Chapter 16
Drought Severity Thresholds and Drought Management in Greece

D. Pangalou, D. Tigkas, H. Vangelis, G. Tsakiris and A. Nanou-Giannarou

Abstract The objective of this chapter is the analysis of the three major components of drought assessment and management in Greece. First, the legal framework and the structure of services related to the water management are presented. Second, drought characterisation is applied for two river basins, Nestos and Mornos, and thresholds for drought management are defined. A new meteorological drought index, the Reconnaissance Drought Index (RDI), similar to the well-known Standardised Precipitation Index (SPI), is introduced. Finally, the operational component for drought management is analysed. This component consists of the formulation of a preparedness master plan and the adoption of proactive and reactive actions.

Introduction – Drought Events in Greece

Due to its climatic conditions, Greece is a country often affected by droughts. Although the Greek organisations have not developed concrete strategies for facing droughts, they have dealt with this phenomenon on a case-to-case basis. However, the country needs a comprehensive effort to rationalise the entire drought analysis, monitoring and mitigation system. There are deficiencies in scientific organisations, legal framework and operational capabilities to combat drought and its consequences. An operating mechanism should be instituted for an effective application of rational measures resulting from a scientific analysis. During drought, water restrictions are imposed mainly in domestic water consumption. However, 85% of the water used in the country is consumed in the agricultural sector (Tsakiris, 2005). It is therefore reasonable, to re-direct water restrictions, giving emphasis to the agricultural use, which is the principal consumer of water. Last but not least, it should be noted that there is a severe gap in the measures for combating drought, i.e. the lack of insurance of people and properties in case of a drought episode.

G. Tsakiris (✉)
Lab. of Reclamation Works and Water Resources Management, School of Rural and Surveying Engineering, National Technical University of Athens, Greece.
e-mail: dialecti@yahoo.com

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The purpose of this chapter is to analyse briefly the three major components of drought assessment and management in Greece:

1. The legal framework and the structure of services related to water management.
2. The drought characterisation and the definition of thresholds for drought management.
3. The operational component for drought management, which consists of the formulation of a preparedness master plan and the adoption of proactive and reactive actions. In addition, actions in the short term and the availability of a reliable monitoring/warning system are of primary importance.

Drought and Greek Legislation

Legal Framework

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

(a) Law 1650/1986 "for the Protection of the Environment"
(b) Law 1739/1987 "for the Management of Water Resources"
(c) The legal implications of the United Nations Convention for Combating Desertification (1994)
(d) European Directive 2000/60/EC
(e) Law 3199/2003 of "Protection and Management of Water"

Laws 1650/1986 and 1739/1987 have constituted the statutory framework for Water Resources Management for 14 years, from 1986 till 2000, when the Water Framework Directive was adopted. The European Directive 2000/60/EC "Establishing a Framework for Community Action in the Field of Water Policy" imposed the need for adopting a new framework for water, fully compatible with its content. Law 3199/2003 for the "Protection and Management of Waters" is based upon the principles of the European Directive and establishes a framework for the achievement of a sustainable water policy. Provisions of the Water-Directive 2000/60 and of its Annexes, not included in Law 3199/2003, were embodied in Presidential Decrees. An important Presidential Decree, which acts as a key supplement of Law 3199/2003 was published recently (March 2007).

The river basin district was first introduced in Law 1739/87 as the fundamental area for any water balance. Greece was divided into 14 river basin districts. This has not been altered within the new Law. However, it is estimated that the existing river basin districts will be changed and reduced through merging of adjacent districts. Within this concept, it is expected that Greece will be divided into 7 to 9 districts. 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 for 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. Desertification may be considered as a process related to drought, since it is usually provoked by persisting and frequent drought episodes, which are customary for the Mediterranean climate.

Structure and Linkages Among the Relevant Institutions, Organisations and Stakeholders

Law 3199/2003 establishes and defines the Institutions and Authorities responsible for water protection and management. The NGOs can express opinion and, from time to time, they are invited to make proposals to the responsible Ministries. The structure is depicted in Table 16.1.

Table 16.1 Organisation chart of services responsible for water resources management in Greece

Parliament	←	**National Committee of Waters** *Responsibilities:* 1. Annual report 2. Set-up of scientific or consultative committees when needed
		↑
Natural Council of Waters Consultative Body	←	**Head: Minister of Environment, Physical Planning & Public Works**
		↓
Consultative Committee of Waters	←	**Ministry of Environment, Physical Planning and Public Works** **Central Directorate of Waters** *Responsibilities:* 1. Proposals, general rules, supervision 2. Coordination – guidelines 3. Representation of Greece 4. Management of hydrological and meteorological databank 5. For each River Basin District, composition of a report of the characteristics and the impact of human activity and an economic analysis of water use 6. Composition of the National Register of Protected Areas 7. Supervision of the protection and improvements in the status of bodies of water
		↓
Regional Council of Waters Consultative Body	←	**Region** *Head:* **General Secretary of the Region, Regional Directorate of Waters** *Responsibilities:* River Basin Districts 1. Establishment and application of River Basin Management Plans, valid for 6 years 2. Establishment of measures aiming at the following tasks: a. Programme for the monitoring of the water status b. Specialization of programmes of measures c. Control over abstraction of water and over hydraulic works d. Encouragement of public awareness and public participation

Drought Characterisation and Risk Analysis

The Nestos and Mornos Basins

Drought characterisation and operational management are analysed in the Nestos and Mornos basins (Fig. 16.1). The Nestos watershed is located in northern Greece. The catchment area belongs partially to Bulgaria (2,872 km^2) and partially to Greece (2,312 km^2). The study presented here covers only the Greek part of the basin. Meteorological data (mainly monthly precipitation and temperature) from 10 meteorological stations, covering a period from 1964 to 1996, have been used.

Mornos watershed is located in central Greece. The entire watershed occupies an area of 1,025 km^2, while the study area (which is the area upstream of the Mornos dam) covers 571 km^2. Analysis was performed with meteorological data collected from 8 stations from 1962 to 2001. Mornos reservoir is the main supplier of the greater Athens area with potable water.

Fig. 16.1 Nestos and Mornos basins in Greece

Intensity, Frequency and Duration of Drought

Two well-known indices, the Deciles (Gibbs and Maher, 1967) and the Standardised Precipitation Index (SPI) (McKee et al., 1993), and a new promising index, the Reconnaissance Drought Index (RDI) (Tsakiris and Vangelis, 2005, Tsakiris et al., 2007), were calculated. The "run method" was applied to further characterise the statistical properties of drought (Rossi et al., 1992). In general, all indices in all the stations of the Nestos basin show a period of time between 1989 and 1993 that is documented as the most severe drought period over the last decades in Greece (Karavitis, 1998, Voudouris, 2006). Results show that the RDI is a promising index that could be more widely used than the other two indices tested, since it is correlated with both of them. The RDI has a mean correlation coefficient equal to 0.9509 when correlated to the Deciles and a mean correlation coefficient equal to 0.9785 when it is correlated to the SPI. The RDI correlates relatively well with the Deciles and the SPI in Mornos basin, too. It has a mean correlation coefficient equal to 0.8924, when correlated to Deciles and a mean correlation coefficient equal to 0.9812, when correlated to the SPI. In order to calculate intensity, frequency and duration of drought, statistical analysis of precipitation data for both basins has been performed. Drought frequency was estimated as the probability of non-exceedance for the annual SPI for each precipitation station. A threshold of "severe drought" event was established, when the SPI was below -1. For each meteorological station in both basins, the different intensities and the return period for each drought spell were calculated.

The data analysis for the Nestos basin has shown that apart from duration, the drought spell of 1989–1993 was also relatively severe for almost all the stations. Furthermore, the northern part of the basin experienced an important drought period during the hydrological year 1984–1985. The main result of the analysis for the Mornos basin is that drought has been a frequently recurrent phenomenon since 1987: in most of the years since then, the Mornos watershed has suffered from drought in almost its entire area. The threshold of the run method was calculated based on the deciles index. The lowest 40% of the average precipitation occurrences was considered as the threshold in order to apply the run method. In Figs. 16.2 and 16.3, for every Thiessen polygon of each basin, the diagram that describes the droughts identified on the meteorological series and their characteristics (length, water deficit and intensity) are constructed. The accumulated water deficits for both basins are presented in Fig. 16.4.

Drought Impacts on Runoff

For the assessment of the drought impacts of runoff, the Medbasin software was used for both of the two case studies. Medbasin was developed at the Laboratory of Reclamation Works and Water Resources Management (National Technical University of Athens) and it includes two conceptual rainfall-runoff models, on a daily and monthly basis, respectively (Tigkas and Tsakiris, 2004).

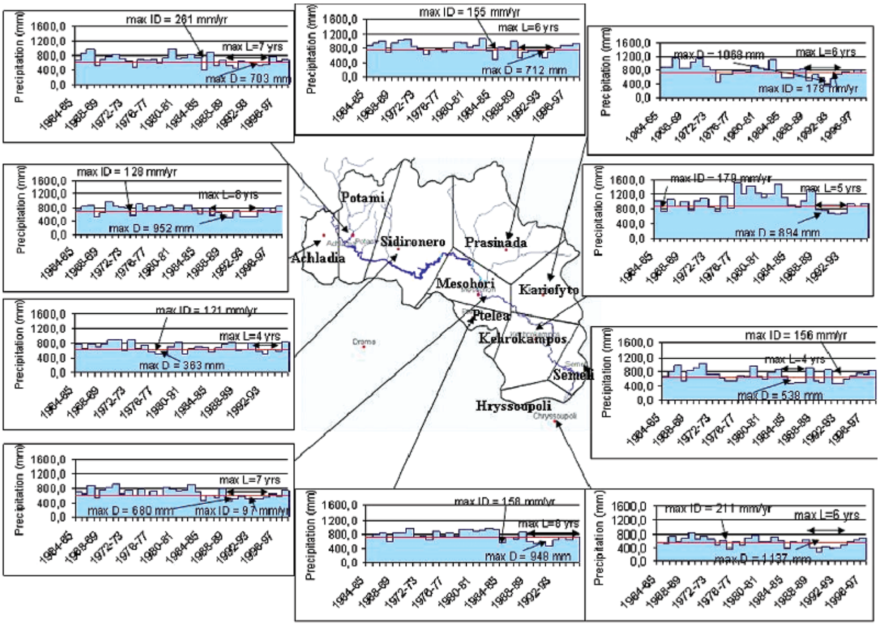

Fig. 16.2 Regional drought identification for Nestos river basin

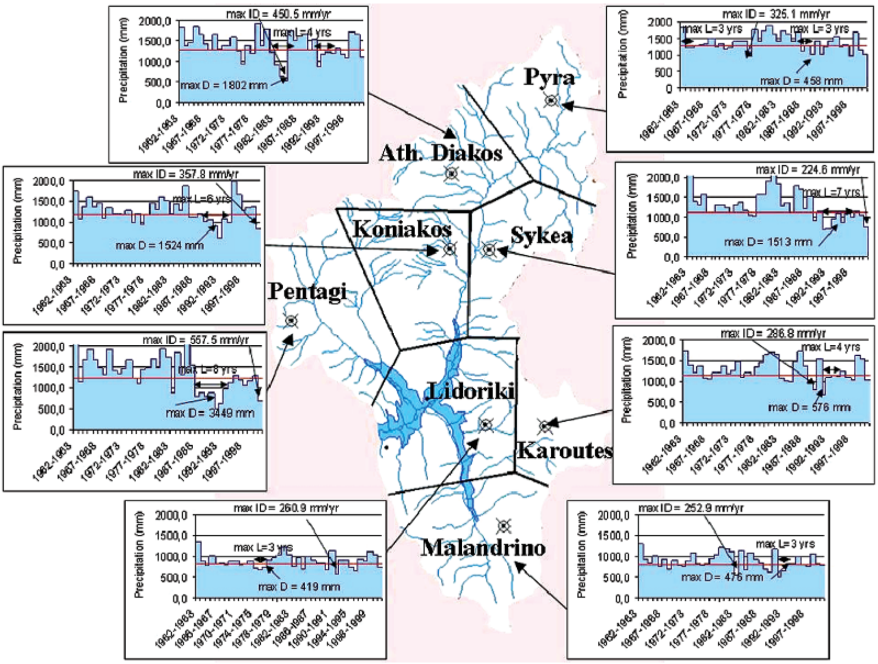

Fig. 16.3 Regional drought identification for Mornos river basin

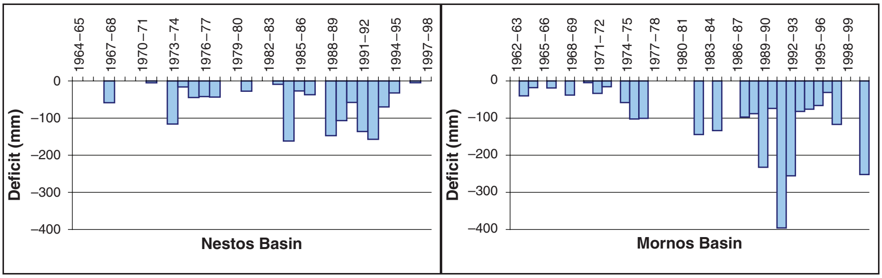

Fig. 16.4 Water deficit along the Nestos and Mornos basins

The methodology followed is based on the formulation of several climatic scenarios, derived from the alteration of the normal climatic conditions of the study area (Tsakiris et al., 2004). For this task, a period of years with normal or near to normal climatic conditions was selected. 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. It should be stressed, that the results of this method are reliable only on an annual or multi-annual basis.

The Nestos Basin

The selected area for the Nestos case study (Fig. 16.5) is a zone of 500 km^2 upstream of the river delta, between the hydrometric stations of Temenos (input) and Paskhalia (output). Using the Thiessen polygon's method, it was calculated that for the period of 1964–1996 the mean annual precipitation is 740 mm and the mean annual potential evapotranspiration is 710 mm.

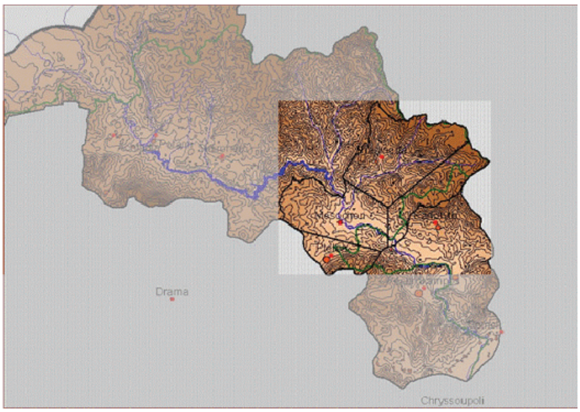

Fig. 16.5 Nestos basin: area of study

For the formulation of the climatic scenarios, the RDI was used in order to define the climatic conditions of the area (Fig. 16.6). A period of eight years (1971–1979) having near to normal conditions was selected in order to run the rainfall – runoff simulation. The input data were the spatial average 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.

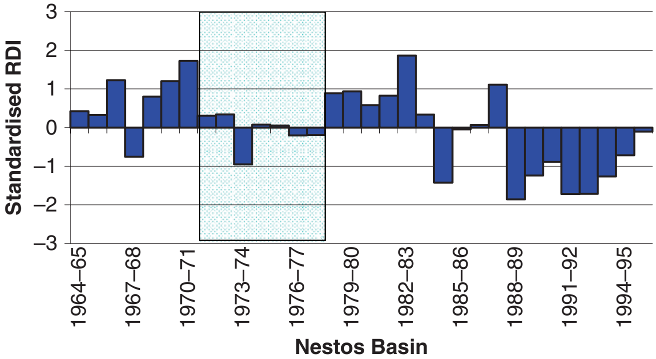

Fig. 16.6 Standardised RDI values for the study area of Nestos basin

About 120 climatic scenarios were synthesised by altering the original precipitation and the potential evapotranspiration data, by different percentages up to –40% and +24%, respectively. The results of the rainfall – runoff simulation of these scenarios are presented graphically in Fig. 16.7 on a two-dimensional diagram.

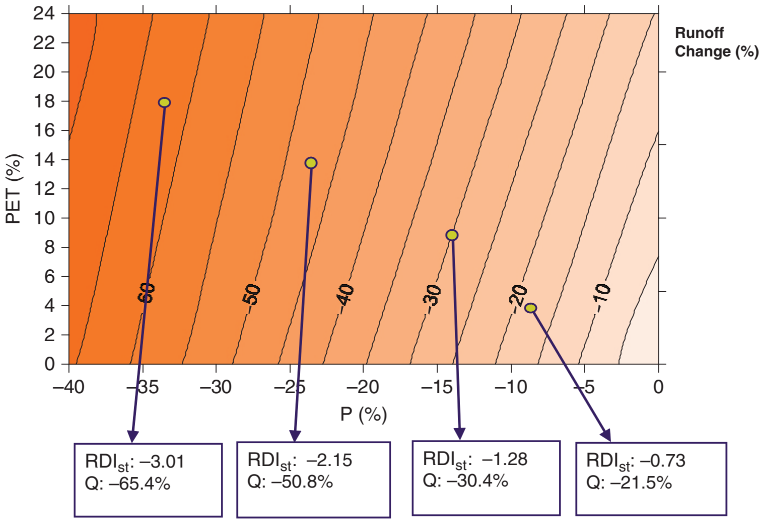

Fig. 16.7 Results of the rainfall – runoff simulation of the climatic scenarios for the Nestos study area

On the 2D diagram, some values of the RDI_{st} (Tsakiris et al., 2007) are presented together with the percentage of the runoff deviation from the normal value. As it can be seen, the runoff reduction is 20–35% for moderate drought conditions, 35–50% for severe droughts and can be up to 65% for extreme drought conditions. In order to check the accuracy of these estimations, they were compared to the actual values of runoff for the dry period of 1990–1995. For the first three years the estimation is good, while for the last two the actual runoff reduction is greater than the estimated. This may be caused by the cumulative effect of the sequence of the drought events, which is not taken into account in this approach.

The Mornos Basin

The same methodology was also applied to the Mornos river basin. Eight years were selected for the rainfall – runoff simulation (1967–1975, Fig. 16.8). The climatic scenarios were formulated by altering the original data of precipitation and potential evapotranspiration by various percentages up to –40 and 14%, respectively. About 170 scenarios were simulated and the results are presented in Fig. 16.9. The comparison of the results with the RDI_{st} shows that the reduction of runoff for moderate

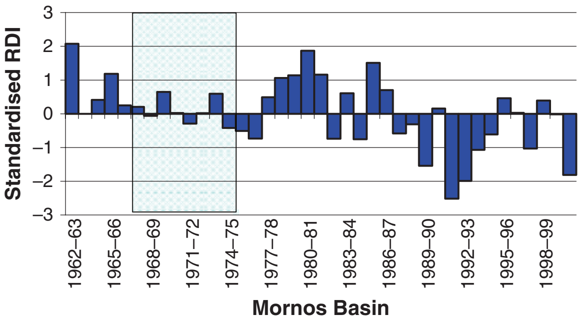

Fig. 16.8 Standardised RDI values for the study area of Mornos basin

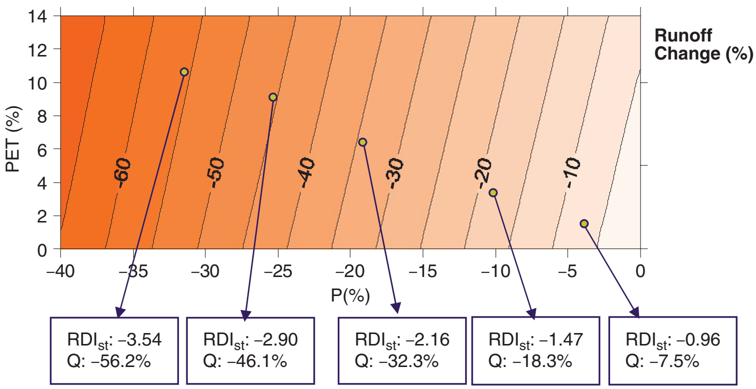

Fig. 16.9 Results of the rainfall – runoff simulation of the climatic scenarios for the Mornos basin

drought conditions is 8–20%, for severe droughts from 20–30% and for extreme droughts can be up to 50%.

Potential Impacts of Drought

For the needs of this work, major stakeholders were interviewed about the potential impacts of drought on the Nestos and Mornos basins. The first general conclusion from these interviews is that the most significant impacts of drought in the Nestos and Mornos basins refer to runoff reduction and reduction in agricultural production. In addition, in the Nestos river basin, the wetland ecosystem influence and biodiversity loss are important issues. In the Mornos river basin the pressure on the water supply system of the city of Athens is crucial.

Drought Management in Greece

The operational component for the drought management consists of the formulation of a preparedness master plan and the adoption of proactive and reactive plans and actions. In addition, actions in the short term and the availability of a reliable monitoring/warning system are of primary importance. Practical examples of water reduction actions and stakeholder analysis are presented. Finally, the strengths and weaknesses of the current legal structure are shown.

Preparedness Master Plan

Regarding the preparedness plan, four are the main aspects that have to be considered:

1. *The technocratic dimension*. This dimension refers to the responsibilities and the timing related to drought management.
2. *The administrative and organizational issues*. It specifies the responsible bodies for each action.
3. *Time and space actions*. The time sequence of the actions as well as the spatial scale of the plan should be carefully scheduled. This step focuses mainly in planning the actions in advance.
4. *Public awareness and participation*. Public should be involved in the implementation of the plan. Non-governmental organisations (NGOs) should also play an important role in the fringe between the public and the authorities.

Proactive and Reactive Plans and Actions

The institutional and legal measures related to water resources and more specifically to the mitigation of drought, are partially covered by the EU Directive 2000/60 and the Greek Law 3199/2003.

The most relevant proactive actions in Greece, i.e. measures taken or planned compatible with the National Action Plan (NAP), include:

1. Construction of small earth dams for collection of rainwater;
2. Canal rectification to reduce water losses and
3. Modernisation and improvements of irrigation networks.

In essence, all proactive measures have the same aim: to increase the storage and improve the efficiency of the conveyance and distribution systems. In this context, important contribution to water saving is the gradual change from conventional surface irrigation systems to modern sprinkler and trickle irrigation systems.

The most relevant reactive actions in Greece include:

1. Constraints in water consumption
2. Intensification of the use of groundwater resources
3. Reallocation of water resources
4. Use of saline and brackish waters and
5. Water transfer and water supply systems interconnection

Short Term Actions

For the short term actions, two directions can be followed:

1. Reduction of the water demand and increase 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. Specific acts of this type are for example the prohibition of excessive use together with a legal framework for a more rational water use. Pricing policy regarding higher costs per unit for higher water consumptions may also be applied. A more successful measure could be the use of economic incentives from the water companies in order to lead the people towards lower water consumption.
2. Advertising and other means of public announcement is always essential not only in informing people of the water shortage situation but also in helping them to consume water in a more rational way in the long term. For the public awareness, information may be diffused through the mass media or leaflets distributed to the citizens, but an important aspect is to pass this information on to young people through schools (or any kind of educational campaigns), in order to form a life style that includes rationality in water use and compatibility with the existing constraints.

Regarding the rural environment, changes in agricultural structure will mainly lead to the desired results. Such changes may be the selection of less water consuming crop varieties, the control of evapotranspiration by artificial means, the optimisation of agronomic techniques and actions that are even more complicated (e.g. the soil enhancement).

Practical Examples of Water Reduction Actions

Emergency water transfers: Emergency water transfers and diversions is another auxiliary solution with the advantage that the source will not remain connected to the supply network after the crisis and the disadvantage of being a more expensive solution since appropriate infrastructure should be constructed just for a short period of time.

Changes of water rights: Diversions between different sectors of water consumption, that should be listed hierarchically in advance, may also be implemented during an emergency situation.

Monitoring Systems

The actions planned for drought mitigation will not be very effective unless information on drought incidents in temporal and spatial scale are available or can be acquired from monitoring systems. In brief, a monitoring system can give information of when a drought period started, how long it lasted, how severe it was and which were its spatial limits. Moreover, a monitoring system applied on historical data series can be useful in the identification of drought prone areas, which helps in a more efficient application of drought mitigation plans. Monitoring systems though, can mainly supply information on past events. A 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 and its accuracy is based on meteorological predictions.

Stakeholder Analysis

In order to better investigate drought severity and its impacts on water resources, a questionnaire was distributed to five stakeholders. The interviewees face the drought phenomenon and the corresponding results from their interest and the interest of the people they represent. The vast majority of the stakeholders agreed that recreational uses (e.g. pools, fountains, etc.) have the last position hierarchically in the list of uses. However, according to Law 3199/2003, municipal water consumption is considered as the first priority.

Strengths and Weaknesses of the Current Legal Structure

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

1. A National Data Bank of Hydrological and Meteorological Information (NDBHMI) has been established. Various software applications are linked to the central Database of the NDBHMI 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.
2. There are sufficient socio-economic data concerning water users mainly in the municipal and the industrial sector, with the exception of incomplete information on farmers and irrigation water.
3. According to the existing situation, 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 governmental and other institutions are dealing with the effects of drought on a case-to-case basis.
4. There is a sufficient number of reservoirs that are being used in drought situations and therefore the water reserves of the country are satisfactorily managed in most of the cases.
5. The domain of agriculture seems to have enough influence on the government and whenever irrigation farmers are affected by drought, the pressure exerted on the authorities has good results in order to combat drought.
6. Law 3199/2003 has been recently adopted. According to this law, all sectors affected by drought are represented in the National Council of Waters and the Consultative Committee of Waters.

The main weaknesses of the Greek institutional framework that stand out from the above analyses are:

1. Up to now, there is no provision for insurance or any compensation policy in the legal framework for the rainfed or irrigated agriculture.
2. No systematic monitoring of drought occurrence and regional extent ever existed in Greece in the past.
3. In the past, decisions concerning droughts were taken on a case-to-case basis. This empirical approach is considered unsatisfactory and it is therefore necessary to formulate a plan for drought mitigation, based on the institutional structure described in the Law 3199/2003 on Water Resources Management.
4. Up to now, there is a lack of information concerning the consumption of irrigation water by individual farmers. Although there are institutions and organisations with experience on the subject, there is no coordination among them and there is no managerial policy at a higher level from a central administration.
5. In Greece, little research was carried out in the past for defining droughts for the different sectors of the economy, i.e. agriculture, power production, domestic use etc. Similarly, drought indicators have not been tested with respect to their applicability in the Greek conditions.
6. There are no drought indicators or any other scientific indices applied in order to identify crisis situations.

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