested or imposed to reduce consumption. The implementation of the EU Water Framework Directive has assisted Cyprus in promoting the water quality and quantity conservation of both surface and groundwater sources.

Water scarcity, drought and climate change

Cyprus has a semi arid climate, with an average annual precipitation of 460 mm (during the period 1971-2000) with an average water crop of 370 Mm^3 per year corresponding to 524 m^3/cap/year. So far more than 250 Mm^3 of the natural resources corresponding to 66% of the total water crop have been developed and utilized compared with 8% worldwide. The total groundwater resources amounting to 135 Mm^3 are over-utilized with an annual extraction of 139 Mm^3 (safe yield is only 110 Mm^3/year), where the surface water resources amounting to 235 Mm^3 are almost totally utilized with only about 48 Mm^3 going to the sea. From the above it seems that the extra natural resources available for development are very limited and very expensive to develop, since the best dam sites have been used. In addition to the water scarcity, with water availability at 524 m^3/cap and water use of 357 m^3/cap, droughts are becoming more frequent. Cyprus prepared and started implementing its water master plan in the 1970s. Since then rapid changes have taken place; (i) the climate change which brought about a steep change in the precipitation time series in 1970, caused a decrease in the precipitation between 15-25% of the mean annual precipitation, which resulted in a reduction of the natural water resources by 40% (FAO/WDD Re-evaluation Study); and (ii) the Turkish invasion in 1974, with the subsequent demographic changes, increased the water demand, and changed the water demand pattern (Cypriot refugees that moved to the Southern part of the island increased by 50% the population of the areas which must now be served by the limited available resources).

Purpose and process

The purpose for the preparation of a Drought Preparedness Plan is to provide the Government, the water managers and all the consumers, the means and ways to minimize the adverse impacts of a drought on regional and national levels. The Plan should contain the technical, legal, social, economic, environmental and any other measures and provisions and short term, medium term and long term actions that should be taken in a proactive, and in few cases in a reactive, manner, by all stakeholders to minimize the adverse effects of a drought event and should be dynamic.

The process shall provide the preparation of the plan by the Drought Management Committee to be appointed by the Government and shall be composed of representatives from all stakeholders. The plan shall be the result of a complex process, in which all stakeholders shall take part, and after preparation and agreement it shall be adopted by the Government with authority to the Drought Management Committee to proceed with its implementation. The Plan should be based on sound technical, legal and institutional frameworks, those affected adversely should be compensated and those favoured by the scheme for any reason should bear some of the extra costs.

Organizational Component

The case study (Paphos Irrigation Project)

The Paphos Irrigation Project (PIP) was selected as the project for the testing of the Drought Management Guidelines developed in Work Packages 6 and 7 of the MEDROPLAN project. The Paphos Irrigation Project, which is situated in the south western part of Cyprus, is using the surface and groundwater resources of three rivers (Dhiarizos, Xeropotamos and Ezouza) originating from the south western side of the Troodos mountain, and from the coastal aquifer, originally for the development of irrigated agricultural in the coastal area extending from the Ha-Potami river in the east to the Agios Georgios of Peyia plane in the west, over an area of 5000 hectares (see Figure 1) and for the supply of domestic water for the rapidly developing Paphos town and other tourist villages in the area. The basic objective of this project was to collect and store surplus water flowing to the sea from the rivers and the aquifers and convey it to areas of demand, for domestic water supply and irrigation. The project planning was initiated in 1968, and its feasibility study was completed in 1972, with the financial and technical support of the UNDP and FAO. The construction works started with a delay of two years, in 1976, and were completed in the year 1983, with a total expenditure around 60 million US$. In the early 2000 the project water availability was augmented by recycling the domestic effluent of the Paphos area town and municipalities. The domestic effluent was first subjected to tertiary treatment and then through recharge underwent soil water treatment, allowing the free use of the water for irrigation.

The present water resources of the project are 20 Mm^3 (initially 32 Mm^3), divided as follows: a) Surface water resources from Asprokremmos dam: 11.6 Mm^3 (initially 22 Mm^3); b) Groundwater from Dhiarizos and Ezouza river aquifers 6.4 Mm^3 (initially 10 Mm^3); c) Recycled water from Paphos Sewerage System: 2 Mm^3 to increase to 6 Mm^3 (initially 0). The present water demand is 20 Mm^3/year, divided as follows: a) Irrigation water supply: 13 Mm^3/year; b) Domestic water supply: 7 Mm^3.

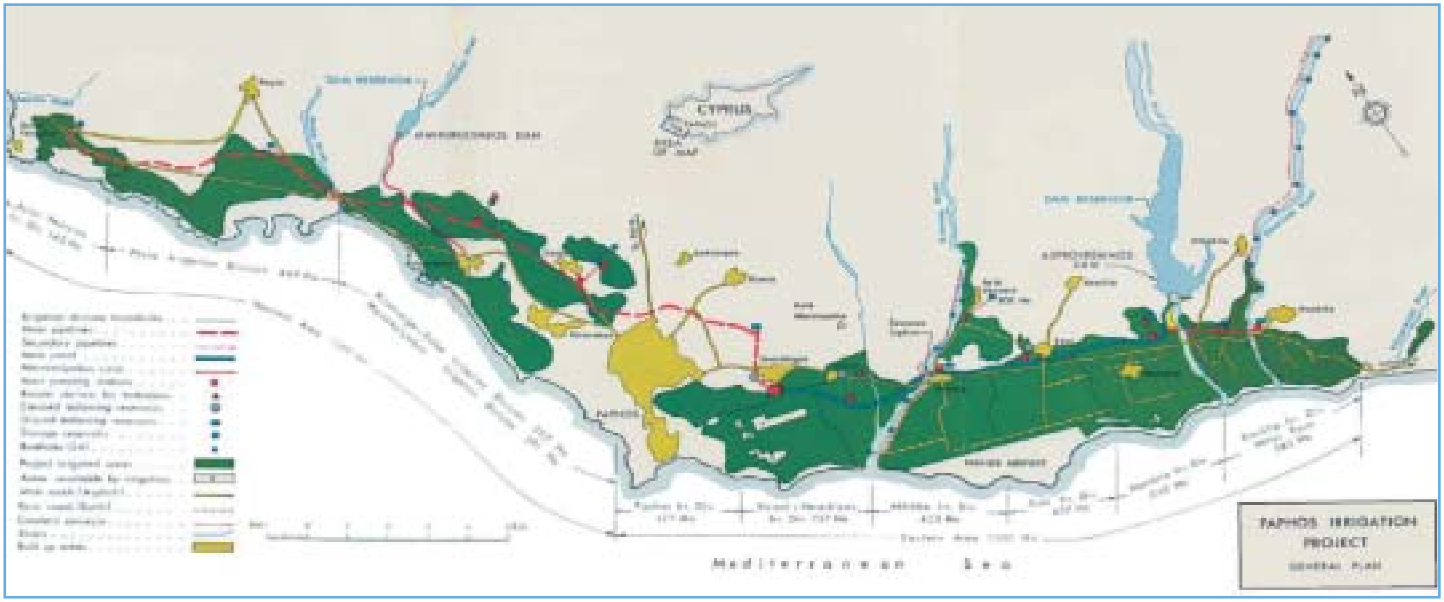


Figure 1. Paphos Irrigation Project area

Legal and institutional framework

The Paphos Irrigation Project was planned, constructed and is now operated and maintained under the Government Waterworks Law. According to this law water and the waterworks of this project belong to the Government and the Council of Ministers can take decisions concerning the allocation and distribution of the project water resources.

The agency in charge of the operation of the project is the Water Development Department, a Technical Department of the Ministry of Agriculture, Natural Resources and the Environment. The project supplies irrigation water to the individual farmers within the perimeter of the irrigated land and for domestic use after treatment in a water treatment plant, to the Paphos town and other municipalities and villages in the area. The Water Development Department bills all the water supplied and collects the approved tariffs from the consumers.

Stakeholders and priorities

The Stakeholder groups that compete for water during droughts and water scarcity, and the priorities are listed in Table 1 below.

Table 1. Stakeholders

Stakeholder	Variable of interest	Priority and compromises
Farmers	Irrigation Water	Second priority after domestic demand Priorities for permanent crops and greenhouses Demand for compensations for loss of income due to drought
Domestic water consumers	Satisfactory quantities to meet basic needs	Top priority Guarantee minimum quantity Secure supply to all consumers irrespective of location Pay more for more secure sources
Environmentalists	Preserve environment	Priorities vary Secure minimum quantities for environment preservation
Urban water supply institutions	Secure, satisfactory quantities of water	Improve domestic water supply reliability and increase water quantities available to meet increasing demand
Water Development Department	Secure enough infrastructure to meet water demand	Apply integrated water resources management and water demand management Apply drought mitigation plans Secure safe reliable water sources

Methodological component

Meteorological and hydrological drought

Drought characterization in a totally regulated water project (a dam with capacity 52 Mm^3 and annual yield 11.6 Mm^3, groundwater yield around 6.4 Mm^3 and recycled domestic effluent system with 2-6 Mm^3) is not easy by using the Standardized Precipitation Index (SPI) or another individual index. Events with lower than normal precipitation are declared as hydrological drought events if the available water resources are not enough to meet the average water demand for domestic and irrigation demand. The time to declare an event as a hydrological drought event or not, which shall trigger the implementation of the Drought Mitigation Plan is around April each year at the end of the wet season. A meteorological drought is much easier to characterize by using the precipitation and the SPI index. However it must be noted that not all meteorological droughts result in hydrological droughts.

Hydrological risk analysis: probabilities of satisfaction and impacts analysis

The preparation of the hydrological risk analysis should be based on the real hydrological conditions on which the project is operating. For this purpose it would be wise to have "normal water management plans", which shall outline the safe average annual yields of the project sources in Mm^3 and the average project water supply that can be satisfied. For example the operators must know the average annual water volumes that can be utilized on average in Mm^3 with a certain reliability of supply, the water demand of each client (irrigation, domestic water supply, power, industrial needs etc., on a monthly basis), and the total average annual water demand. This shall constitute the basis for comparison in defining the impacts of a drought event. Based on the above, the hydrological risk is calculated by carrying out the following operations (see also Figure 2).

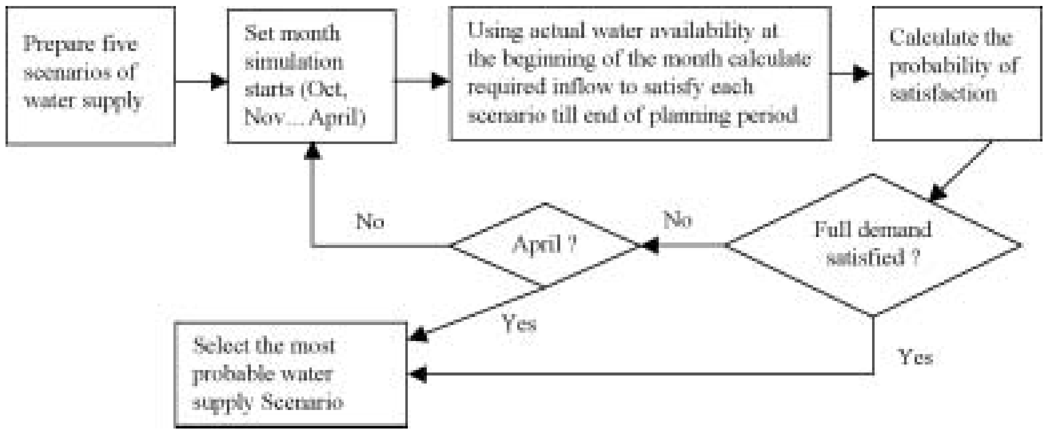


Figure 2. Diagram showing the steps in the hydrological risk analysis for deciding the most probable water supply scenario

a) Prepare water supply scenarios: Early in September each year, using the projected monthly water demand profiles for irrigation and domestic water use, prepare five water supply scenarios for the next period May-April (12 months). The water supply volumes during the period September-April, before implementing the new plan shall be those decided in the previous year. Each water supply scenario has a different level of satisfaction of domestic water supply (DWS) and irrigation as follows: (i) Pre-Alert (100% satisfaction for DWS and for irrigation); (ii) Alert 1 (100% satisfaction for DWS and 90% satisfaction for irrigation); (iii) Alert 2 (100% satisfaction for DWS and 80% satisfaction for irrigation); (iv) Emergency 1 (90% satisfaction for DWS and 70% satisfaction for irrigation); and (v) Emergency 2 (80% satisfaction for DWS and 60% satisfaction for irrigation).

b) Calculate by simulation the required river inflow to the dam to satisfy the water demand scenarios: For each scenario using the relevant water demand and losses data, use a simulation model to calculate the inflow required during the next hydrological year to satisfy the demand. The simulation model shall be run every month or every two months starting in October and finishing in April and shall cover a period ending 12 months after April. Table 2 shows the five scenarios (column 1), the normal and reduced demands (columns 2 and 3), the total demand, the source of supply and the gross water demand (columns 4,5,6,7 and 8), the water available at the beginning of the month (columns 9 and 10) as well as the calculated required inflows (columns 11 and 12). Columns 13 and 14 show the calculated probabilities of satisfaction of the demand.

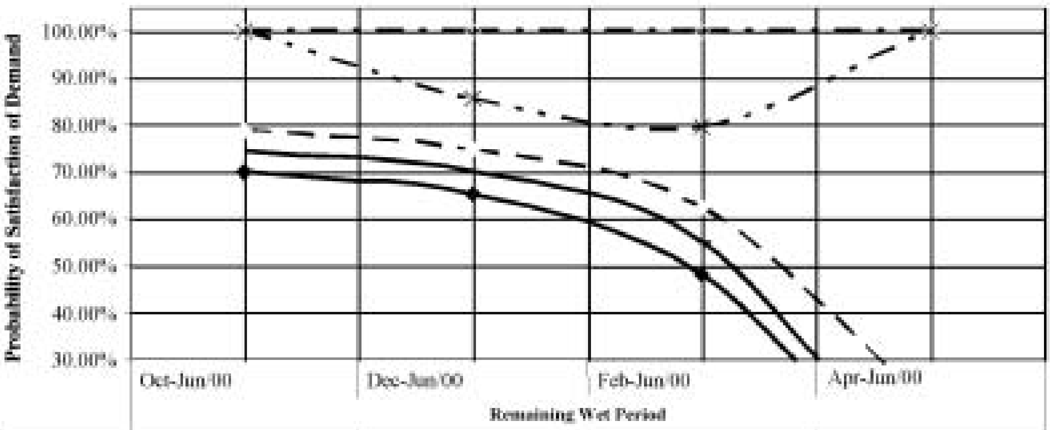
Table 2. Water demand scenarios

Scenario No	Water demand and supply by sector and by source							Water available		Calculated required-Inflow		Probabilities %	
	Irrig.	Do mestic	Total	Dam	Ground water	Tot. Demand	Gross Demand	Oct -99	Dec -99	Oct-Jun /00	Dec-Jun /00	Oct-Jun /00	Dec-Jun/00
(1) FD*	(2) 16.0	(3) 2.70	(4) 18.70	(5) 17.9	(6) 0.8	(7) 17.90	(8) 19.69	(9)	(10)	(11)	(12)	(13)	(14)
1	Pre-Alert Scenario												
%	100%	100%	100%										
Mm^3	16.00	2.70	18.70	17.90	0.8	17.90	19.69	12.08	10.66	7.62	9.03	70	65
2	Alert 1 Scenario												
%	90%	100%	91%										
Mm^3	14.40	2.70	17.10	16.30	0.8	16.30	17.93	12.08	10.66	5.86	7.27	74	70
3	Alert 2 Scenario												
%	80%	100%	83%										
Mm^3	12.80	2.70	15.50	14.70	0.8	14.70	16.17	12.08	10.66	4.10	5.51	79	75
4	Emergency 1 Scenario												
%	70%	90%	73%										
Mm^3	11.20	2.43	13.63	12.83	0.8	10.11	11.12	12.08	10.66	0.00	0.46	100	85
5	Emergency 2 Scenario												
%	60%	80%	63%										
Mm^3	9.60	2.16	11.76	10.96	0.8	9.63	10.59	12.08	10.66	0.00	0.00	100	100

* FD: Full demand.

c) Calculation of the probability of satisfaction of the demand: For each scenario and for each month of reference the required inflow to satisfy the demand is calculated. For each inflow the probability of having equal or more flow is derived using the cumulative distribution of the inflows of the remaining wet period (i.e. Oct-April, Nov-Apr, Dec-Apr, Jan-Apr, Feb-Apr, Mar-Apr). This gives a matrix of probabilities of having each scenario satisfied for each of the next five months, which can be plotted on a graph as shown in Figure 3 below.

d) Decide the scenario or level of alert: From the graph of Figure 3 it can be seen that by February 2000 the most probable scenarios to be implemented for the next year are scenarios 4 and 5, since the probabilities of satisfaction of scenarios 1, 2 and 3 are comparatively low. Therefore Scenario 4 is applied since it is the most probable and the Emergency 1 situation is declared. A very close result can be reached by studying in detail the inflow patterns during the period October-January or October–February and comparing results with existing records of previous years.



	Oct-Jun/00	Dec-Jun/00	Feb-Jun/00	Apr-Jun/00
Scen 1	69.82%	65.21%	47.97%	0.05%
Scen 2	74.43%	70.12%	55.13%	1.94%
Scen 3	78.65%	74.69%	62.13%	19.94%
Scen 4	100.00%	85.49%	79.54%	100.00%
Scen 5	100.00%	100.00%	100.00%	100.00%

Probabilities

Figure 3. Probability of satisfaction of the demand vs remaining wet period

Operational Component

After selecting the scenario of water supply to be adopted for the forthcoming period May/00-April/01 the operational component is put into operation which includes the risk analysis, who will do what, the measures and actions and how the measures and actions shall be implemented. The project drought policy is summarized and a list of actions and measures to be taken is prepared.

The long and short term measures and actions are both summarized as follows.

a) Water demand reduction measures: These measures provide for the reduction of wasteful use of water and the reduction of losses. The measures may be technical or legal such as intensification of the water demand management, intensification of use of water saving equipment, use of more efficient on-farm irrigation systems, water consumption, prohibition of certain uses etc. Big consumers' water bills are audited and measures are proposed to reduce their consumption.

b) Water supply augmentation: Development of non-mobilized natural water resources of lower quality water, (drilling of boreholes within the cities for gardening, or toilet flushing), water re-use, water transfer from other regions, use of strategic reserves by over-pumping from groundwater aquifers, or introducing desalination.

c) Water supply reduction measures: These measures, in contradiction to the water demand reduction measures, are taken by the water supply managers to restrict the water supply and include water supply restrictions to domestic water supply institutions and water consumers, water rationing to irrigators, reallocation of water from non-priority areas to high priority areas etc.

d) Compensation for those adversely affected: Some consumers shall be adversely affected and for facilitating the implementation of some measures it will be wise to compensate these people. The compensation is usually given by the Government.

e) Public awareness and water use education: It is obvious that the implementation and the success of an acceptable Drought Mitigation Plan would not be possible without the cooperation of all the stakeholders. All the stakeholders should be involved from the very beginning including the preparation of the scenarios, the decision as to which scenario to adopt, which measures and actions to take and what compensations to be given to those adversely affected.

The Drought Mitigation Plan shall be prepared and applied by a Drought Management Committee in which all stakeholders shall be represented, after approval by the Government. This Committee shall be established and continue to exist as long as there is a drought. It is the objective of the Drought Preparedness Plan in conjunction with a sound technical water management plan to reduce drought impacts to a minimum.

The hydrological risk analysis model as outlined above has been applied to the Paphos Irrigation Project for the period 1988-2005 and the findings concerning the project water shortages were found to agree with the actual conditions. The various measures were approved by the Drought Management Committee within the central Government and the actions were implemented by the water managers in charge of the operation and maintenance of the project.

2. Greece

> This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
> Chapter 16: Application of the Drought Management Guidelines in Greece

The planning framework

Drought events in Greece

Greece is a country often affected by droughts. No concrete strategies for drought mitigation have been developed, but the Greek organizations have dealt with this phenomenon at times. However, the country needs an effective effort to rationalize the entire drought analysis, monitoring and mitigation system. There is a lack of scientific organizations, legal framework and operational capabilities to combat drought. It is also necessary to devise preparedness plans for achieving pro-active defence against drought. During historical droughts, water restrictions were imposed mainly on domestic water consumption. However, they need to be re-directed, since 84% of the water used in the country is consumed in the agricultural sector. There is a severe gap in the measures for combating drought. However, following Law 3199/2003 and the subsequent presidential decrees that harmonize the Greek legal water framework with the European Directive 2000/60, several scientific and technical commissions have been planned to analyse the occurrence and mitigation of droughts.

The Nestos and Mornos Basins

Drought characterization and operational management are analysed in the Nestos and Mornos Basins (Figure 4). The Nestos watershed is located in northern Greece. The total catchment area of 5184 km^2 belongs partially to Bulgaria (55%) and partially to Greece (45%), however the study presented here covers only the Greek part of the Basin. The Mornos watershed is located in central Greece. The entire watershed occupies an area of 1 025 km^2, while the study area covers 571 km^2. At the Mornos River, a dam was constructed in the late 70s to supply potable water to Athens greater area.

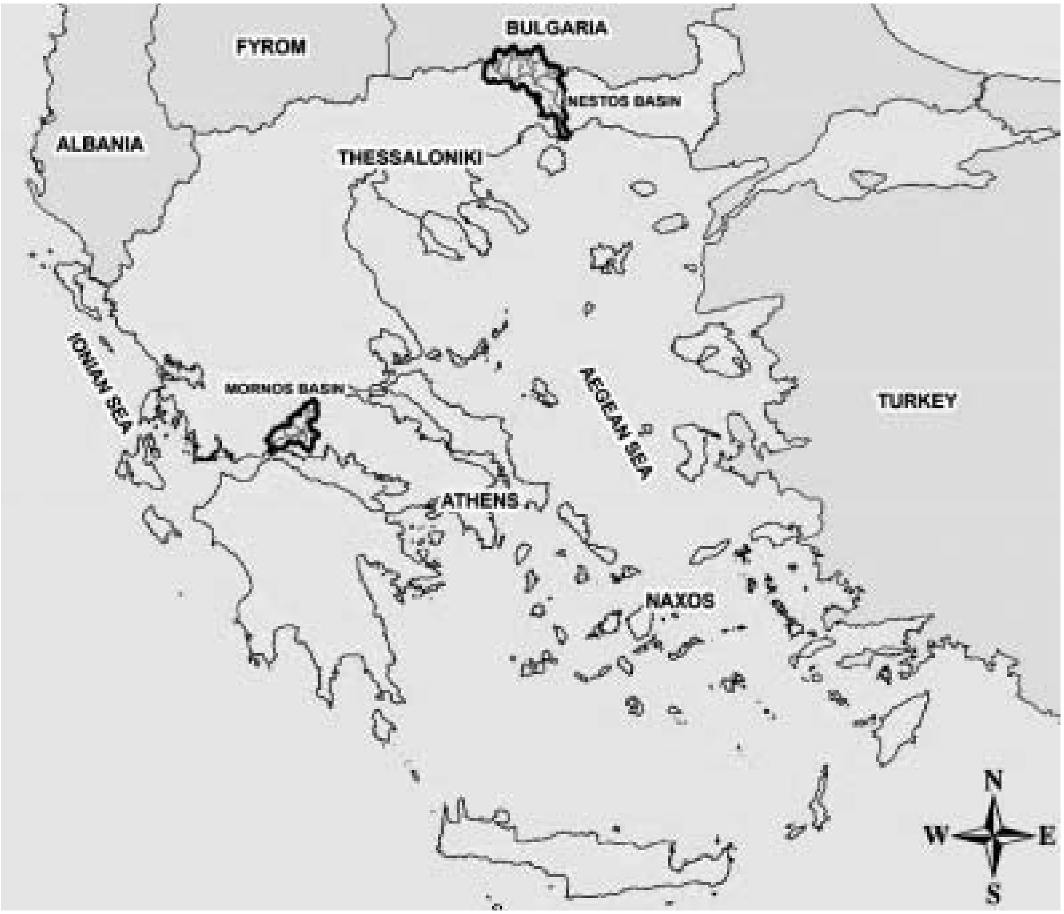


Figure 4. Map of Greece including the location of Nestos and Mornos River Basins

Organizational component

Legal framework

The key legal actions in Greece related to water and drought management are:

- Law 1739/1987 “for the Management of Water Resources”
- Law 1650/1986 “for the Protection of the Environment”, regarding the quality of water
- The European Directive 2000/60/EU “Establishing a Framework for Community Action in the Field of Water Policy”
- Law 3199/2003 of “Protection and Management of Water”
- The legal implications of the UNCCD (94) convention

Law 1739/1987 “For the Management of Water Resources” covered all issues related to water policy (research, organization, planning) by establishing procedures and structures that permitted water management on a national and a regional scale.

Law 1739/87 defines among others the River Basin Districts, the cardinal role of the Ministry of Development, an Intra-Ministerial Water Committee, Regional Water Committees, Regional Water Resources Management Authorities, water use-permits, the preservation and protection of water resources, disposal of waste water, disposal of industrial waste and disposal of low-quality water to aquatic recipients. The Law 1739/87 sets as primary goal the reservation of adequate water supply to satisfy the present and future demand for different water uses.

The European Directive 2000/60/EC imposes the need for adopting a new framework for water, fully compatible with its content. Law 3199/2003 is based upon the principles of this European Directive. This law establishes a framework for the achievement of a sustainable water policy and, as a consequence, of a sustainable development of the country. The law also establishes regional water councils, in which most of the stakeholders take part. The decisions on water resources of each basin are taken by the region in the territory to which the basin belongs.

Most of the articles of Law 1739/87 have been replaced by Law 3199/2003.

Although there are no specific articles regarding drought mitigation, it is implied that the bodies responsible for the water resources management will be also responsible for drought issues.

Specific measures of drought mitigation have not been legislated in the past in Greece. However, in 1994, Greece signed the Desertification Convention of the United Nations, which was ratified by the Greek Parliament in 1997. Within the implementation of this Convention, the National Committee to Combat Desertification (NCCD) was established and finally in 2002 the Greek National Action Plan (NAP) for Combating Desertification was developed.

In Figure 5 an organization chart of the services that concern water resources management in Greece is presented.

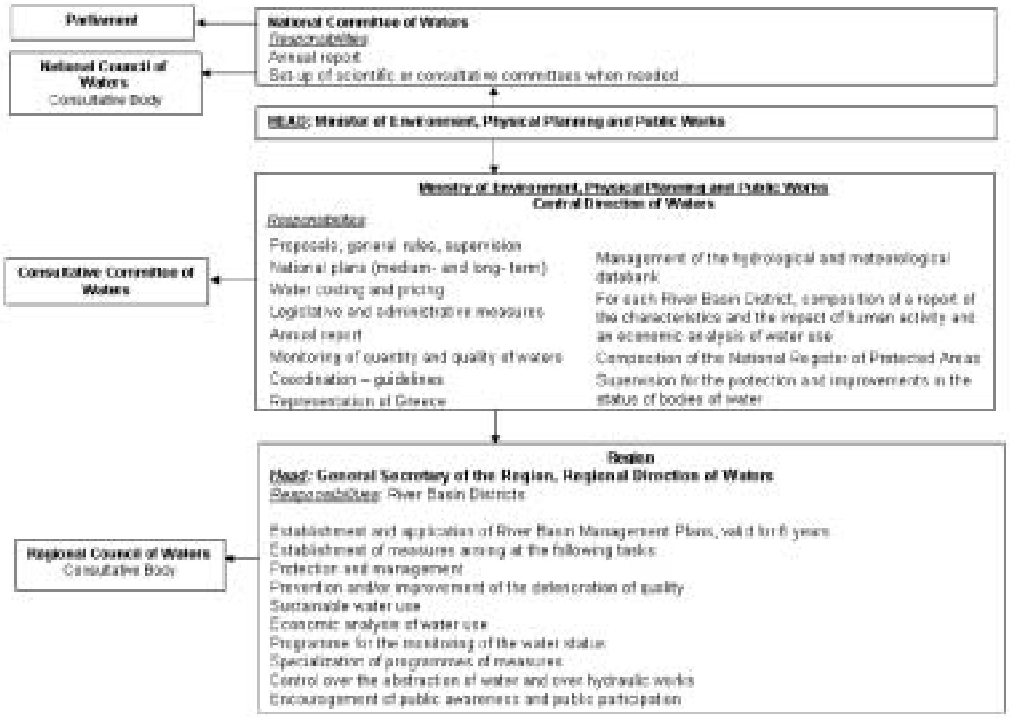


Figure 5. Organization chart of services concerning water resources management in Greece

Methodological component: Drought characterization and risk analysis

Intensity, frequency and duration of drought

Intensity, frequency and duration of drought were estimated at the Nestos and Mornos River Basins from historical records. Two well-known indices, the Deciles and the Standardized Precipitation Index (SPI), and a new index, the Reconnaissance Drought Index (RDI), were evaluated. The “run method” was applied for characterizing the areal coverage of drought.

Monthly precipitation data were collected at 10 stations within the Greek Nestos Basin with a record length of 32 years, and at 8 stations within the Mornos Basin with a record length of 39 years.

The Nestos Basin

All indices in all stations show a severe drought period during the years 1989-1993; a period documented as the most severe drought period over the last decades in Greece. The correlation between indices during this extreme drought period is high.

In order to characterize the statistical properties of drought, the following parameters were considered: duration, frequency and intensity. Drought frequency was estimated as the probability of non-exceedance for each precipitation station. Apart from duration, the drought spell of 1989-93 was also relatively severe for almost all the stations of the Nestos Basin. Furthermore, the northern part of the Basin experienced an important drought period during the hydrological year 1984–85.

The Mornos Basin

Drought is a recurrent phenomenon. In most years since 1987 the Mornos watershed has suffered from drought in almost all the stations.

During the most serious drought occurrence in Greece, throughout the period 1989-1993, the deficit reached 400 mm of annual deficit out of a normal 1245 mm per year. In August 1992 the Mornos reservoir had water to supply to the Athens greater area only for 40 days.

Drought effects on runoff

Medbasin software was used for the assessment of the reduction of streamflow for the above two case studies.

The methodology is based on the formulation of several climatic scenarios, derived from the alteration of the normal climatic conditions of the study area. A period of years with normal or near normal climatic conditions was defined (e.g. using a drought index). By applying the climatic scenarios for this period in the rainfall-runoff model, the percentage of the change of runoff compared to the normal value was estimated.

For the formulation of the climatic scenarios, the RDI was used in order to define the climatic conditions of the area. A period of eight years with near normal conditions was selected for using the rainfall-runoff simulation model.

The input data were the average monthly values of precipitation and potential evapotranspiration of the area, while for the calibration of the model the measured streamflow data at Temenos and Paskhalia stations were used.

About 120 climatic scenarios were created by altering the original precipitation and potential evapotranspiration data by different percentages up to -40% and +24%, respectively.

The streamflow reduction was calculated 20-35% for moderate drought conditions, 35-50% for severe droughts and up to 65% for extreme drought conditions.

Potential impacts of drought

The most significant impacts of drought in the Nestos and Mornos Basins refer to streamflow reduction and reduction in agricultural production. In addition, in the Nestos River Basin an important effect on the wetland ecosystem and biodiversity loss was observed. In the Mornos River Basin the pressure on the water supply system of the city of Athens was a very significant issue.

Operational component

Table 3 summarizes the levels of drought management in Greece and the actions corresponding to each one of the levels.

Table 3. Drought planning and operational actions to manage drought in Greece

Component of drought planning	Operational actions
Preparedness master plan	1. Ongoing monitoring and early warning 2. Definition of the responsible officials for the action to be taken 3. Definition of the time to implement the action 4. Ensure laws are in place to take action 5. Ensure public participation
Actions in the short term (actions taken when drought is occurring)	1. Reduction of water demand - prohibition of use - pricing (not effective) - incentives to save water - advertising to raise public awareness - agricultural practices that save water 2. Increment of water supply 3. Monitoring
Practical examples	1. Improvement of the operational management of the water system 2. Use of emergency and auxiliary water resources 3. Emergency water transfers 4. Changes in rights of water use 5. Monitoring 6. Concrete applications in the city of Athens in the Mornos Basin

Actions in the short term

Two directions can be followed: Reduction of the water demand and increment of the water supply. In an urban environment, this may be achieved through the administrative actions along with new and sometimes even strict laws and essentially through the stimulation of public awareness. Regarding the rural environment, changes towards less water consumption in agriculture will lead to the desired results.

Emergency water transfers and diversions are another auxiliary solution with the condition that the source will not remain connected to the supply network after the crisis. Obviously, the disadvantage of this solution is the cost of construction of appropriate infrastructures, serving just for a short period of time.

Measures and actions to minimize the impacts of drought should be also considered. Minimization of water supply impacts should be made through water supply system adjustments. The same implies for the agricultural sector, while in the other economic sectors impacts may be minimized with direct and indirect public aid and the use of insurance policies.

Monitoring systems

The actions planned for drought mitigation will not be very efficient unless information on drought incidents on temporal and spatial scales are available or can be acquired. Such information can be obtained from monitoring systems. In brief, a monitoring system can provide information of the onset and termination of a drought episode, its severity and its spatial extent. An early warning system of extreme situations is a more useful tool, since it can provide the authorities with sufficient time in order to apply measures to prevent the situation. A warning system can be the result of a combination between a monitoring system and a weather prediction system.

Proactive and reactive plans and actions

Measures taken or planned that are compatible with the National Action Plan include the implementation of the plans for developing water resources at all levels, the establishment and operation of the regional water management services, the circulation of regulation decisions by prefectures to protect water resources in each river basin and the application of effective control on the infringement of the law and respective penalties, as well as the support for a more efficient operation of local land reclamation organizations.

The repairing and renovating of the irrigation networks, the application of integrated irrigation systems, the water recycling and re-usage is implemented through the plans of the Land Reclamation Directorate for facing drought as well as by the local land reclamation organizations.

According to the planned actions for combating drought, several proactive and reactive measures have been proposed. Such measures include the construction of dams and off-stream reservoirs in drought-prone areas. Other actions include the restoration of artificially drained lakes and the planned ambiguous diversion of the Acheloos River towards the Thessaly plain, which is threatened by desertification, the development and expansion of the National Data

Bank of Hydrological and Meteorological Information and the support of research for increasing available water supply.

The most relevant proactive actions in Greece include small earth dams for collection of rainwater, canal rectification to reduce water losses and modernization and improvements of irrigation networks.

The most relevant reactive actions in Greece include constraints in water consumption, intensification of the use of groundwater resources, reallocation of water resources, use of saline and brackish waters and water transfer.

Strengths and weaknesses of the current structure

No specific model for confronting drought and its consequences exists in Greece. The main strengths of the Greek institutional framework are:

- A National Data Bank of Hydrological and Meteorological Information (NDBHMI) has been established. Various software applications are linked to the central Database of the NDNHMI supporting the analysis and synthesis of the data and the elaboration of secondary information. A GIS subsystem was developed to support the spatial analysis of hydrological data.
- There is sufficient socio-economic data concerning water users, with the exception of incomplete information on agricultural water use.
- All institutions involved in drought preparedness and mitigation, have a good experience concerning recent drought episodes. Although there are no specific plans for drought mitigation in Greece, many government and other institutions are dealing with the effects of drought on a case to case basis.
- There is a sufficient number of reservoirs that are being used in drought situations and therefore the water reserves of the country are well managed.
- The domain of agriculture seems to have enough influence with the government and whenever irrigation farmers are affected by drought, the pressure exerted on the authorities has good results in order to combat drought.
- According to Law 3199/2003, all sectors affected by drought are represented in the National Council of Waters and the Consultative Committee of Waters.

The following statements address main weaknesses of the Greek institutional framework that stand out from the above analysis:

- Up to now there is neither an insurance nor a compensation policy provided by the legal framework for the rainfed or irrigated agriculture, in the case of severe droughts.

- No systematic monitoring of drought occurrence at regional scope exists in Greece.
- In the past, decisions concerning droughts were taken on a case to case basis. This approach is considered unsatisfactory and it is therefore necessary to elaborate a plan for drought mitigation, based on the structures described in Law 3199/2003 on Water Resources Management.
- Up to now, there has been a lack of information concerning the consumption of irrigation water by individual farmers.
- Although there are institutions and organizations with experience on the subject, there is no effective coordination among them and there is no managerial policy on a higher level from a central administration.
- No drought indices or any other objective scientific indices are used in order to assess drought severity.

3. Italy

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 18: Application of the Drought Management Guidelines in Italy

Introduction

In the last twenty years, Italy has experienced many drought events both in semiarid southern regions (where the greater variability of the hydro-meteorological variables and the limited amount of water resources with respect to increasing demands lay the basis to more frequent conditions of water deficit), as well as in the northern regions, characterized by humid climate and a large amount of water resources.

Despite the severity of past droughts, in particular the event occurred during the period 1988-1990 and the most recent drought of 2002-2003, apparently very few lessons have been learned at political and institutional level, since the prevalent mitigation approach remains reactive, with a preference to managing emergency situations rather than preventing them through an integrated approach to drought management.

Organizational component

The Italian institutional legal framework related to drought management

So far, drought management in Italy has coincided with management of water emergency due to drought, within the policy for coping with natural disasters. Generally, ad hoc measures have been implemented to face emergency conditions. For instance, during the drought event of 1988-90, the Department of Civil Protection, which has been entrusted with the task of coping with drought, has defined and implemented contingency interventions (generally structural measures, such as: deepening of wells or construction of new ones, extraordinary maintenance of the main hydraulic infrastructures, temporary allocation of water resources for irrigation purposes to drinking/municipal use, etc.).

Recovery of agricultural damage due to drought is based on the Declaration of Natural Disaster by the Agricultural Ministry and, then, by financial aid from the National Fund of Solidarity. Regional governments request the Declaration of Natural Disaster, following the indications provided by the provincial agricultural offices, based on the assessment of crop damage. Funds are managed by regional institutions through the agricultural provincial offices, and allocated among farmers affected by drought, as contributions to increase insurances.

During recent droughts, Commissioners for Water Emergency have generally been appointed by the Prime Minister. This is the case of the Basilicata and Apulia regions, where two Emergency Commissioners were appointed after the declaration of water emergency following the 2001-2002 drought, with the objective of drafting a programme of actions to face water shortage situations, to accelerate the realization of hydraulic works in progress or already funded and to design and to construct necessary works for improving withdrawal, conveyance and distribution networks in each region. At the same time, the Acquedotto Pugliese, which supplies municipalities, on behalf of the Apulia Region established an Emergency Plan to face the likely situation of all reservoirs emptying completely.

With regard to the drought event that affected the Po River Plain in 2003, a different approach was adopted, by constituting a permanent task force with representatives of all the institutions involved in water resources management (in particular, pre-Alpine lakes and reservoirs for hydropower use) and institutions involved in the management of irrigation districts, through the activity of the Po Basin Authority. In particular, in June 2005 a formal preliminary agreement was signed to define common indicators of water resources status, to assess the water balance for the whole Basin and to develop simulation models and a database.

A positive example of a proactive approach to drought in Italy is represented by the Water Protection Plan of the Emilia Romagna Region that has identified vulnerable areas to drought, both on the basis of previous studies carried out by the Basin Authority, and on the basis of the spatial distribution of the drought index SPI. This Region has also defined protective actions in four categories: a) Soil protection; b) Sustainable water resources management; c) Impact reduction of productive activities and d) Reorganization of the territory. Moreover, criteria for drought management programmes in municipal, agricultural and industrial fields are defined. Moreover, a preliminary document to prepare a "Drought Management Programme", foreseen by the Water Protection Plan of the Region has been drafted. Such a programme will define the activities related to drought (i.e. monitoring, identification of alert and emergency conditions corresponding to the activation of specific measures, public campaigns to increase awareness, etc.) to be carried out at a regional level, as well as to address the actions of the local institutions involved.

Besides, other regions, which have experienced the inadequacy of the reactive approach to drought management, are attempting to adopt a proactive approach. For instance in the Sardinia region, after the severe droughts of 1987-1994 and 1997-2002, as a result of the increased awareness on the vulnerability of water supply systems, a regional law for reorganizing water resources management has been proposed, aiming at a clear distinction between competences of water governance and control (by the Regional Agency as support to the Hydrographic District Authority) and competences related to operation and maintenance of water supply systems (by the Regional Agency of Water Supply Management).

Proposals for a more effective drought prevention and mitigation

At national level an improvement of the Italian policy on drought management is required. In fact, the indications given by the current legislation to identify the areas prone to drought risk within the municipal water supply system (Decree 47/96) and to define the areas vulnerable to drought and desertification to be considered within the Regional Water Protection Plans (Legislative decree 152/99), have not been widely implemented in real planning processes. In particular: (i) the necessity of a proactive approach to face drought consequences efficiently does not seem to be widely shared, (ii) a clear distinction between long term and short term measures for drought impact mitigation is lacking, and (iii) the assignment of competences among institutions in charge of planning, water supply agencies, and Civil Protection Agency, or other bodies in charge of emergency management, is ambiguous.

Taking into account the European Water Framework 2000/60, as well as the distinction between water governance and management competences, a proposal to improve the legislative framework on drought management planning processes has been developed (Rossi, 2004), including three main planning tools, namely: (1) Strategic Shortage Preparedness Plan, (2) Water Supply System Management Plan under drought conditions, and (3) Drought Contingency Plan. A few detailed contents follow.

Strategic Shortage Preparedness Plan, whose institutions in charge are the Basin or the Hydrographic District Authorities, should provide:

- criteria to identify drought vulnerable areas;
- appropriate long-term interventions for water supply systems;
- definition of the priority in water allocation under shortage conditions among different users (e.g. municipal, agricultural and industrial);
- definition of acceptable levels of water rationing;
- criteria to compare alternative drought mitigation measures;
- strategies to ensure adequate public information on drought problems.

The main contents of the Water Supply System Management Plan prepared by management agencies of each supply system for a specific sector or multipurpose supply should refer to:

- definition of drought indicators for three different risk levels: pre-alarm, alarm and emergency;
- definition of measures (mixture of long term and short term) to be implemented to avoid emergency conditions;
- cost assessment of the measures and indication on the sources of financing;
- strategies to improve stakeholders’ participation and public awareness.

Finally the Drought Contingency Plan, whose institutions in charge are the Basin Authority or the Regional Government, represents a planning tool which identifies short term interventions to be adopted in drought conditions. In particular, it provides:

- drought indicators for calamity declaration;
- indications on the establishment of an Institutional Committee for coping with drought (e.g. Drought Task Force);
- list of short term drought mitigation measures (to increase water supply, to reduce water demands and to minimize drought impacts) with relative costs;
- special directives for coordinating actions among National Government, Regional Government and water supply agencies;
- strategies to improve stakeholders' participation and public awareness;
- list of actions to recover drought damage.

The drought management planning process described is illustrated in Figure 6. The planning process has to be dynamic in order to succeed in its purpose; therefore a review of the plans is necessary either periodically (e.g. every 5 years) and after each drought period, by evaluating: the performance and suitability of drought indicators to define threshold levels, the real effects of long term and short term measures and the effective implementation of the plan.

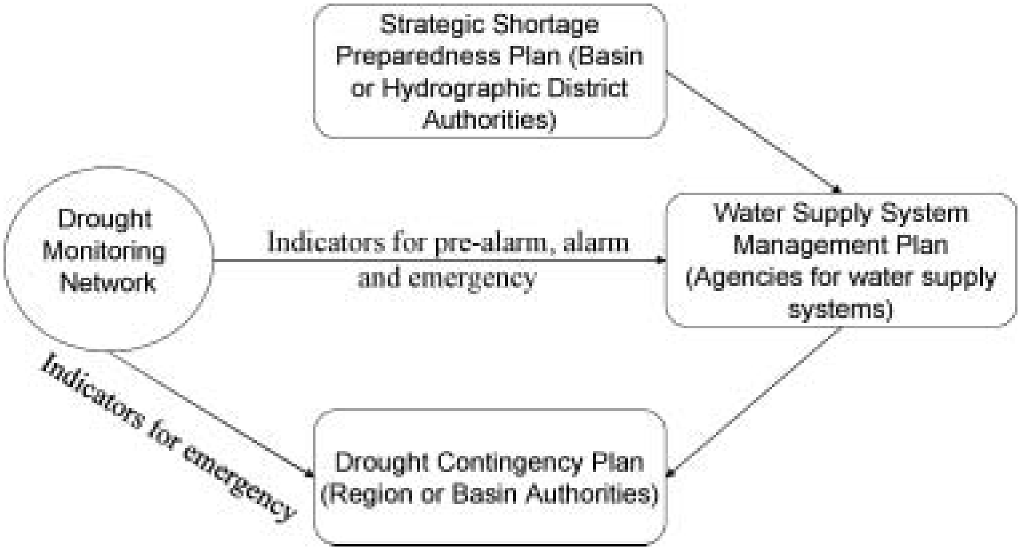
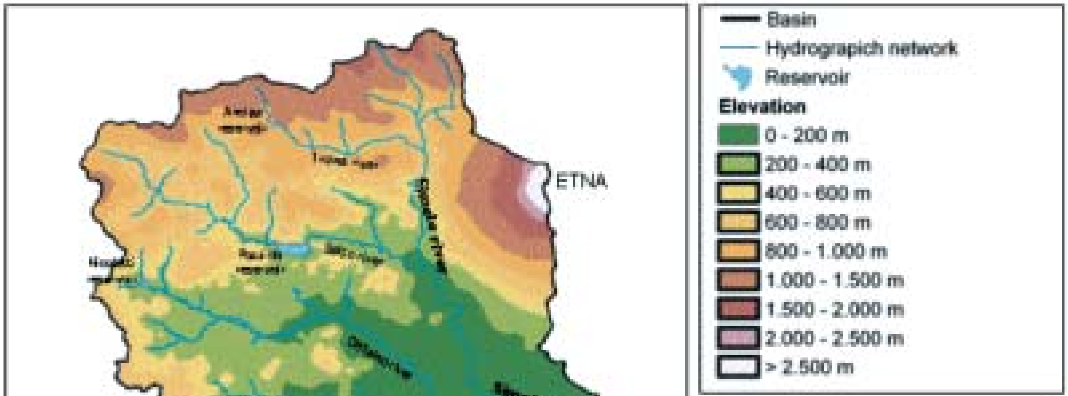


Figure. 6. Drought management planning process

Methodological component

The Simeto Basin case study

The Italian case-study selected for the application of the methodological component of the Guidelines within the Medroplan project is the Simeto River Basin (see Figure 7), located in Eastern Sicily. The climatic conditions are typical of a Mediterranean semi-arid region, with a moderately cold and rainy winter and a generally hot and dry summer.



Area	4079 km^2
Mean elevation	545 m a.s.l.
Max elevation	3274 m a.s.l.
Min elevation	0 m a.s.l.
Main stream length	116 km
Main slope of stream	0.70%
Main slope of basin	6.60%

Figure. 7. The Simeto River Basin

The Basin includes various agricultural, municipal and industrial uses and is mainly supplied by a set of multipurpose plants for regulation and diversion of streamflows. The current water supply system can be divided into two sub-systems: the Salso-Simeto system and the Dittaino-Gornalunga system. The main features of the reservoirs of the Simeto water supply system are summarized in Table 4.

Table 4. Reservoir storage capacities, watersheds and annual average inflows of Simeto water supply system reservoirs

Reservoir	Surface area (km^2)		Storage capacity (10^6 m^3)	Annual average inflows (10^6 m^3)
	Direct basin	Tributary basins		
Ancipa	51	58	27.8 (9,3*)	52.8
Pozzillo	577	–	123	92.3
Lentini	16	1086 + 341	127	96.4
Don Sturzo	171	285	110	31.58
Nicoletti	49.5	13 + 42	17.4	22.73

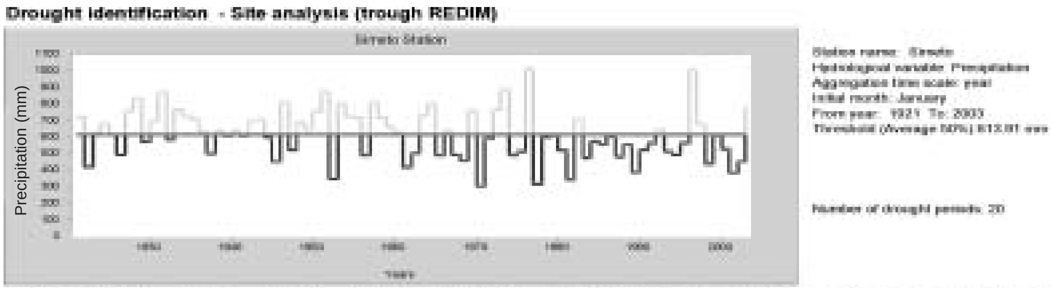
**Operational constraint.*

Drought identification and characterization

The methodology for the identification and characterization of drought has been carried out by means of several indices commonly adopted to monitor drought (e.g. SPI, Palmer index, Run method). Furthermore a method for the estimation of the return period of droughts has been developed and applied. Such a method is based on the probability distributions of drought characteristics, whose parameters can be derived from the distribution of the underlying hydrological series and the threshold adopted for the drought identification through the run method.

Figure 8 illustrates an example of drought analysis carried out for the Simeto Basin. For each drought event identified through the run method, beginning and final year, drought characteristics (duration, cumulated deficit and intensity [that is calculated as cumulated deficit / duration]) as well as return periods for several characteristics of drought are reported.

The results of the drought identification and characterization analysis have shown that the most critical drought event, either for duration or severity, was the one that occurred during the second half of the 80s and the early 90s. Also, the most recent drought of 1999-2002, despite its shorter duration, has been perceived as an extreme event characterized by a wide spatial extent.



N	Begin	End	Durat. [years]	Cum. Def. [mm]	Drought Int. [mm/year]	Tr(L=l) [years]	Tr(L>=l) [years]	Tr(D>=d) [years]	Tr(L=l,D>=d) [years]	Tr(L>=l,D>=d) [years]
1	1922	1922	1	189.84	189.84	8.58	7.55	8.39	61.67	8.57
2	1926	1926	1	123.43	123.43	8.58	7.55	6.23	24.70	6.20
3	1929	1929	1	39.29	39.29	8.58	7.55	4.46	10.09	4.32
4	1932	1932	1	29.47	29.47	8.58	7.55	4.32	9.45	4.20
5	1937	1937	1	116.38	116.38	8.58	7.55	6.04	22.59	6.00
6	1939	1939	1	6.79	6.79	8.58	7.55	4.06	8.63	4.03
7	1941	1941	1	6.49	6.49	8.58	7.55	4.06	8.63	4.03
8	1944	1945	2	181.81	90.91	16.13	14.19	8.09	27.39	9.70
9	1947	1947	1	90.55	90.55	8.58	7.55	5.62	16.55	5.52
10	1952	1952	1	267.25	267.25	8.58	7.55	12.10	159.17	12.55
11	1956	1956	1	126.17	126.17	8.58	7.55	6.30	25.59	6.29
12	1961	1962	2	312.21	156.11	16.13	14.19	15.05	88.57	16.29
13	1965	1965	1	127.16	127.16	8.58	7.55	6.33	25.92	6.32
14	1967	1968	2	275.60	137.80	16.13	14.19	12.60	61.00	13.98
15	1970	1971	2	329.82	164.91	16.13	14.19	16.42	107.77	17.64
16	1974	1975	2	230.16	115.08	16.13	14.19	10.13	40.00	11.52
17	1977	1981	5	689.83	137.97	107.07	94.14	103.30	539.97	121.36
18	1983	1991	9	823.28	91.48	1335.45	1174.21	208.38	1744.18	730.45
19	1993	1995	3	268.62	89.54	30.32	26.66	12.18	46.82	17.64
20	1998	2002	5	662.11	132.42	107.07	94.14	89.38	445.58	109.45

Figure 8. Drought characteristics of of drought events occurred in the Simeto Basin. Tr: Return period for different drought characteristics; L: duration; D: Deficit; d: Deficit threshold

Drought risk analysis

The methodology for the unconditional and conditional risk assessment has been applied to the Salso-Simeto water supply system that includes two dams, Pozzillo on the Salso River and Ancipa on the Troina River, and one intake located on the Simeto River. In addition, the Lentini reservoir is connected to the system via the Ponte Barca intake on the Simeto River.

Streamflow data include 40 years (1959-2000) of reconstructed streamflows at the Ancipa and Pozzillo reservoirs and Barca diversion while annual demands to the system have been estimated as follows: municipal demand from Ancipa reservoir 23.5 10^6 m^3/year, irrigation demands 121.4 10^6 m^3/year and 3.4 10^6 m^3/year for the Catania Plain (LRC9) and Enna (LRC6) respectively. Furthermore, instream flow requirements equal 9.1, 6.4 and 39.1 10^6 m^3/year downstream from the Pozzillo and Ancipa dams and Barca diversion respectively have also been considered.

In order to perform both the unconditional and conditional risk assessment the calibration of a stochastic model for the generation of a streamflow series is needed. In particular to save the lag 0 monthly cross correlations between the three streamflow series (Pozzillo inflow, Ancipa inflow and Barca streamflows) the stochastic modeling of the three series has been carried out by means of a seasonal multivariate model, able to take into account the cross correlations, as well as their seasonal variability from month to month.

Simulation of the system has been carried out by means of a specifically developed model particularly devoted to simulating the behaviour of the water supply systems as result of the implementation of drought mitigation measures according to a specified plan.

Three different hydrological states namely normal, alert and alarm have been defined as a function of the available storage in reservoirs. For each simulation step the volume stored in the system has been compared with the defined monthly triggers to activate the mitigation measures relative to the current state of the system.

For the Salso-Simeto water supply system the simulation of the system in normal conditions has been performed according to the following operating rules:

- Target storages are imposed at Pozzillo and Ancipa reservoirs.
- Municipal demand has the highest priority over the other demands and up to a percentage equal to 90% is not affected by target storages (i.e. 90% of the demand will be released regardless of the target storages).
- A water transfer of up to 8 10^6 m^3/month from Ancipa to Pozzillo is activated during the winter months if the volume stored in Ancipa is greater than 85% of its capacity.
- Instream flow requirements are released from the reservoirs and the diversion. If the upstream inflow is less than the instream flow requirements, the whole upstream inflow is released.
- During the winter months, a water transfer from Barca to Lentini is activated up to 11.7 10^6 m^3/month.

Mitigation measures adopted in correspondence to the different states of the system have been set as follows:

<u>Alert</u>

- Relax target storage requirement for Ancipa reservoir.
- Restrictions on irrigation.
- No irrigation release from Ancipa.

<u>Alarm</u>

- As Alert + relax instream flow requirement.

Both unconditional and conditional risk assessment of the Salso-Simeto water supply system has been carried out through two sets of simulations. In the first case, no mitigation measures have been considered, i.e. the system has been assumed to be always in normal conditions. In the second case mitigation measures have been activated as mentioned previously. Simulations have been carried out with reference to 500 generated series with the same length of the historical one (42 years) for the unconditional risk assessment and 36 months for the conditional.

Results analysis has been carried out both by means of the traditional performance indices (time-based reliability, volume-based reliability, mean average deficit period length, max. monthly deficit, max. annual deficit, sum of squared deficits) and through graphs showing the frequency of deficits of a given severity as a result of the Montecarlo simulations.

In the case of unconditional risk assessment Figure 9 shows monthly frequencies of shortages for irrigation demand as results of the simulation on generated series with and without the activation of mitigation measures.

Implementation of mitigation measures produces in general almost the same monthly frequency of deficits of the simulation without mitigation measures but decreasing the class of shortage.

In the Monte Carlo simulation without the activation of mitigation measures (a) deficits belonging to the class of more than 75% of demand appear for almost all the months of the irrigation season whereas in the case of the Monte Carlo simulation with mitigation measures (b) the frequency of deficits belonging to that class decreases, globally lessening the amount of deficit during the whole irrigation season.

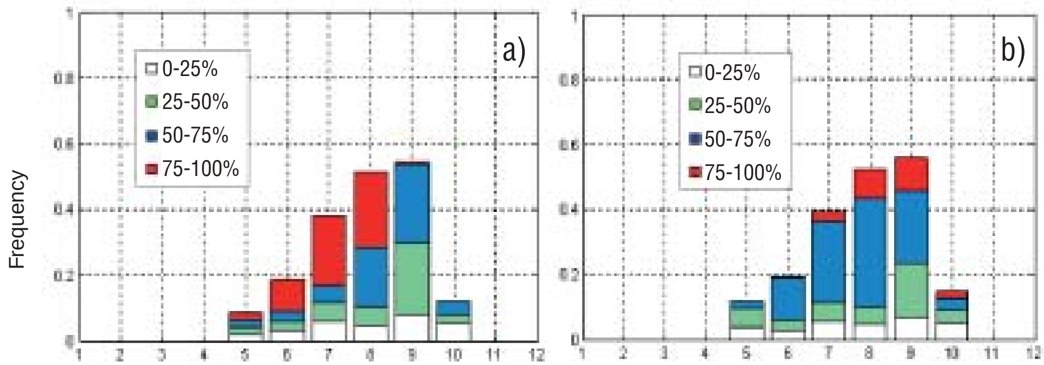


Figure 9. Unconditional risk assessment: Monthly irrigation deficit frequency (in LRC9) without mitigation measures (a) and with mitigation measures (b)

In the case of conditional risk assessment the initial condition that the system presented in correspondence of a particularly severe historical drought event (March 1989) has been considered. Starting from this initial condition Monte Carlo simulations have been performed considering a 36-month time horizon. Figure 10 shows that due to the fact that mitigation measures are particularly devoted to the satisfaction of municipal demand, the reduction of severe deficit for irrigation demand is not as high as for municipal demand, nevertheless it is worth noticing that starting from the second simulated irrigation season, activation of mitigation measures results in a general decrease of the frequency of deficit. Better results obtained for municipal demand both in terms of frequency and severity of deficit are shown in Figure 11.

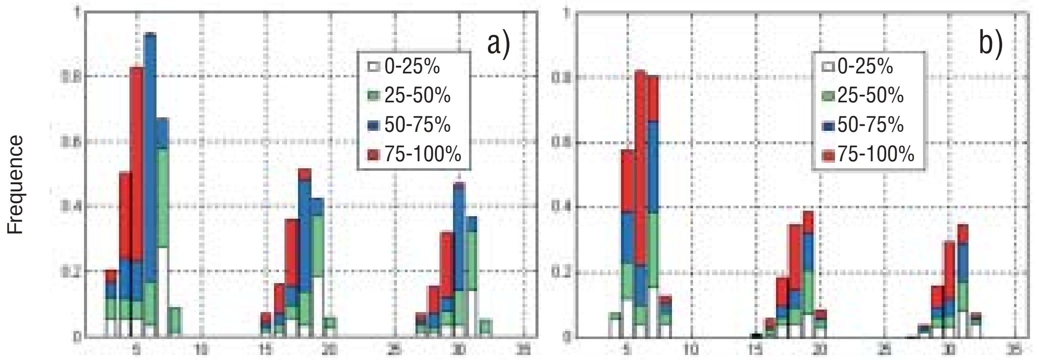


Figure 10. Conditional risk assessment: Monthly irrigation deficit frequency (LRC9) without mitigation measures (a) and with mitigation measures (b)

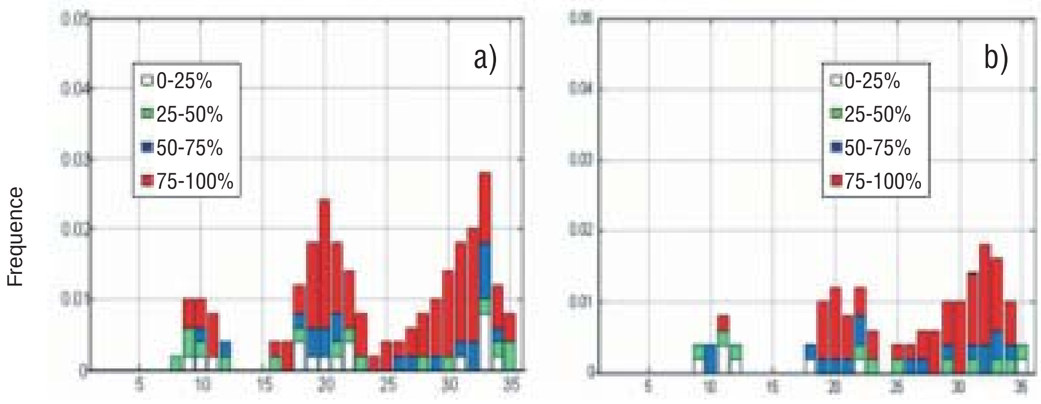


Figure 11. Conditional risk assessment: Monthly municipal deficit frequency without mitigation measures (a) and with mitigation measures (b)

Operational component

Mitigation measures adopted in the past to mitigate drought impacts on agriculture can be divided in two classes: actions undertaken by Land Reclamation Consortia and private actions. In particular, the main actions undertaken in the Simeto River Basin by Land Reclamation Consortia of Catania, Caltagirone, Siracusa and Enna, were:

- Priority allocation of available resources for agricultural use in Ancipa and Pozzillo reservoirs to perennial crops (i.e. citrus trees) and water rationing for annual crops.
- Maintenance of canal networks for reducing water losses.
- Projects to transform the canal network (conveyance and distribution) in pipelines.
- Projects of emergency pumping plants of water stored in the Lentini reservoir (currently not operational).
- Projects of public ponds to improve the operation of irrigation systems.

Private farmers have implemented two different types of mitigation measure to cope with drought in irrigated agriculture:

- Measures to increase preparedness for water scarcity:
  - Introduction of more efficient irrigation techniques (micro-irrigation).
  - Construction of farm ponds (to be filled by water delivered by the consortium before the irrigation season starts and/or by private wells).
  - Reduction of irrigated areas for annual crops.
- Measures for coping with drought:
  - Deepening of existing wells.
  - Construction of new wells.
  - Water transfer by trucks (in extreme cases and for small farms).

Also financial benefits for the farmers related to the “natural disaster declaration” by the national or regional government are to be mentioned, even if they have been insufficient to cover damages during the past drought periods.

Among the main actions undertaken at regional level, it is worth mentioning the activities carried out by the Regional Hydrographic Service of Sicily (UIR). In particular, a real time hydro-meteorological network, including 230 gauges to measure precipitation, temperatures, water levels and other hydrometeorological features (wind velocity, humidity), 40 gauges to measure the water level in the aquifers and 23 gauges to monitor the storage volumes in the most important Sicilian reservoirs, has been developed in 2000. Besides, a web-based monthly bulletin for drought monitoring (www.uirsicilia.it) has been developed by the Department of

Civil and Environmental Engineering of Catania University, with the aim of providing the agencies in charge of water management with the information necessary to adopt appropriate drought mitigation measures and to reduce drought vulnerability of water supply systems.

Finally, campaigns for increasing population awareness to water saving, either at municipal or regional level, have been promoted by the Sicilian Regional Government.

4. Morocco

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 19: Application of the Drought Management Guidelines in Morocco

The main feature of the Moroccan agricultural economy is its climatic variability, in particular drought. In fact, most of the Moroccan land is arid or semi-arid. Rainfall is low and highly variable from one season to another and within the crop year. Although drought is not a recent problem, its frequency has been increasing in the last twenty years. Preliminary analysis of some longer tree-rings series over 1000 years, suggested that Morocco often knew in the past periods of intense drought. Since 1896, twelve main very dry periods which were generalized in most parts of the country and had moderate to strong intensities were 1904-05, 1917-20; 1930-35; 1944-45; 1948-50; 1960-61; 1974-75; 1981-84; 1986-87; 1991-93; 1994-95; and 1999-2003.

The planning framework

Economic and social impacts of drought

In Morocco, agriculture provides a livelihood to 43% of the economically active population and contributes around 15% of gross domestic production (GDP). Consequently, drought episodes have a multiplier effect on overall economic activity, with serious consequences for incomes and dramatic social and environmental impacts. For example, the drought of 1995 decreased cereal production from 9.6 million tons in 1994 to 1.7 million; it reduced employment by 60% and led to a reduction of 50% in agricultural added value, as compared to the 1989-1994 average. The rural development strategy has mainly focused on improving the modern irrigation sector which consumes, on average, 85% of available water resources (as low as 60 to 70% in a dry year) while 12 and 3% of resources are respectively used for public water supply and industry. The whole irrigated area contributes 45 % of the agricultural GDP and produces 75% of the agricultural exports.

Water scarcity

The uneven and erratic nature of rainfall in Morocco compounds the challenges associated with the uneven geographic distribution of water resources and makes the country highly susceptible to inter and intra-annual long periods of drought. This creates highly variable surface flows and threatens water supplied to households and farmers alike. Water resources per capita are estimated at 700 m^3/person/year only, which is well below UNDP's scarcity criterion of 1000 m^3/person/year. Moreover, by 2025, per capita water resources will be below the absolute threshold of 500 m^3/person/year.

Purpose and process

The challenges associated to water scarcity, long and periodic droughts and increasing water demands led the Moroccan Government to recognize that greater attention needs to be paid to the conservation and protection of water resources and to increasing on- and off-farm water efficiency. With the new 1995 water law, the emphasis changed from heavy investments in water resources developments, which was almost complete, to integrated water resources management through better water use efficiency, resource allocation practices, and protection of water quality. Learning from the recent drought episodes also led to moving from crisis to proactive drought management.

Organizational component

Legal framework

The 1995 Water law constitutes the main water legal framework in modern Morocco. It recognizes water as an economic and social good and establishes river basin agencies for more decentralized and participatory water management programmes.

Institutional water management

The main institutional stakeholders in the water sector are represented by the key ministerial departments including agriculture, water and environment, local collectivities (Ministry of Interior), health, energy and mines, and finance departments. NGO’s such as water user associations, and natural resources / environment protection associations are also actively operating in the country in response to civil society’s needs. Figure 12 resumes institutional water resources organization in Morocco.

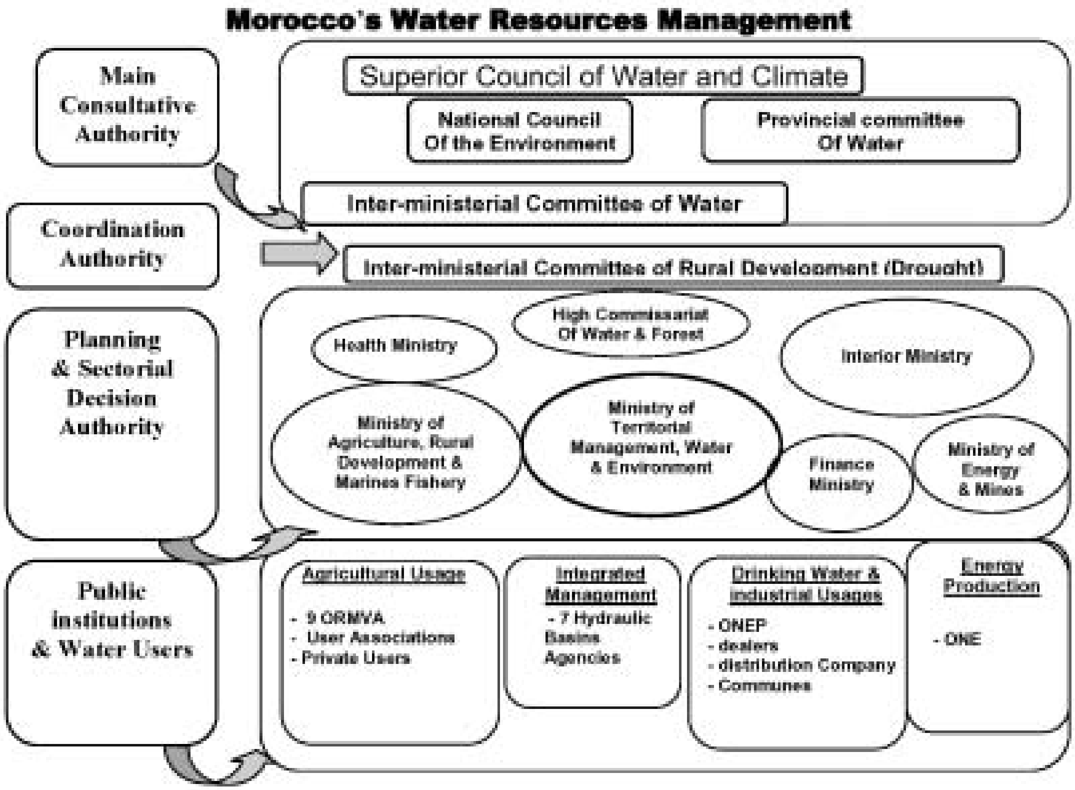


Figure 12. Institutional water resources organization in Morocco

Methodological component

THE NATIONAL DROUGHT CONTEXT

Meteorological and hydrological drought

Preliminary analysis of some of the longer and more climatically sensitive Moroccan tree-ring series suggest the appearance of about 20 years in the recurrence of historical droughts (defined as tree-ring value of 70% of normal or less). Concerning recent droughts at the national level, Morocco often experienced periods of intensive droughts. Since 1896, 12 main very dry periods which were generalized in mosts parts of the country occurred with moderate to strong intensities.

Two recent drought periods (1980-85 and 1991-95) were analysed at regional level showing that the global balance of the 2 periods varies between a precipitation deficit of -29% on the Southeast of the Atlas chains to - 60% on the rest of the country. Maximal deficits affected more particularly the regions of the North, the Oriental (-60%) and the Oceanic plains of the Northwest (-55%).

Impacts of recent droughts

The recent drought episodes from 1980-81 to 1985-86, 1991-92 to 1994-95 and 2000-2001 to 2002-2003 engendered net declines of dam's water reserves, deficits in subterranean water resources, and limitations in drinking water and irrigation water supply. Drought effects resulted also in the degradation of water quality in terms of increased water pollution leading to fish death, dysfunction or interruptions in the service of drinking water treatment plants, and increase of waterborne diseases. Hydroelectric production underwent drought impact because of water stock decline and fall height of all dams. Finally, drought episodes greatly affected agriculture production, livestock and their contribution to overall gross domestic production (GDP).

Analysis of drought using drought indices and modelling tools

The drought indices and modelling tools mostly used in Morocco for monitoring and prediction purposes are:

- The Deviation from Normal Precipitation.
- The Precipitation Deciles analysis.
- The Standardized Precipitation Index (SPI).
- The Surface Water Supply Index (SWSI).
- Modelling tools like the Ribasim Model.

RISK ANALYSIS IN AGRICULTURAL SYSTEMS: CASE STUDY OF OUM ER RBIA BASIN

The Oum er Rbia Basin is the main geographical unit selected to characterize drought events and to analyse the associated risks in relation to irrigated systems, rainfed agriculture and livestock. It is located in the centre of Morocco and extends over a surface of 35 000 km^2. The main irrigated areas of Tadla, Doukkala and Haouz perimeters depend on water resources of this river basin (Figure 13).

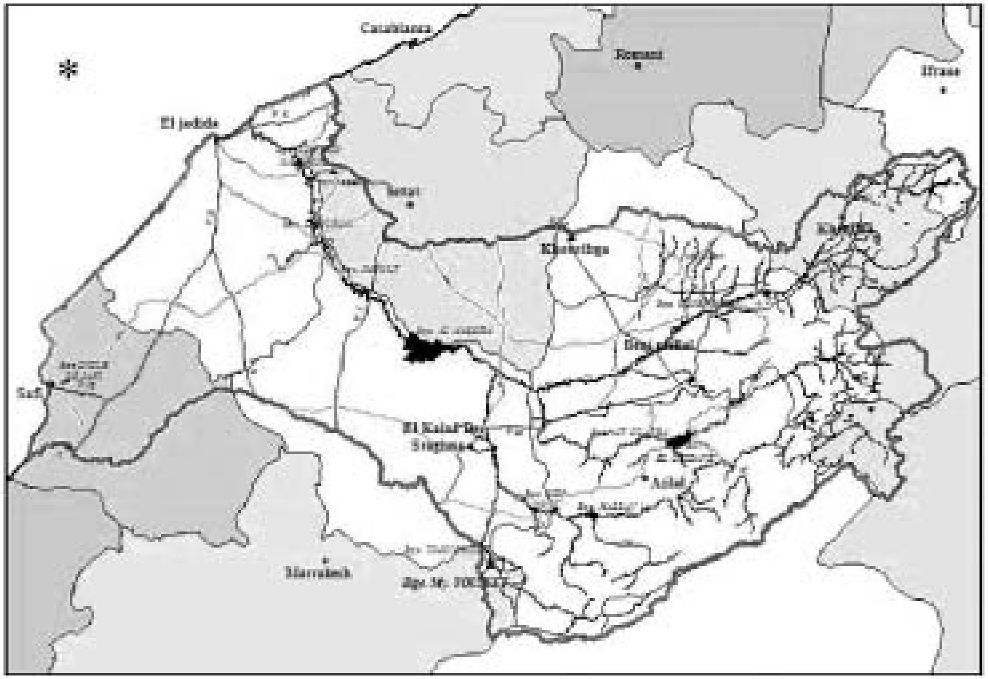


Figure 13. Oum Er Rbia Basin

Methodology for agricultural drought risk analysis and vulnerability assessment

Drought risk in agriculture is a product of both exposure to the hazard and vulnerability of cropping practices in drought conditions. Therefore, the first step is to characterize drought hazard and then to assess the vulnerability of the agricultural system to the degree of exposure to this hazard. Impacts vary depending on the type of production systems and here, focus is placed on rainfed cereal production systems in the Oum er Rbia River Basin.

Characterization of drought hazard in rainfed agricultural systems

To characterize drought years and their impact on cereal yields which represent appropriate drought indicators in rainfed cereal production systems, two methods are used. The first is based on the yield threshold for profitability. The second is based on the cereal production regression line over time.

Spatialization of drought hazard

For an adequate interpretation of the extent of drought within a given region and/or a comparison of drought intensities between regions and/or the mapping of seasonal drought intensities, SPI is best suited.

Drought vulnerability assessment

Probability of seasonal crop moisture deficiency, soil root zone available water-holding capacity and land use maps were combined to produce an agricultural drought vulnerability map of the Basin; GIS was used to determine the area extent of combinations of classes present. The output map contains four classes of vulnerability: "low", "low to moderate", "moderate" and "high" (see Figure 14). However, drought vulnerability should also include socio-economic data such as sources of income and percent of acreage under crop insurance. The map of drought vulnerability can help to adjust agricultural practices and select more appropriate cropping patterns in order to alleviate reduction in crop yields and income loss during drought years. Vulnerability maps are also important tools to orient policies, strategies and actions at national, regional and local levels.

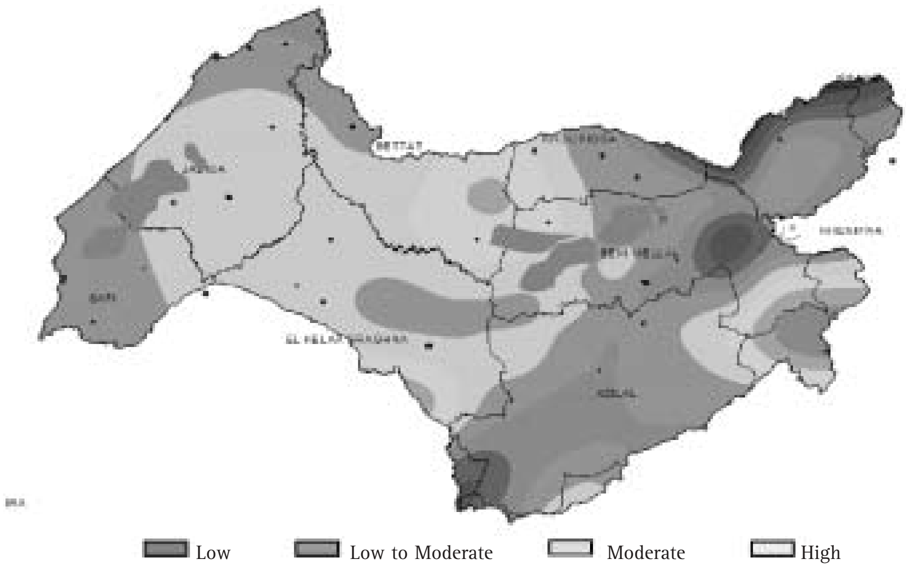


Figure 14. Agricultural drought vulnerability of Oum Er Rbia Basin

Operational component

Overall coordination of drought management issues is the responsibility of the Permanent Inter-Ministerial Council for Rural development (PICRD) which represents the political board and has the ability to officially declare the onset of drought. National advisory and executive boards and regional and local settings of drought managers represent the other operational actors of drought management.

How to shift from reactive to proactive plans of drought?

Because of the severe droughts of the last 30 years, a reactive action plan was adopted in 1985 to mitigate the drought effects and focused initially on population drinking water and livestock relief. However, due to more dramatic subsequent development of droughts, the actual national programme for drought mitigation has 2 clear orientations:

- An operationally oriented short term programme with relief operations as the main focus.
- A structurally oriented drought planning programme focusing on the long-term proactive approach to drought mitigation.

REACTIVE DROUGHT MANAGEMENT

When a drought occurs nationwide, the policy so far applied consists of setting up a national drought programme to combat the deleterious consequences of drought. This is typically a crisis-management oriented approach whose cost is tremendous in terms of public money investment, time and human resource needs.

Meteorological drought and weather forecasts

Meteorological drought can be described in terms of reactive and proactive responses. Thus, series of triggers such as daily weather forecast, rainfall departure from normal and numbers of dry days are used to analyse the development of the drought situation whereas long-term weather forecast simulation models are used for a more proactive drought management approach.

Agricultural drought

A series of triggers such as meteorological indices, warnings from field survey reports, farmers complaints, regional/provincial authorities warning, decrease of food and water availability for livestock, decrease of drinking water supply engender different reactive answers related to priority needs (potable drinking water, livestock feed and water), support to household income (job opportunities, credit redemption), financing of agricultural activities, regulation of market (subsidized barley and food stuff), public awareness and communication.

Hydrological drought and water management

The General Hydraulic Directorate has the responsibility of surface and underground water resources mobilization and water storage in the dams. It also evaluates the water needs throughout the drought period with the relevant structures of agricultural sector and other users. The evaluation is regularly made on the basis of indicators concerning the average rainfall deficit across the country, the amount of water stored in dams and the situation of the main ground water tables.

Socio-economic drought

One of the major impacts of drought is the considerable loss of agricultural seasonal jobs and the risks of rural migration to urban areas. Thus, the government has included job creation activities in the national drought relief programme such as the organization and construction of country roads, operations of land improvement like land stone clearing, and irrigation management operations of small and average hydraulic structures.

PROACTIVE DROUGHT MANAGEMENT

In 1995, preliminary guidelines for a new approach to drought based on risk management principles provided the basis for a more proactive drought management approach. Drought risk management can be achieved by encouraging development of reliable climate forecasts and prediction, comprehensive early warning systems, preparedness plans, mitigation policies and programmes that reduce drought impacts and population vulnerability.

Working towards this end, the National Drought Observatory was created in 2001, and was conceived as a coordinating structure and also as a link between the scientific community working on various drought issues and the decision markers in charge of the drought mitigation activities. Its specific objectives are to:

- Collect, analyse and deliver drought-related information in a timely systematic manner.
- Characterize drought and define reliable indicators that can provide early warning on emerging drought conditions.
- Conduct vulnerability assessments to determine those sectors most at risk from the occurrence of drought.
- Establish criteria for declaring drought and triggering mitigation and response activities.
- Ensure timely, accurate assessment of drought impacts.
- Establish procedures to evaluate the effects and impacts of drought programmes.

However, there are still weaknesses to overcome, the most important being:

- Institutional constraints associated with the major restructuring of the ministry departments dealing with water management.
- Lack of availability of clear mechanisms for the circulation of information as required by the proactive approach to drought management.
- Lack of internal financial resources to meet the recurrent cost of the proposed activities for institutional capacity building in proactive drought management.

5. Spain

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 20: Application of the Drought Management Guidelines in Spain

The planning framework

Societal responses to drought

Drought can have serious effects on the economy and the environment of Spain and on the population's well being. The major drought of the mid 1990s affected over 6 million people, almost ten times more than the number of people affected by floods in Spain during the last fifty years. The economic damage caused by drought in Spain during the last twenty years is about five times more than in the entire United States. Drought events affect water supplies for irrigation, urban, and industrial use, as well as the health of the ecosystem, and give rise to conflicts among users that limit coherent integrated water resource management. Ecosystems are deteriorating and drought is a main issue. Deteriorating water quality parameters may not be acceptable for human consumption during drought. Reduction of wetland area (over 1200 km^2 in the 1970s to less than 800 km^2 in 2000, excluding the Guadalquivir marshlands) has been in part related to recurrent drought episodes and surface water scarcity, and amplified by excessive groundwater pumping to compensate for these problems.

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. 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.

The implementation of the new European Water Framework Directive (WFD) gives Spain the opportunity to develop integrated drought management plans that incorporate the extensive national experience in hydrological management with the new environmental challenges. Historically, urban, cultural, and agricultural development in Spain has demonstrated a profound knowledge of adaptation strategies to drought, water scarcity, and precipitation variability.

Drought, water scarcity and aridity are overlapping issues

Water resources are limited, scarce, and difficult to predict from year to year. Regulated water resources in Spain account for 40% of total natural resources, compared with 8% worldwide, since the potential use of surface water under natural regime is only 7%. 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. Water use is mainly for agriculture (over 68% of water demand), but other economic and social water demands are rapidly increasing, such as tourism (current urban demand is 13%) and ecosystem services.

Purpose and process

The Tagus Basin is currently developing a Drought Management Plan, which is integrated into the long-term strategies for water management. The elaboration of the Plan is the result of a complex process in which user participation is encouraged and stimulated. Once the Plan is drafted, it is submitted to public scrutiny, and concerned individuals and social or political groups can make allegations that are discussed and negotiated in the Water Council, where a majority vote is required for acceptance. If the drafted plan obtains a favourable vote, it is approved by Royal Decree, and is legally binding to all stakeholders.

The disagreements among stakeholders usually concern the timing of measures to be applied during drought. Users that are going to be benefited by measures, because their demands will be protected due to the high priority of urban supply, tend to encourage early action, even at the risk of incurring frequently in false alerts and unnecessary restrictions. Users whose demands are going to be restricted, because of lower priorities of irrigation or power production, tend to support the delay of the application of exceptional measures, even at the price of depleting the reserves completely.

To avoid conflict among stakeholders and ensure the effective application of measures, it is important that the rationale behind the measures proposed in the plan can be understood by all affected bodies, and therefore, special emphasis has been placed on developing a methodology to establish an objective link between quantitative drought indicators and concrete measures. The methodology involves a comprehensive analysis of alternative policies and an objective procedure to plan the ordered implementation of management actions based on quantitative drought indicators.

Organizational component

The case study (Tagus River Basin) and the national context

The Tagus River Basin is the geographical unit selected as the case study for the application of the MEDROPLAN Guidelines (Table 5 and Figure 15). The Tagus Basin is located in the centre of the Iberian peninsula, with a contributing area of 83,678 km^2, of which 55,870 km^2 are located in Spain and the rest in Portugal. The amount of water that has to reach the river in Portugal is determined by the international Albufeira regulation. The Tagus Basin also supplies water to the Segura Basin, a water-scarce basin in the eastern Mediterranean area of Spain.

Table 5. Total freshwater resources, available resources, demands, and water reliability in the hydrological basins of Spain

	Total Fresh-water Resources (km^3)	Available resources (km^3)(a)	Reservoir capacity (km^3)	Regulated water (%)(b)	Demand (% of available resources)	Irrigation demand (% of total demand)	Population (millions)	Total resources per capita (m^3/hab)
Norte (1)	44.2	6.8	4.4	15	37	42	6.7	6542
Duero (2)	13.7	8.1	7.7	60	47	93	2.2	6071
Tajo (3)	10.9	7.1	11.1	65	57	46	6.1	1784
Guadiana (4)	5.5	3.0	9.6	54	85	90	1.7	3298
Guadalquivir (5)	8.6	3.6	8.9	42	104	84	4.9	1755
Sur (6)	2.4	0.54	1.3	21	268	79	2.1	1135
Segura (7)	0.8	0.7	1.2	90	253	89	1.4	590
Júcar (8)	3.4	2.0	3.3	58	149	77	4.2	819
Ebro (9)	18.0	13.0	7.7	72	80	61	2.8	6509
Catalonia (10)	2.8	1.1	0.8	40	122	27	6.2	451
Baleares (11)	0.7	0.3		45	96	66	0.8	785
Canary Is. (12)	0.4	0.4		102	102	62	1.7	241
SPAIN	111.2	46.6	56.1	42	76	68	40.1	2728

(a) Surface and groundwater. Overall groundwater contribution is under 20 percent of total.

(b) Regulated water: rate of available resources from total natural resources.

Figure 15. Hydrological basins in Spain (see Table 5 for names)

Legal and institutional framework

The Spanish water codes and statutes derive from two main legal sources: the Spanish Constitution (1978) and the European Union Water Framework Directive (2000). These two legal bodies are at the top of the hierarchy of laws and statutes pertaining to water and droughts. Three instrumental laws are identified as the main precursors of drought preparedness and planning: The Water Law (2001), the Law of the National Hydrological Plan (2001) and the Agricultural Insurance Law (1978).

The analysis of drought risks is incorporated in the Law of the National Hydrological Plan, within the realm of agricultural and hydrological droughts, although there is room for improvement on the risk analysis within the contingency plans of the Hydrological Basins. Future adaptation options of the basin institutional framework to the requirements of planning based on risk analysis and strategies design, rather than work-based plans, remain a challenge for the future.

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 on the Ministry of the Environment. The Basin Authority includes in its organizational structure representatives of different regional and central administrations, water users and other stakeholders. The Ministry of the Environment also hosts the National Drought Observatory that provides updated general information.

Stakeholders and priorities

Table 6 summarizes the stakeholder groups that may compete for water during periods of drought and water scarcity.

Table 6. Stakeholders in the Tagus Basin

Stakeholder	Variable of interest	Preference and compromise
Farmers	Water to irrigation	More water May be willing to accept lower abstraction permits in exchange for lower price (or vice versa, may be ready to pay higher prices to obtain more water)
	Price of water for irrigation	Lower price Subsidies for switching to less water-demanding crops
	Dam and reservoir capacity	More capacity (decrease vulnerability to drought)
Environmentalists	Residual water	Well above minimum flow requirement
	Dams and reservoirs	No additional investment, to protect biodiversity Sustain ecological flow
Urban and rural dwellers	Secure access to safe water	Closer safe water sources Guaranteed minimum water quantity Participatory water planning
Urban water supply companies	Dams and reservoirs	Increase storage capacity Infrastructure
Basin Authority	Dams and reservoirs	Integrated resource management Evaluate storage capacity First priority is urban water supply Other uses and services of water may be negotiated
	Ecological water	Guarantee ecological services and flow requirements

Methodological component

Meteorological and hydrological drought

Drought characterization in highly regulated systems is complex and calls for multiple indicators. Time series of aggregated precipitation in Spain define meteorological drought episodes. The SPI and other indices have been used with important limitations when used in isolation, especially over short time periods. The applied methodology is based on a system of drought indicators and a list of pre-specified drought mitigation actions for every system. Executive drought indicators are used to declare drought scenarios, which are associated to the implementation of managing actions.

Data show a possible intensification of drought conditions in recent years, during the decades of 1980s and 1990s. However, since droughts were also important during the 1940s and 1950s, the question arises of whether drought has a multi-annual cycle of wet and dry conditions with a period of about 40 years or whether recent droughts are a consequence of man-induced climate change.

Hydrological risk analysis

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 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 monitoring tool. Executive variables are objective indicators that are used to trigger specific actions in an operational context.

Two types of analysis are performed: Probabilistic and deterministic.

a) 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.

b) Deterministic analysis

From the perspective of user involvement in the process, the presentation of probabilistic results is always faced with reluctance. 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: (1) Definition of characteristic droughts; (2) Definition of drought thresholds; and (3) Validation of the model.

The cumulative distribution of annual flows in the system can be 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%. According to this, three scenarios are defined to link risk evaluation with operational aspects:

- Pre-alert scenario: The stored water volume can satisfy 90% of the urban water supply demand and 80% of the irrigation demand during at least 1 year.
- Alert scenario: The stored water volume can satisfy 80% of the urban water supply demand and 60% of the irrigation demand during at least 1 year.
- Emergency: The stored water volume can satisfy 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. There are three severe drought episodes in the historic record in which the reservoirs of the system are 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.

Operational component

The operational effectiveness of the drought management plan is greatly enhanced if the selected measures for every system are grouped. In the Tagus Basin Plan, drought management strategies are grouped in three scenarios, corresponding to increasing levels of severity: Pre-alert, alert, and emergency scenarios. The Basin drought policy is 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, prevention of leaks, or revision of rules for the operation of infrastructure.
- 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. Drought measures focus on conservation and protection of stored resources, activation of additional resources or monitorization of indicators of water quality.
- Institutional. 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. 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.

The operational implementation of the plan requires a connection between the system of drought indicators and selected measures. To avoid untimely negotiations, the drought plan contemplates the activation of the set of measures associated to a drought scenario when a given drought indicator reaches a predefined level. The final goal is to achieve a balance between the frequency of declaration of drought scenarios and the effectiveness of the application of the measures. If drought scenarios are declared too early, users are frequently exposed to unnecessary restrictions. If the declaration of drought scenarios is delayed, it may be too late for the measures to be effective. Computer modelling is an essential tool to analyse the problem and to find a consensus among users by testing different options.

Actions

- Pre-alert scenario: no specific demand reductions. Only awareness measures are contemplated.
- 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. For example, irrigation can be supplied using waters from a nearby supply, although farmers usually disagree with this option, since it may imply lower water quality and an increase in the pumping costs.
- Emergency scenario: reduction of 50% of the demand, which corresponds to no supply to irrigation and a 15% reduction in supply to urban demand. Urban demand can use alternative water supplies, but this possibility depends on the situation of their own water supply systems.

The results of these actions have been simulated with the probabilistic and deterministic risk analysis methods described above. As shown in Figure 16, 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 a 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 analysed to assess the frequency of drought declarations.

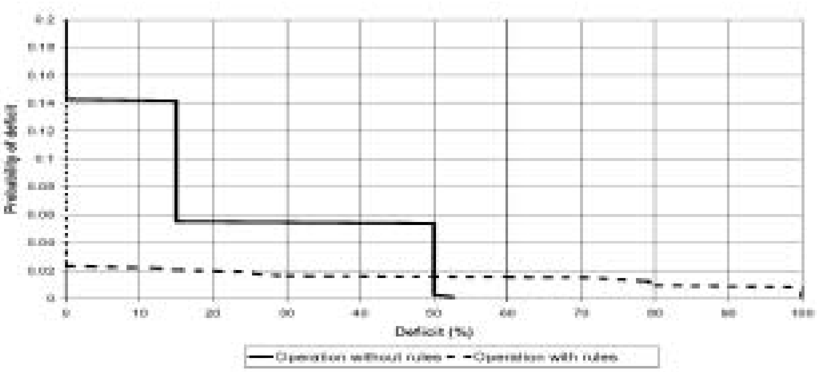


Figure 16. Effect of drought management rules on maximum deficit reduction

6. Tunisia

This section is fully developed in the Technical Annexes of the MEDROPLAN Drought Management Guidelines:
Chapter 22: Application of the Drought Management Guidelines in Tunisia

Rainfall and water resources in Tunisia

Figure 17. Minimum regional rainfall during the 20th Century in Tunisia (precipitation and year) (Source: DGRE).

Rainfall in Tunisia is characterized by spatiotemporal variability. Around 1500 mm/year is basically received on the northwest and the rainfall drops to less than 50 mm/year in the southern desert zone. Tunisia is submitted to drought periods that could be restricted for one or some regions or could be generalized for the whole country. The drought duration could be one month, one season or one year and more, but with a variable intensity. Figure 17 points out the regional minimum rainfall observed during the 20th century in Tunisia.

The rainfall temporal variability results in receiving 90,000 million m^3 during the wet year, that could decrease during a drought event to only 11,000 Mm^3/year. The global mean allows 36,000 Mm^3/year. Within this quantity, 2700 Mm^3/year is the potential surface renewable water resources and represents the capacity of dams and lakes, and also a part is collected by several traditional water catchment techniques (this volume dropped to 780 Mm^3 during the drought event of 1993-1994), the renewable water stored in the shallow aquifers is 720 Mm^3/year. A part of the water resources flows into the sea, or is lost due to evaporation from bare soil lands, and the rest allows the sustainability of the natural ecosystems and rainfed farming systems, that covers around 93% of agricultural lands (the area of total agricultural lands is 5 M ha). On the other hand, deep aquifer resources ensure around 1250 Mm^3 of non renewable water. Hence the total conventional water resources are estimated at 4670 Mm^3, of which about 90% is actually mobilized. In terms of salinity concentration, the percentages of water resources having less than 1.5 g/l are 72%, 3% and 22% respectively for the surface water resources, shallow and deep aquifers.

The total area under irrigation by conventional and non conventional water currently covers 368,500 ha (7% of effective agricultural area) and it is expected to rise to nearly 400,000 ha by 2010. This sector consumes about 80% of the total water resources and provides 32-40% of the mean value of the total agricultural production. In the near future, 50% of the agricultural production should be provided by this area.

The analysis of water resources in Tunisia shows the importance of rainfall in the irrigated and rainfed agricultural production systems and also in the water supply for the other sectors. The water resources spatial variability is so important that the ecosystems and their responses to drought are different. When drought occurs, the natural water resources availability displays a substantial deficit, and consequently, the irrigated area as well as the rainfed lands are strongly affected, and the other water demands are evenly subjected to some restriction. For coping efficiently with the drought periods, Tunisia established a drought management system which demonstrated its capacities in drought mitigation during 1987-1989 and 1993-1995. Latter, the first guideline of drought management “Guide pratique de la gestion de la sécheresse en Tunisie” was elaborated by Tunisian experts.

Water resources data and information system

Water resources in Tunisia are classified as surface water, groundwater and non conventional water resources. Tunisia devoted great attention to the Data Information System on Water Resources (quantity and quality) in order to satisfy the different water demand equitably. The natural resources sustainability and the socio-economic approach are maintained as a policy basis. There are several water information data institutions, that have various use objectives, but they are complementary. Since the Tunisian water system is complex, the water data system includes eight major components:

- Precipitation (rainfall)
- Surface Water (hydrometric data, reservoirs data –dams, hill dams, lakes–, water transfer by network connection, etc)
- Aquifers (management and artificial charge)
- Non conventional water (desalinized and reclaimed used water)
- Water quality monitoring network
- Water demand, cost and pricing
- Soil sweetening and drainage
- Demography (population)

The actual water information system is characterized by highly diversified but complementary sources of information and data on water. Nevertheless, this diversity leads to constraints in the water data and information exchange, and consequently hamper the efficient valorization of the important recorded information. To avoid this weakness, the Tunisian Government decided to establish a Unified Water Resources National Information System called "Système d'Information National des Resources en Eau (SINEAU)". The first phase of the identification study was completed in October 2003. The SINEAU system will add more efficiency in the water data collection, analysis and its real time diffusion.

The Unified Water Resources National Information System (SINEAU) has a main objective to establish a coherent and efficient information water system, which is set by an advanced data management and updating system and uses unified and normalized data analysis softwares. This system will allow an efficient support for data use and will serve as a tool for decision making on water resource management in diversified situations of availability. The major strengths of the SINEAU system are the standardization of data language, the integration of all water information in a unique database, and consequently information transfer or use will be endowed with a high efficiency. Such a system will be characterized by an easy and rapid communication process between all organizations and institutions involved in the water management, particularly in the drought mitigation.

National organizations and institutions

According to the updated Decree N° 2001-419 dated 13 February 2001 (JORT, the Official Journal of the Republic of Tunisia), MARH (Ministry of Agriculture and Water Resources: Ministère de l'Agriculture et des Ressources Hydrauliques) is entrusted with the water management. The MARH duties are realized by its different directorates and departments defined in the updated Decree N° 2001-420 (13 February 2001, JORT).

The Tunisian water system complexity results in a complex institutional water management framework, where the water competencies and responsibilities are spread among several organizations and institutions. Consequently, all those institutional bodies are linked to the drought mitigation process. Moreover, several departments in the MARH and other Ministries, which are not working in the water management, are associated in the drought management.

The principal organization involved in the water mobilization, management and planning as well as in the drought management is MARH, wherein especially the BPEH department (bureau of Water Planning and Hydraulic Equilibrium), the central directorates and the regional services (Departments) are positioned as the major institutions for the said tasks. In addition, there are some organizations supervised by MARH, such as the NGOs (GIC, Collective Interest Associations), which are professional and users associations.

Under the supervision of MARH, the institutions involved in water resources and drought management are invited to periodical coordination meetings in order to specify the major decisions related to water resources allocation and management. Emergency sessions are conducted depending on the extreme weather situations (flood and drought).

In every water management plan that is realized and supervised by one institution, numerous institutions are associated in the relevant studies as well as in the realization process. Coordination is already consolidated by representatives of the institutions linked by the water resources management programme. Figure 18 summarizes the linkages among the institutions.

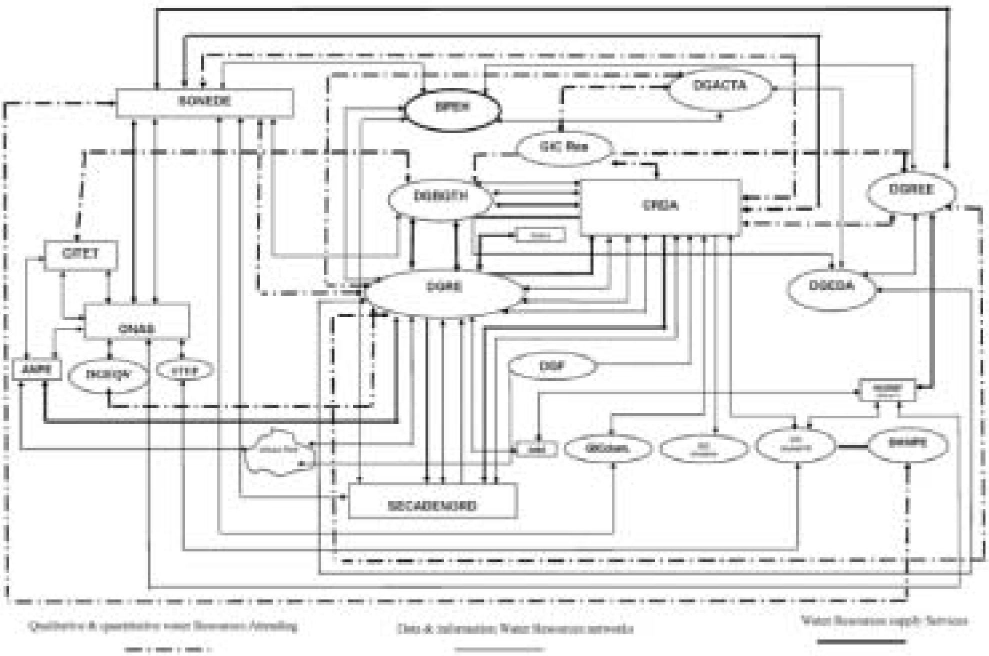


Figure 18. Map of the organizations and institutions involved in water management in Tunisia.

In this connection, it is noted that the Integrated Water Resources Management in Tunisia is continually viewed and updated by national studies and also by international cooperation programmes.

Tunisian water resources and drought policy and legislation

The water legislation history in Tunisia could be subdivided into 4 principal periods:

(1) From the first millenary BC until the arrival of Islam, especially during the Roman civilization, water resources were managed by the building of aqueducts for domestic and agricultural uses.

(2) During the Islamic empire, especially the Hafsidesn (1236-1574), the water was considered as “God’s Gift”, and consequently it was considered as public property and free access was promulgated.

(3) The French colonization period (1881-1956) was characterized by the first water Decree favouring the colonists. The Decree of 24 September 1885 defined the public surface water domain, without any reference to the groundwater resources. In 24 May 1920, a water committee was appointed. The Decrees which appeared in 1933, 1935, 1936 and 1938 instituted a water use regulation and fixed the dues for the water use; the Decrees of 30 July 1936, 11 January 1945 and 17 March 1949 instituted the regulations related to the NGOs organization involved in the water use.

(4) The fourth period, that started with the independence of Tunisia, is characterized by an evolutionary water legislation, that is related especially to the resources mobilization, exploitation by different users (urban, agricultural, industrial and touristy uses) and focused on water quality and environmental problems. In order to satisfy the different water demand, the socio-economic development national programmes realized large hydraulic works. With the evolution, the hydraulic planning was established as a legislative system, having the objectives to identify the competencies of all operators and users in the water field, to preserve the water resources and to ensure equitable allocations. In 1975, all legislative water texts were updated and promulgated in the Water Code (Law N° 75-16, 31 March 1975).

Since 1975, the Water Code has been continually updated by modification of some legislations and adding new ones regarding socio-economic development, water demand evolution and environmental issues required to preserve the natural resources.

The Water Code created in 1975 was further updated in November 2001. The benefits provided by the Water Code results from the increased awareness that politicians and decision makers need to understand the importance of water in the country's economy and development, the need to manage the demand for water according to the availability, and the sustainability of natural resources. Because the successive drought events occurred in Tunisia, a deep awareness of water problems and improvement of efficiency in water use in all sectors became the first priority in the water management policy of Tunisia. The Water Code has placed priority on drinking water supply. Considerable measures are taken for water saving in agriculture under the grants ranging from 40 to 60% of the farmers investments who adopted the irrigation techniques allowing the water saving in their fields. The objective is to save around 25% on water consumption by 2010.

The drought management system in Tunisia is composed of: (i) drought announcement; and (ii) decisions by the Minister of MARH to cope with the drought and the duties loaded to the National Commission (committee), which is in charge of supervision of the execution of all the operational actions related to the 3 drought management phases (Before: Drought Preparedness; During: Drought Management; After: Subsequent Drought Management), with close collaboration of the regional and sector or specialized committees. The Minister of MARH promulgates several decisions related to the different drought committees and the operation programmes for the drought mitigation rather than its crisis management. The Tunisian Central Bank (Banque Centrale de Tunisie: BCT), delivers a circumstance circular establishing easiness in the credit delivery for farmers. Special decisions are taken in order to exempt the importation from the custom duties.

Drought Preparedness and Management System

Generally, drought occurs in Tunisia once every 10 years. In order to reduce the resultant effects of the drought in Tunisia, a related management system was developed and adopted for the drought events which occurred during 1987-1989, 1993-1995 and 2000-2002. During 1999, Tunisia published the first guideline on drought management entitled “Guide pratique de la gestion de la sécheresse en Tunisie” (Louati et al., 1999). The guideline was elaborated by referring to the drought management system and by analysing the data and information recorded during the drought periods of 1987-1989 and 1993-1995. This guideline consists of methodological approaches, identification of principal drought indices, description of drought preparedness and management processes, and maps of intervening parties.

The drought management system in Tunisia has 3 major successive steps (Figure 19):

1. Drought Announcement: Referring to meteorological, hydrological and agricultural indicators as observed in the different regions affected by drought and transmitted by the agricultural, economic, and hydrologic districts relevant to MARH, a drought announcement is established by means of a circumstance memorandum.

2. Warning: This announcement, qualified as warning note, is transmitted to the MARH Minister, who proposes a scheduled operations plan to the National Commission (committee), which is composed by decision makers and beneficiaries.

3. Action implementation: The National Commission is in charge of supervision of the execution of all the operation actions, in strong collaboration with the regional and specialized committees. The National Commission also supervises all operations when the drought is over.

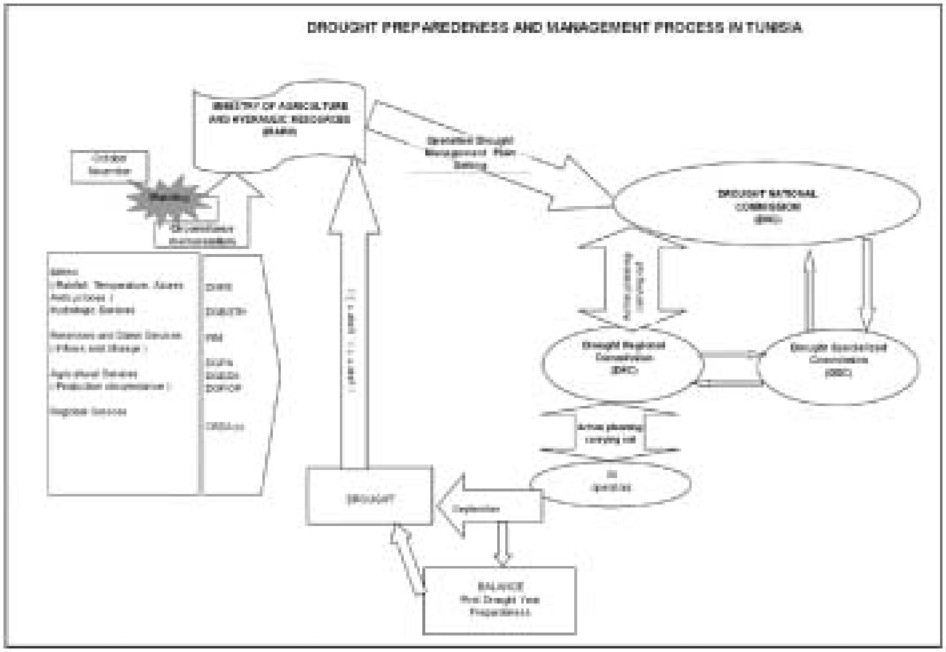


Figure 19. Drought management plan in Tunisia

Although the drought management system has not been analysed deeply until now in Tunisia, the strengths and weaknesses of the system are identified as stated below:

Strengths

- A high Presidential interest and support is devoted to the drought mitigation system in Tunisia.
- The approach based on three drought management phases (before, during and after drought process), is a very important strategy and relevant to the basic elements of drought management theory.
- Capital productive sharing and preservation.
- Sustainability of farmers' incomes.
- Integrated and optimized water resources management in Tunisia, especially during drought depending on its intensity and duration.
- Water saving is a national policy and is not related only to drought.

Weaknesses

- The financial incidences are supported by the State budget because of the absence of insurance systems linked to drought and private sector contribution is limited.
- Updating the drought mitigation plan is based until 2003 on simple note-taking and observation findings, without any wide-spreading evaluation study. The latter would be realized by an in-process study “The climatic changes and their impacts on the agricultural sector and the ecosystems”.
- The deficiency in the relations between the different institutions that provide information and data about water, which should be resolved by the establishment of the Unified Water Resources National Information System “Système d’Information National des Resources en eau (SINEAU)” in the near future.

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