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

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Chapter 15. Application of the Drought Management Guidelines in Cyprus

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SUMMARY – Cyprus is the third largest island of the Mediterranean Sea with an average area of 9,251 Square kilometers and with an intense Mediterranean climate with an average annual precipitation around 476 mm. The annual water availability is less than 500 m3/capita and so far it has developed more than 75% of the natural water resources, and has implemented sea water desalination and re-use of the treated domestic effluents. Its legal framework vests ownership of the water resources to the Government and it gives to the Government the power to construct waterworks and sell water at prices approved by the Parliament. It also gives the right to physical and legal entities to drill their own borehole and abstract groundwater and the right to organized communal entities to construct their own water works for surface and ground water development and utilization. The law is now adapted to comply with the Water Framework Directive. Cyprus prepared its water master plan in the 1970's and its implementation lasted for more than 30 years, with almost all surface water resources developed and the groundwater over-pumped. However, due to the observed climate changes and the repeated droughts the island faced serious periods of water shortages during the decade of the 1990's. To adapt to drought and minimize its adverse effects Cyprus was forced to modify its water policy by the introduction of seawater desalination, to accelerate the construction of new water projects and the recycling of the domestic effluents, to intensify the water demand management methods, and finally to develop and implement drought mitigation plans.

Key words: Southern Conveyor Project, legal framework, institutions, drought mitigation plan, drought characterization, impacts, monitoring, actions, stakeholders.

The planning framework

Defining the planning purpose and framework

Overview

Cyprus being one of the most drought prone areas in the Mediterranean area, with frequent drought events of high severity and long duration, has great experience on drought management. The authors of this Chapter have been involved in the preparation and execution of drought mitigation plans in Cyprus during the last 30 years when the worst of the drought events occurred.

Cyprus is an island in the North Eastern end of the Mediterranean Sea, with an area around 9251 square kilometers. The island has a Mediterranean climate with mild wet winters and hot summers with an average annual precipitation around 476 mm, mainly falling in the winter and spring months and geographically varying from 250 mm in the plain areas to 1200 mm on the top of the high mountains. The evapotranspiration varies from 1722 mm/year in the low lying areas to 1243 mm/year in the areas above 300 meters, 75% of which occurs in the months May to October.

Cyprus is inhabited by 802,000 people, of which 68% live in urban areas and the remaining in the rural areas. Today's economic activity is centered on the services, which contribute more than 75.6% to the GNP, the industry contributing 20% and the agriculture contributing 4.4%. About 715,000 people live in the Government controlled areas.

The natural water resources of Cyprus in the areas under Government control are very limited amounting to 307 million cubic meters (or 429 m3/capita), made up from 197 million cubic meters surface water, 110 million cubic meters from groundwater. Another 36 million cubic meters are available from non-renewable sources: 30 million cubic meters from desalination of seawater (introduced in 1997), and 6 million cubic meters from treated recycled domestic effluents.

From the total area of 9251 square kilometers, 45.8% is agricultural land, 7.5% is carob land, 19% is forest land, 9% is scrub land, 11.9% is barren land and 6.9% is build up areas. From the agricultural land 90% is dry or rainfed land, 6% is cultivated with annual crops (potatoes, onion, and vegetables) and the remaining 4% is cultivated with permanent crops mainly grapes, citrus, deciduous and olives. Agriculture consumes about 75% of the water resources, while the domestic and industrial sectors consume the remaining.

Cyprus with very limited water resources is vulnerable to droughts because it has developed most of all its natural water resources, with most of its aquifers depleted, and no perennial rivers. Due to climatic changes the water availability has decreased by as much as 40% compared to the original quantities estimated in the 1970's with all projects yielding less water, while the demand is increasing because of population increase, the population redistribution (movement of 200,000 people since 1974's Turkish occupation) and the rising of the standard of living.

Water resources development

In 1971, Cyprus started implementing a Water Master Plan, based on the Integrated Water Resources approach. Since then it has implemented five out of the six major projects included in the master plan with the sixth not being implemented because of the Turkish occupation of 37% of the island area, developing almost all its natural water resources, surface and groundwater. The remaining undeveloped water resources are very limited and expensive to develop. Since the year 1960, the capacity of the constructed dams has increased from 6 million cubic meters to 307 million cubic meters in 2002. The groundwater resources were developed early in the 1950's and 1960's, being easier and cheaper to develop, by individuals, by digging wells or drilling boreholes. Although water conservation measures were implemented early in the 1960's as soon as it was realized that their depletion was imminent, this did not avoid the depletion of the major aquifers, since water demand continues to increase at a higher rate than sustainable water resources development. Finally to keep up with the increasing growth of water demand and to face the water shortages caused by the repeated drought events, water augmentation was achieved by the introduction of seawater desalination and the recycling of the domestic effluents much earlier than anticipated in the master plan. From the implementation of the water resources development plans the available water resources now presently used are estimated at 245 million cubic meters per year as shown on Table 1 below.

Table 1. Water availability in Cyprus by source

Description	Quantity (Km^3/year)	Remarks
Renewable water resources	0.209	All internal
Surface	0.099	From dams with capacity 304 Mm^3
Groundwater	0.110	From aquifers all in the area under Government control
Non renewable water resources	0.036	Recycled and desalination
Recycled domestic effluents	0.006	Tertiary treated domestic effluents
Desalination	0.030	From two desalination plants
Total water resources	0.245	

Water use by sector

The present water demand is estimated at 245 million cubic meters per year out of which 60-70 million cubic meters are used for domestic consumption and for tourism, 5 million cubic meters are used by the industry and 170-180 million cubic meters are used for irrigation. Table 2 shows the total water consumption for the year 2002 by source, including the production of waste and the desalination water. The irrigation demand is consumed for the irrigation of permanent crops (about 40% of the total area and 55% of the total annual water demand) and for annual crops covering an area 60% of the total with 45% of the total irrigation water consumption. The wastewater discharge on the table shows the amount of domestic effluents that could be treated and recycled to be used by the irrigation sector.

Table 2. Total consumption and wastewater discharge by sector

Description	Quantity (Km^3/year)	Remarks
Consumption		
Domestic consumption	0.070	
Agricultural	0.170	
Industrial	0.005	Included in domestic
Electric power and cooling	0.000	Use of seawater
Total consumption	0.245	
Wastewater discharge		
Domestic	0.05	
Industrial	0.00	
Total wastewater (industrial + domestic)	0.05	
Discharge into continental	0.04	
Discharge directly to sea	0.04	

Case study: The Southern Conveyor Project (SCP)

The Southern Conveyor Project (SCP), one of the six identified in the Master Plan, is the largest water development project ever undertaken by the Government of Cyprus. The basic objective of this project is to collect and store surplus water flowing to the sea and convey it to areas of demand both for domestic water supply and irrigation. The project aims at the agricultural development of the coastal region between Limassol and Famagusta, as well as to meet the rising domestic water demand of the towns of Limassol, Larnaca, Famagusta, and Nicosia, of a number of villages and the tourist and industrial demand of the southern, eastern, and central areas of the island (Fig. 1).

Fig. 1. Southern Conveyor Project layout.

Hydrological structure of the SPC (Fig. 1)

The project consists from three dams, one main conveyor, two water treatment plants, two desalination plants, an irrigation distribution system and a domestic waste water treatment plant for recycling the domestic effluent.

Water availability and allocation in the SPC

The project water yield was originally estimated at 96 m^3/year, about 38% of the total annual water demand in the areas under Government Control and was allocated to the two main sectors as follow.

(i) Domestic water supply: 50 m^3, increasing annually by 2%.

(ii) Irrigation (for 13,985 Hectares): 46 m^3 for irrigation.

The Southern Conveyor Project is operating since the year 1987 and during these years it was found out that it was unable to supply the originally planned quantities because due to repeated droughts and due to climatic changes the quantities of water available from the project were by 40% less than the planned with a water deficit of 43 million cubic meters. This resulted to the implementation of water rationing in the years 1991 and 1996-2000 both on the domestic supplies and on irrigation supplies and the construction of two seawater desalination plants by almost 10 years ahead of the planned time.

Organizations, stakeholders and legal framework in the SPC

Organizations

The administrative body, which is responsible for the construction, operation, and maintenance of the Southern Conveyor Project, and generally for the supply of the available water resources, is the Water Development Department. The Council of Ministers approves the annual budget for the operation and maintenance of the project, within the Government Budget, and set the water tariffs, with the approval of the House of Representatives.

Stakeholders

The clients to the project are made of two groups, the domestic water users legal entities and the irrigators, mainly individual persons and in some cases legal entities. Since Cyprus is suffering from water scarcity there is always a conflict between the consumer groups and within the groups both at the planning stage and during the operation especially under water shortage conditions.

Legal framework

Although the existing laws do not mention specifically any action that must be taken under water scarcity conditions, the existing provisions give the right and power to the Council of Ministers to allocate the existing water resources, based on criteria and conditions with a view to minimize adverse effects. Based on the existing law the Council of Ministers approves proposals or modifies proposals for the water allocation and reallocation under water scarcity conditions. The Government usually compensates the stakeholders adversely affected by the water scarcity.

Organizational component

Legal framework

Existing legal framework

The legal framework in Cyprus has been enacted during the colonial era (1928-1950) and still remains in force by virtue of the provisions of Article 188 of the Constitution of the Republic of Cyprus, which got its independence in 1960. Additions and modifications were made to the legislation since then to take account of changes, new developments and trends, but these are very limited. The existing legal structure and content in relation to water development, management and distribution, is described below.

Water ownership

Water in Cyprus is a public good and the constitution of the Republic of Cyprus vests all powers for the management of this resource to the Council of Ministers. The ownership of the water resources at the time of the implementation of the main legislation, which is still valid, was defined as follows thus respecting private use or ownership:

(i) Surface water and groundwater ownership: All surface water running to waste and groundwater not brought to surface before 1928 (the year the Government Waterworks Law was enacted) is vested to the Government, which is acting through the Council of Ministers.

(ii) Private water rights protected: The water rights of any citizen, physical or legal are protected and riparian rights are given to those who can prove that they are entitled or own such rights.

According to the Government Waterworks Law access to any water is given to any individual for abstracting water for his own personal use, i.e. for drinking and washing purposes. The amount of water that can be taken is all that can be carried in the palms of the hands.

Powers of the Council of Ministers to develop and allocate water resources

Since the State is the owner of almost all the natural water resources on the island the existing Legislation gives to the Council of Ministers the right to manage, protect and conserve the natural water resources, and to plan, design, construct, manage, operate and maintain waterworks and the water resources and sell water at a price approved by the Parliament, and to allocate and reallocate the water resources according to the existing water availability and the needs provided the existing water rights are satisfied.

Rights of natural or legal bodies to use public water

Although almost all water resources belong to the Government the Legislator has given the right to individuals to develop and use surface or groundwater water for their own needs, i.e. for irrigation, domestic, industrial or other uses. It has also provisions allowing to legal communal entities to develop and sell or use water. In all cases, the issue of permits for the development and use of water is governed by specific laws administered by Government Bodies such as the District Administration.

Rights of water owners to develop and use their water

The laws also provide for the development and use of privately owned water resources. For this purpose a special law titled "Irrigation Associations" Law, gives the right to individuals or legal bodies, who own water rights, to form Irrigation Associations and construct, maintain and operate irrigation works for the development and use of their water. Only persons or Legal Bodies who own water rights, by title, or otherwise recognized by the Laws can form Irrigation Associations.

Water rights protection and rights of Council of Ministers

Water rights are protected but the Council of Ministers has the right to expropriate such rights and provide compensation for the public interest. So in areas where Government Waterworks are planned the Council of Ministers has the right to appoint the Water Commissioners with the specific duty to identify, evaluate and register in a Register any existing water rights. For this purpose the Commissioners have the right to carry out surveys and investigations and to make inquiries. In case the Government expropriates the water rights the owners are compensated accordingly.

Rights and obligations of the Director of the Water Development Department

The Water Development Department is a Technical Government Department belonging to the Ministry of Agriculture, Natural Resources and the Environment responsible for the Management of the Water

Resources, acting under the directions of the Council of Ministers. Accordingly this Department is given the right to carry out surveys for identifying and estimating any existing water rights for a specific water project work before the project is executed, to refuse the issue of a building permit for the construction of any structure in areas within the hydrological catchments of a project if the construction is likely to affect the water resources in the catchments, both qualitatively and quantitatively, to enter private property for carrying out surveys for the study and execution of water development projects and to refuse the issue of a permit for the sinking of well, or borehole in an area under the Special Measures Law, if such borehole or well shall affect qualitatively or quantitatively the groundwater resources.

Environmental issues

Environmental issues on water are covered by Law no 69/91-"Water pollution control" and other relevant laws, which provide for the reduction, control and abolition of water pollution for the best protection of the natural water resources and the health and the well being of the population.

Main laws

Water laws

The legal framework consists of a number of individual laws, the most important of which are: (i) the Government Waterworks, which gives the right to the Government to construct waterworks, (ii) the Wells Law, which gives the right to individuals (physical or legal entities) to apply for a permit to drill wells and abstract groundwater, (iii) the Irrigation Division Law, which gives the right to land owners to associate and construct communal waterworks, (iv) the Water Supply Law, which gives the right to communities to form water boards and develop water projects for their domestic requirements, (v) the Sewage and Drainage Law, which provides for the creation of sewage boards for the collection, treatment and disposal of the sewage effluents, and (vi) the Water Pollution Control Law, which provides for the abolition or reduction and control of water pollution.

Agricultural Insurance Law

This law, which was established in 1978 provides for the compulsory insurance of deciduous fruits against losses due to hail, frost and windstorm and due to rain only on cherries at ripening stage, of grapes against losses due to hail, frost and heat waves, of citrus against losses due to hail, frost and windstorm and due to "water spot" only on "Local and Clementine" mandarin varieties, of cereals against hail, drought and rust, of dry-land forage crops against drought and hail, of potatoes against hail, frost and flooding, of beans against hail, frost, flooding, prolonged rainfall and hot dry wind and of artichokes and loquats against hail and frost. The premium paid by the farmers equals to 3% of the total crop value and is the same for all crops covered by the scheme. The insurance is public and the Agricultural Insurance Law defines the premiums. The Government subsidizes this premium with an amount equal to the amount of premiums paid by the farmers. The ultimate aim of the Organization is the gradual improvement and expansion of the legislation and the formulation of an integrated insurance scheme, which shall cover the main crops against all the major calamities.

Legal framework under consideration

Because the existing legislation is considered inadequate to deal with the new conditions and challenges on the water resources management in relation to the socioeconomic and environmental needs with respect to the European requirements and vision and the new approaches related to the Integrated and Sustainable Management, a new law is under consideration. This law provides for the creation of a Water Entity, within the Government, to undertake the management of the water resources of Cyprus all in accordance with the integrated water resources principle and taking into consideration the EU Water Framework Directive.

Additional laws

(i) European Water Framework Directive. At the time of drafting this report, Cyprus was preparing to join the European Union. Since May 2004 Cyprus joined the EU and adopted the European Water Framework Directive. According to the decisions taken, due to its size (only 9,125 Square kilometers) the whole of Cyprus is considered as one basin and it is already mobilized to carry out the necessary studies related to the protection of the natural water resources. Under the European Water Framework Directive there are no additional laws dealing with water resources management except those related to environment. There are no any other laws or regulations relating to proactive or reactive drought policies.

(ii) Modifications of the Agricultural Insurance Law. Since the existing Agricultural Insurance Law does not cover against losses due to drought with the only exception of the cereals and dry-land forage it is necessary that this law is gradually improved and expanded to an integrated insurance scheme, which shall cover all crops against all major calamities including drought.

Need for further legal development

Although Cyprus experienced very acute water shortages due to repeated droughts, no attempts were made to introduce new legislation on drought mitigation. A few measures through legislation were promoted by submitting to the parliament the relative bills, one for enforcing the prohibition of use of hoses for car cleaning, which was approved and the second legislation providing for the installation of separate plumbing systems within the houses for enabling the use of second quality water for sanitary purposes and for the installation of separate waste-water collection systems enabling the collection of the grey water for treatment and reuse at the house level, which is not approved.

The updating, revision and/or totally new water legislation, taking into account the new trends in water management (water demand oriented), the recently approved European Water Framework Directive and the Directives on the Environment were on the agenda of the various Governments since the 1960's. During 2002 a new Legislation was drafted and approved by the Council of Ministers and then submitted to the Parliament for approval. This new legislation, which is not yet approved by the Parliament due to differences between the parties in the Parliament, provides for the creation of a Water Entity, within the Government, to undertake the management of the water resources of Cyprus all in accordance with the integrated water management principle and taking into consideration the EU Framework Directive. However the new law does not deal with the preparation of drought mitigation plans.

Water resources and drought management plans

The Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment is responsible for formulating and, after approval by the Government, executing the Government's overall policy on water resources management (planning, design, construction, operation and maintenance of the projects and the management of the water resources). Plans, designs and policy proposals are prepared by the Water Development Department, which are then submitted to the Ministry of Agriculture, Natural Resources and the Environment and after approval is secured from the Council of Ministers, they are implemented.

The financing of the Government waterworks, the Irrigation Division projects, the village water supplies and the town water supplies are made either through Government funds or through loans from international financing institutions such as the World Bank, the Kuwait Fund or the European Investment Bank. In case of sewage projects constructed by the sewage boards or for works carried out by the water boards the plans are prepared and implemented by the respective organizations and their financing are done by the organizations themselves. Generally the Water Development Department, although no legally defined as the administrative authority for water resources management, acts like one, carrying out water resources balance for each project including water availability evaluation (surface and groundwater) and water demand evaluation, keeping water resources inventory and to some extent exercises control over the surface water supplies and the ground water abstraction.

Structure of the institutions, organizations and stakeholders

Water Administration relates to all non-physical measures[1] taken to provide beneficial, efficient and effective use of water resources and prevent harmful effects. Such measures include legislation,

1. Institutions: Non physical non-material, spiritual, moral, mental measures, as opposed to structural measures, such as the ones related to staff, buildings and works.

which has been dealt in the previous section and the institutional arrangements (organization), required for implementing the laws.

The organization map linking all relevant institutions, organizations and stakeholders[2] representing the existing arrangements, (as depicted in the relevant laws) for water resources administration is shown on Fig. 2. The map shows three levels of activity i.e. the policy level, the executive level and the water users[3] level.

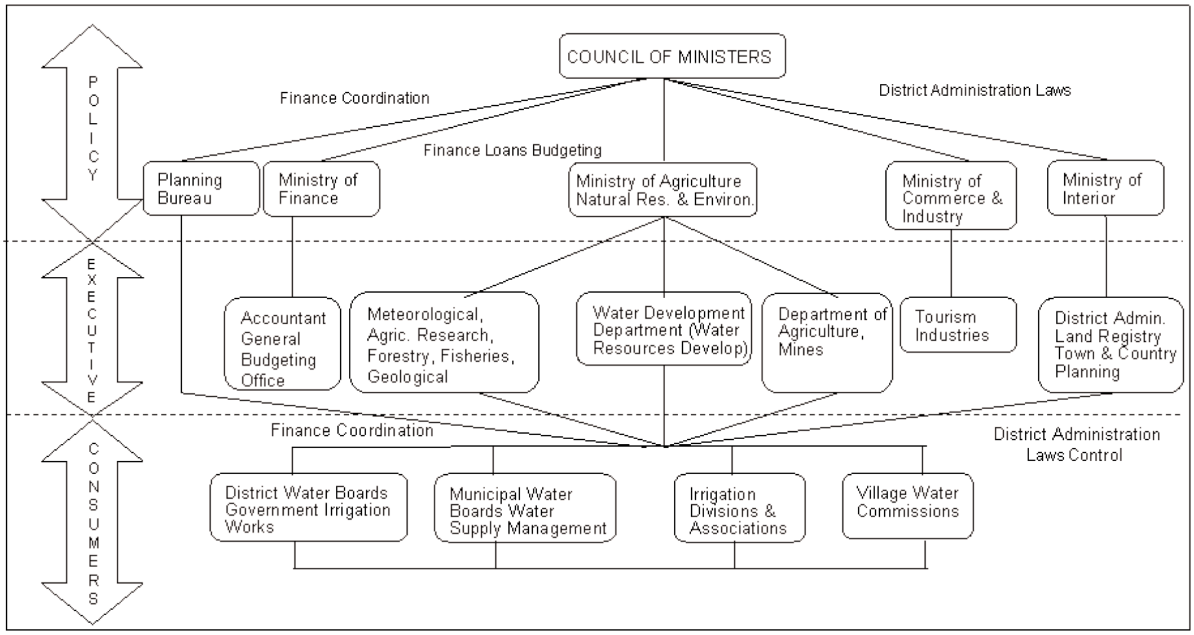


Fig. 2. Cyprus water resources management organization.

The institutions involved in drought preparedness and drought management are the same involved in the water resources management, but they are engaged in different actions for meteorological and hydrological drought preparedness planning and mitigation. This separation is made because meteorological-agricultural drought events are faced mainly within the context of the agricultural insurance scheme, while the hydrological drought is faced by a more complex setup of departments and organizations. A complete description of agricultural and hydrological drought management is included in the following sections.

Policy level – the Council of Ministers

The ultimate responsibility for all policy on water resources management and administration is within the Council of Ministers made up of eleven ministers and joined by various independent services such as the Attorney General, the Audit Office and the Planning Bureau. In formulating the water policy four ministries are involved, being the Ministry of Agriculture, Natural Resources and Environment, the Ministry of Interior, the Ministry of Finance and the Ministry of Commerce and Industry. The Planning Bureau is the coordinator of all development projects. The Ministry of Agriculture, Natural Resources and the Environment provides the technical support through the Departments of Water Development, the Geological Survey, the Agriculture and other Departments such as the Meteorological Services, the

2. Stakeholders: Water stakeholders are people, legal entities or institutions that hold any interest in the water resources.

3. Water users: Users are people or entities that continuously use water, or deal with water management and development.

Fisheries Department, and the Agricultural Research Institute, etc. The Ministry of Commerce and Industry deals with water for industries and tourism, the Ministry of Finance provides the financing for the execution of the waterworks and the Attorney General is the legal adviser.

Executive Level – Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment, and the Ministry of Interior

Responsibilities for water administration at the executive level are primarily divided between the Ministry of Agriculture, Natural Resources and the Environment and the Ministry of Interior. The Ministry of Agriculture, Natural Resources and the Environment through the Water Development Department, a competent technical organization, formulates the water resources development policy. This Department is responsible for formulating and executing the Government's overall policy on water resources planning, design, and construction on the island. It also operates and maintains all of the Government Waterworks and gives advice to other local organizations with regard to the operation, maintenance and management of local projects. Other departments of the Ministry of Agriculture, Natural Resources and Environment are the Department of Agriculture and the Agricultural Research Institute, closely concerned with the efficient and effective use of irrigation water, and the Geological Survey Department dealing with ground water surveys and investigations. The Ministry of Interior has the legal power, mainly through the district officers, both at the executive and the water user levels, dealing with the supervision of the administration of the town water boards, the irrigation divisions, the village water commissions, and the town and village sewage boards, carried out by committees partly elected and partly appointed by the Government.

User Level – water boards and unions

At the water user's level we have the water boards, that manage the distribution of town water supplies and are semi-governmental organizations, the improvement boards and village water commissions that manage the domestic water supplies in small towns and villages, the municipal water supply and sewage boards that manage the town water supplies and town sewage collection treatment and disposal and are chaired by the town Mayor, the irrigation divisions and associations that manage the irrigation water supplies to small irrigation schemes and are chaired by the correspondent district officer of the Ministry of Interior. In addition to the above there are the farmers unions, that take care of the Farmer's interests including the supply of irrigation water, and the environmentalist organizations (governmental and non-governmental) which look for the interests of the environment. Cyprus does not use water for power production, where the use of water for industrial purposes is very limited.

Drought mitigation plans within the existing structure

The drought mitigation plans were prepared along with the monitoring process. Fig. 3 shows the steps followed for drought monitoring and drought mitigation plan preparation by using the meteorological, hydrological, water in storage, and water demand data. This exercise is repeated every two months starting in August, before the next hydrologic year and finishing by the end of next April. During this period the water balance sheet is prepared each time based on the actual and projected water inflows and demand under different scenarios of inflows and demands and accordingly, the probable adverse impacts on the economy, on the social life and on the environment are defined and roughly evaluated, and the Council of Ministers is informed. No levels of severity were defined but the adverse impacts were identified and preliminarily evaluated with proposals on how to mitigate such adverse effects. The final decisions on the water saving, water augmentation and compensations in the case that no technical measures were enough to mitigate the adverse impacts, are taken by the Council of Ministers based on proposals of the Water Development Department. It must be mentioned that the existing legislation does not provide anything on drought preparedness plans. Although drought phenomena hit frequently Cyprus, droughts in most instances are dealt "as crisis management phenomena" under the General Disaster Laws. In case of drought, the Government mobilizes in a proactive manner but all its actions are reactive in nature as is explained below.

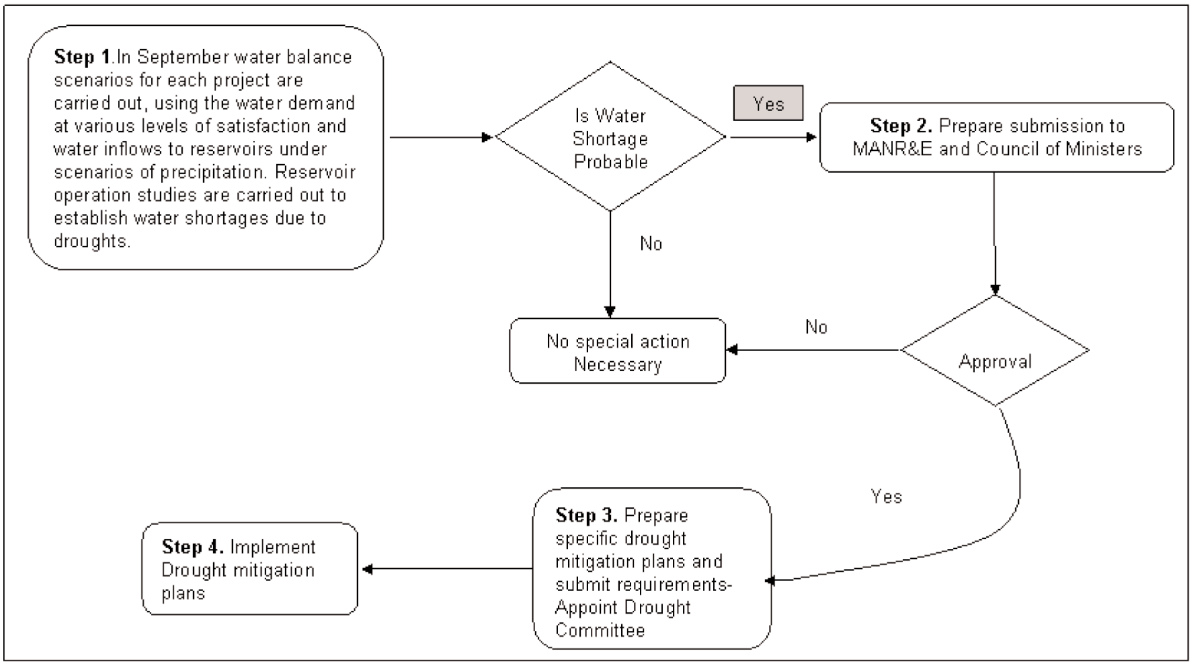


Fig. 3. Drought mitigation proactive plan steps undertaken by the Water Development Department in Cyprus.

Step 1

Early in August before the commencement of the new hydrological year, and every two months thereafter, till the end of next April (wet season), the Water Development Department prepares the water balance sheet for each project, based on the water resources available at the time, the forecasted water inflows to the dams and to the aquifers during the remaining wet season (October-May) and on the projected demand till the end of the next year. Different water supply scenarios are developed and other inflow scenarios are developed. Each water balance sheet, covering the period August to December next year, presenting one scenario depicting a different situation is a spreadsheet containing for each project the available water sources (groundwater, surface, reuse and desalinated water), existing and projected and the water supply scenario (domestic, irrigation, industrial and environmental).

For each water supply scenario (depicting different levels of satisfaction) the inflow required is estimated and the probability of having this inflow is calculated. In the water supply scenarios the losses to evaporation and seepages from the dams are taken into account and a reservoir operation study on a monthly base is carried out for finding out the additional water inflow required. The results for each scenario are then evaluated and are ranked according to the level of satisfaction and the probability of their satisfaction and a "Table of Results" is prepared. In parallel, a preliminary evaluation of the severity of the drought is made and the impacts on the economy, on the social life and on the environment are identified and preliminarily evaluated, and suggestions are made as to the actions that must be taken. The different scenarios take into account strictly technical data (i.e. hydrological, hydro-geological, agricultural, and environmental).

Step 2

The outcome of the exercise including the balance sheet, the "Table of Results", comments and suggestions are submitted to the Ministry of Agriculture, Natural Resources and Environment for consideration. Normally no actions are taken until the end of January when the two wet months (December and January) are over and the results show that a drought is more probable or is not. The scenarios are revised every two months, and scenarios that are fully satisfied are not considered further. In parallel to this the Agricultural Insurance Organization is monitoring any developments with respect to agricultural drought, which affects mainly the rain-fed agriculture.

Step 3

Based on the outcome of the revised scenarios, if a drought is already on, the most probable scenario is chosen and a detailed action plan is prepared early in February, which is referred again to the Ministry of Agriculture, Natural Resources and Environment, and then to the Council of Ministers, for decisions. The plan includes drought mitigation measures, such as water transfer, new water supply emergency schemes, water cuts, water reallocation, water saving campaigns, etc. For the implementation of the plan an *ad hoc* Drought Management Committee is formed which meets and examines the implementation of the proposed measures and take decisions concerning the implementation of the measures and the allocation of the funds, on a biweekly basis or earlier if it is necessary. The Drought Management Committee is a multidisciplinary committee with members from the Ministry of Agriculture, Natural Resources and the Environment, the Water Development Department, the Department of Agriculture, the Geological Survey Department, the Ministry of Interior (District Office level), the Planning Bureau, and depending on the occasion under consideration, with officers from other Government Organizations. The Committee does not include any water consumers or their representatives. To a certain extent, however, they are represented by the district officers.

Step 4

The implementation of the Drought Mitigation Plan starts in May and lasts until the end of the drought phenomenon or until the effects are minimized. The Drought Management Committee does not examine applications for compensations or subsidies to persons or communities suffering from the adverse effects of droughts. Any such claims are submitted to the Government in general and decisions are taken by the Council of Ministers.

The funds for financing the implementation of the Drought Management Plans are provided from the Government Budget, either from previously approved funds under the heading "Damages from Drought and Other Natural Calamities" or under the heading "Contingencies and Reserve", under the control of the Ministry of Finance.

For the meteorological drought, the Agricultural Insurance Organization mobilizes later in May-June to evaluate the damages caused by the drought and payments are made from its own resources

From the above it is seen that the action to Drought Management is not proactive but reactive and is based not on the principle of risk management but on the principle of crisis management. The above procedure has been used in the recent droughts faced in Cyprus during the period 1990-2000.

Agricultural drought management

The institutions involved in the process for facing the meteorological and agricultural droughts are the Agricultural Insurance Organization, the Department of Agriculture, the Planning Bureau, the Ministry of Finance and the Council of Ministers. Since the existing insurance scheme covers only losses against drought from cereal and dry land forage crops, losses from the remaining crops due to drought are in many cases covered by the Council of Ministers using government funds, by using the Agricultural Insurance Organization and/or the Cooperatives for transferring the funds.

The process for responding to the agricultural drought effects is reactive and involves the following steps.

Step 1: Evaluation. Upon realization of the agricultural drought effects the Agricultural Insurance Organization mobilizes by itself for the evaluation of the losses in cereals and dry land forage. For crops not covered by the Agricultural Insurance Scheme the Government usually acts by itself providing compensations to the farmers. In such situations the Council of Ministers through the Ministry of Agriculture, Natural Resources and Environment gives instructions to the Agricultural Insurance Organization or the Department of Agriculture for the evaluation of losses.

Step 2: Compensation. Upon evaluation of the losses the Agricultural Insurance Organization proceeds with the payments of losses from crops covered by the insurance plan all in accordance with the valid agricultural insurance scheme. For those crops not covered by the insurance plan the procedure is quite long since it involves further considerations before a decision is taken by the Council of Ministers and the Parliament for approval of the funds.

Model structure validation

The mapping model presented above was implemented and validated in a number of occasions during the period 1990-2000, by the author. This model is not based on a specific law or regulation but on the necessity to mitigate the adverse effects from water shortage caused by repeated droughts. Since there is no law or regulation the model was the best possible under the circumstances of acute water shortage. The model made the best use of the existing institutions and organizations and its success was based on the good will and understanding of all stakeholders.

The model, although not covering all affected sectors, is validated in recent drought situations, observing that the model current structure provided support of the following essential points:

(i) To satisfy the basic needs of water with priority in the supply of drinking water but without neglecting the needs for other sectors. This necessitated the reallocation of the very limited water resources available at the time.

(ii) To alleviate the impacts of the water shortage by promoting water saving measures and methods, and augmenting the water resources availability, where possible, by mobilizing natural water resources, by recycling domestic effluents, by introducing seawater, desalination and by using lower quality water, where possible.

(iii) To promote water savings in all sectors of the economy, indicating that water shortage is a problem concerning all consumers irrespective of the priority given to one or the other sector for satisfaction.

(iv) To raise public awareness and to educate the population on the importance of the water and how to use wisely and efficiently the limited water resources. It was also stressed and understood by all that the best method to mitigate droughts and avoid the repetitions of water shortage due to droughts was to save water when it is available.

The model was validated form the conclusions of the stakeholders' interviews that were carried out in the framework of the MEDROPLAN project, which are summarized below:

(i) Perception of drought. The perception by the professionals and the population that droughts are natural phenomena that occur periodically affecting the water resources availability and that the drought mitigations plans should be part of the water resources management plans.

(ii) Actions. The legislators and the Government understood how serious could be the impacts from the droughts and embraced all the plans that could alleviate the adverse effects and relief the consumers, domestic users, irrigators and industrialists from the difficult situation created by the shortage of water. For this purpose they approved and authorized the expenditure of funds for new projects, for promoting water saving, and for compensations to those adversely affected, mainly farmers.

(iii) Collective approach. The population understood very soon that mitigation of the adverse effects could not be undertaken individually but by all and under the direct supervision of experts, who have the expertise and the know-how.

The validation of the model does not mean that the model is the best or it is always adequate or does not have weaknesses. The main weaknesses of the model are the following:

(i) It is a reactive and not a proactive plan. Although the plan is drafted ahead of time its implementation is commencing after political decisions are taken. Water saving plans and measures included in drought preparedness plans, are abandoned once the crisis is over where other measures involving emergency plans for additional water supplies continue to operate thus increasing the water demand and depriving the authorities of a source that could be used again in the future. This occurs often with the drilling and operation of emergency boreholes, which after the crisis is over, continue to operate mainly depleting the strategic sources and increasing the permanent water demand.

(ii) Lack of legal framework. The procedure and criteria for development of the Drought Preparedness Plan and its implementation are not based on any specific law or regulation. The implementation of most actions is not based on legislative articles but on the good will and understanding of those affected, positively or negatively.

Strengths and weaknesses on current drought management plans

Legislation

Since no specific legislation exists for the preparation of drought mitigation plans no strengths and weakness can be reported, but the absence by itself is a great weakness for fighting drought. Generally the absence of laws and regulations (defining drought, the preparation of drought mitigation plans, when drought mitigation plans are to be implemented, and when drought is terminating, as well as criteria, rules and priorities for water reallocation, who shall be compensated, how much and to what extend, how economic, environmental and economic issues are mitigated, as well as defining the responsible institutions and their powers, etc.), is a serious weakness of the whole system.

In general actions on drought are left to the good will of some organizations or persons who do not have a legal responsibility or the obligation to watch and prepare plans for facing situations under drought.

Another dimension of the drought impacts is the fact that the impacts are not confined to water scarcity only but extend to a number of other activities not easily manageable under a crisis management approach.

The power of the Council of Ministers to declare "a situation of emergency" under certain conditions, requires the approval of the Parliament and contains too many other considerations which Governments usually do not exercise unless the situations is very serious and lives are at stake.

Institutions

The comments on strengths and weakness of the existing institutions dealing with drought are based mainly on the complete absence of a legal framework, on the lessons learned and the experiences gained in facing the recent drought events.

From the point of view of the collection, processing and storage of data on meteorology and water resources, the institutions do not show weaknesses. There is a good network of meteorological and hydrological stations which collect on a regular permanent basis the basic information. Although there is no provision in their duties and responsibilities to deal with drought phenomena, since such phenomena are recurrent in Cyprus the institutions and organizations are collecting and processing such data with a view to identify drought events.

The same is true with the water resources management, where the responsible institution is continuously monitoring the availability of surface and groundwater resources and prepares scenarios for future actions. The data on water availability and use, like the hydro-meteorological data are continuously updated and analyzed for the identification of droughts events and the Ministry of Agriculture, being the ministry responsible, is continuously informed. However this does not mean that the institutions are fully staffed to monitor and analyze drought events in a comprehensive manner, or to prepare drought preparedness plans or to initiate actions for drought mitigations. Knowledge and know-how are not available since nobody has the responsibility by law or regulation for acquiring such expertise or specialty. All the above weaknesses lead in many instances to the preparation of incomplete reactive plans or to reactive plans in the case of plans to mitigate the effects of drought on the social and economic sectors.

In conclusion it can be said that the weaknesses of the existing system is the total absence of legislation for drought preparedness plans, for drought definition and for definition when drought initiates and when drought terminates. Also the absence of legislation defining the obligations, duties, responsibilities and powers of institutions to act under drought conditions is a fatal weakness since neither complete monitoring systems are guaranteed, nor integrated drought proactive mitigation plans can be prepared and no organization or institution is named with the duties and responsibilities to act accordingly. The inadequate reactive drought mitigation plans usually lead to high cost measures, but ineffective in the long term. The institutions also lack experience on risk analysis and drought preparedness plans.

Methodological component: Drought characterization and risk analysis

Drought characterization

Historical drought events

During the years, 1989-2000 Cyprus has suffered from a number of severe droughts as shown on Table 3. In all cases, the events are initiated as meteorological droughts but very quickly they develop into hydrological droughts since Cyprus has no perennial rivers and the rivers length is very short. By studying Table 3 it can be easily concluded that drought phenomena in Cyprus are very frequent and severe since reduced precipitation in drought conditions is between 65-88% of the normal with runoff reduction from 17 to 52% of the normal.

Table 3. Drought events in Cyprus in the period 1989-2000

Year	Precipitation (mm)	Percentage of average precipitation	Percentage of average runoff	Remarks
1989/90	363	68.1	18	Two year drought
1990/91	282	52.9	0	39.5% deficit on precipitation
1993/94	417	78.2	35	One year drought
1995/96	383	71.9	20	Five year drought
1996/97	399	74.9	30	24.7 % deficit on the average
1997/98	388	72.8	28	per year on Precipitation
1998/99	473	88.7	52	
1999/00	363	68.1	18	

Of importance is the period 1996-2000, during which the average precipitation was only 75.3% of the long-term average and the average inflow to the reservoirs was only 24.7% of the average. This shows that meteorological droughts in Cyprus quickly develop into hydrological droughts causing acute water shortages.

The relationship between precipitation and run-off is shown in Fig. 4, which shows the actual precipitation, expressed as the percentage of the long-term average, versus the actual reservoir inflow, expressed as the percentage of the average annual. The average annual inflow is the one calculated at the planning stage of the project, which corresponds to the average normal precipitation. As can be seen in Fig. 4, the relationship is not linear due to the changing hydro-geological and other conditions prevailing in the different catchments, with runoff decreasing at a higher rate than precipitation. As an example for precipitation around 82% of the average the runoff is only 40% of the normal i.e. for precipitation reduction of 18% from the average the runoff reduction is 60%. It is also seen from Fig. 4 that the recorded percentage of inflows versus the recorded precipitation is not always the same but shows different percentages these being due to the time and space distribution of the precipitation as well to other parameters such as temperature, wind, humidity etc. Although the above is not fully studied and the relationship not scientifically defined this relationship can be used to give a measure of the severity of water scarcity in the various projects.

Meteorological drought in Cyprus

Droughts and their effects on the economy, on the social life and on the environment are very well known in Cyprus since ancient times. The frequency of drought events in Cyprus, with lower than average precipitation of varying severity, duration and scale has been changing during the last century as it is seen on Table 4 and Fig. 5, which shows the actual average annual rainfall during the period 1916-2000. In the early years of the century the droughts frequency was 2.4 years with rainfall below the average out of ten (10) years, while after 1970 the frequency of droughts increased to 6 years out of 10 and in the period 1990-2000 out of 11 years 8 years had a rainfall lower than normal.

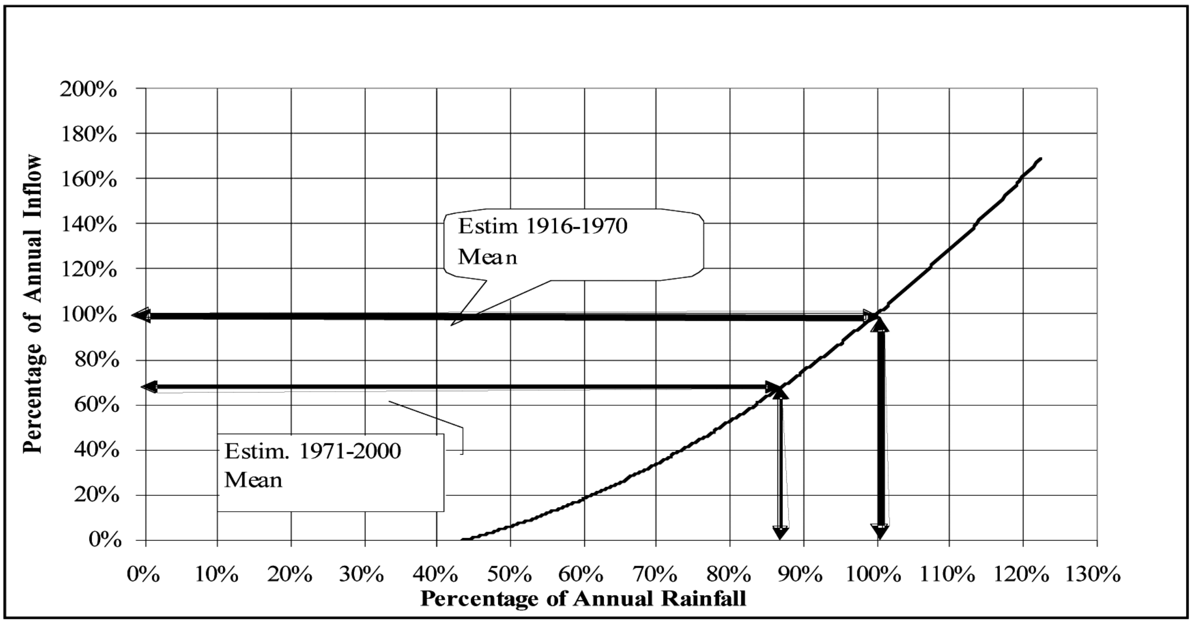


Fig. 4. Relationship between precipitation and annual inflow in Kouris dam.

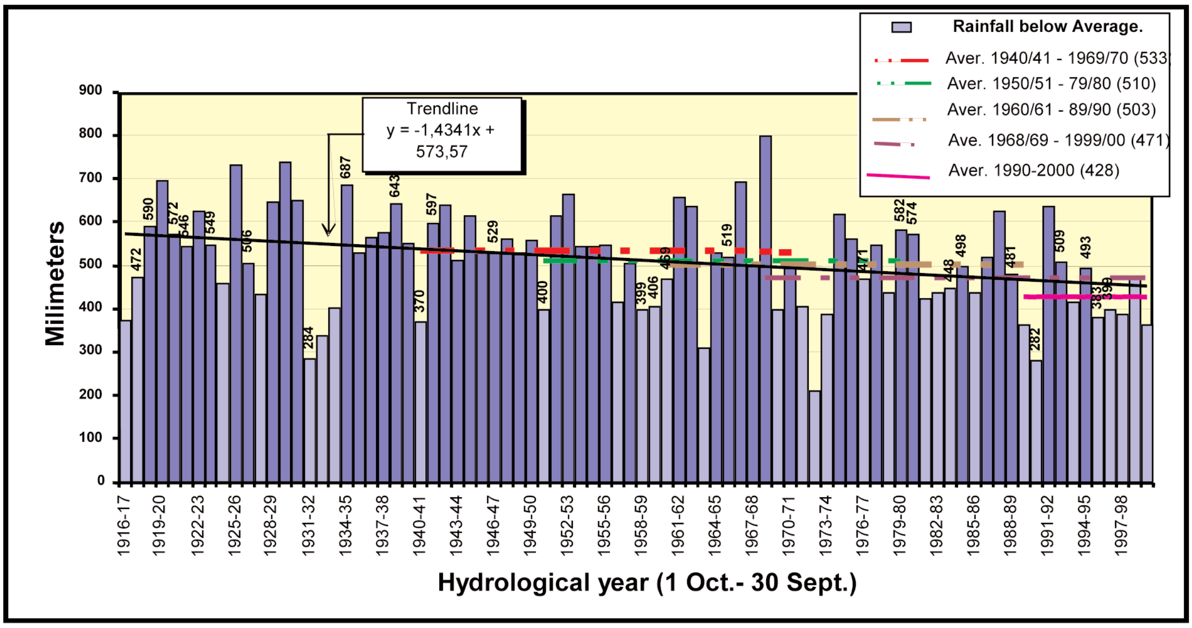


Fig.5. Average annual rainfall in the free area of Cyprus (1916-2000).

Table 4. Meteorological drought events in Cyprus (1916-2000)

No	Years	Precipitation in mm	Percent of Average	Deficit %	Remarks
1	1916/17 1917/18	373 472	70.0 88.5	30.0 11.5	Two year drought 20.6% deficit
2	1924/25	460	86.3	13.7	One year drought
3	1927/28	434	81.4	18.6	One year drought
4	1931/32 1932/33 1933/34	284 341 401	53.3 64.0 75.2	46.7 36.0 24.8	Three year drought 35.8% deficit on the average per year
5	1940/41	370	69.4	31.6	One year drought
6	1950/51	400	75.0	25.0	One year drought
7	1958/59 1959/60 1960/61	399 406 469	74.9 76.2 88.0	25.1 23.8 12.0	Three year drought 20.3% deficit on the average per year
8	1963/64	309	58.0	42.0	One year drought
9	1969/70	398	74.7	25.3	One year drought
10	1971/72 1972/73 1973/74	408 213 389	76.5 40.0 73.0	23.5 60.0 27.0	Three year drought 36.9% deficit on the average per year
11	1976/77	471	88.4	11.6	One year drought
12	1978/79	439	82.4	17.6	One year drought
13	1981/82 1982/83 1983/84	425 437 448	79.7 82.0 84.0	20.3 18.0 16.0	Three year drought 18.1% deficit on the average per year
14	1985/86	438	82.2	17.8	One year drought
15	1989/90 1990/91	363 282	68.1 52.9	31.9 47.1	Two year drought 39.5% deficit
16	1993/94	417	78.2	21.8	One year drought
17	1995/96 1996/97 1997/98 1998/99 1999/2000	383 399 388 473 363	71.9 74.9 72.8 88.7 68.1	28.1 25.1 27.2 11.3 31.9	Five year drought 24.7 % deficit on the average per year

Drought is a recurrent feature of climate that is characterized by temporary water shortages relative to normal supply, over an extended period of time. On the other hand climate, which represents the normal average state of the atmosphere for a given time of years and a given location, was considered for many years as a constant with its daily, weekly, monthly and seasonal variations with fixed means and standard variations. Climate changes are now occurring in many parts of the world because of the green house effect with noticeable changes on precipitation temperature. While temperature globally increases, the precipitation and other parameters are different in various parts of the world. Cyprus had an increase of 0.5°C in temperature during the last century, which is expected to increase the irrigation water requirements and water demand. However, from statistical analysis of the records available over the period of the hydrological years 1916/17-1999/2000, the rainfall shows that the precipitation time series displays a step change around 1970 and can be divided into two separate stationary periods. For the 1916/17-1969/70 period precipitation records do not show any trend where for the period 1970/71-1999/2000 the data show a slight decrease in precipitation but this trend is not significant compared to the variations from year to year. The mean precipitation of the recent period 1970-2000 is lower than the mean precipitation of the older period as is shown on Fig. 6.

The shift in the mean precipitation was found to be larger in the Troodos Mountains sectors that in the coastal and inland plains, and since some 80% of the runoff originates on these mountains, then the effect is comparatively more. Thus at every location of elevation higher than 500 m the mean annual precipitation in the recent period is lower by 100 mm or more than the mean in the older period resulting in 15-25% decrease of the mean annual precipitation of the older period resulting in a reduction of the mean annual inflow to the dams from 24% to 58% compared to the older mean. This means that in preparing the drought mitigation plans the climatic change that already occurred has to be taken into consideration. Thus a re-assessment of the water availability and water demands has to be made for each project before a drought mitigation plan is prepared.

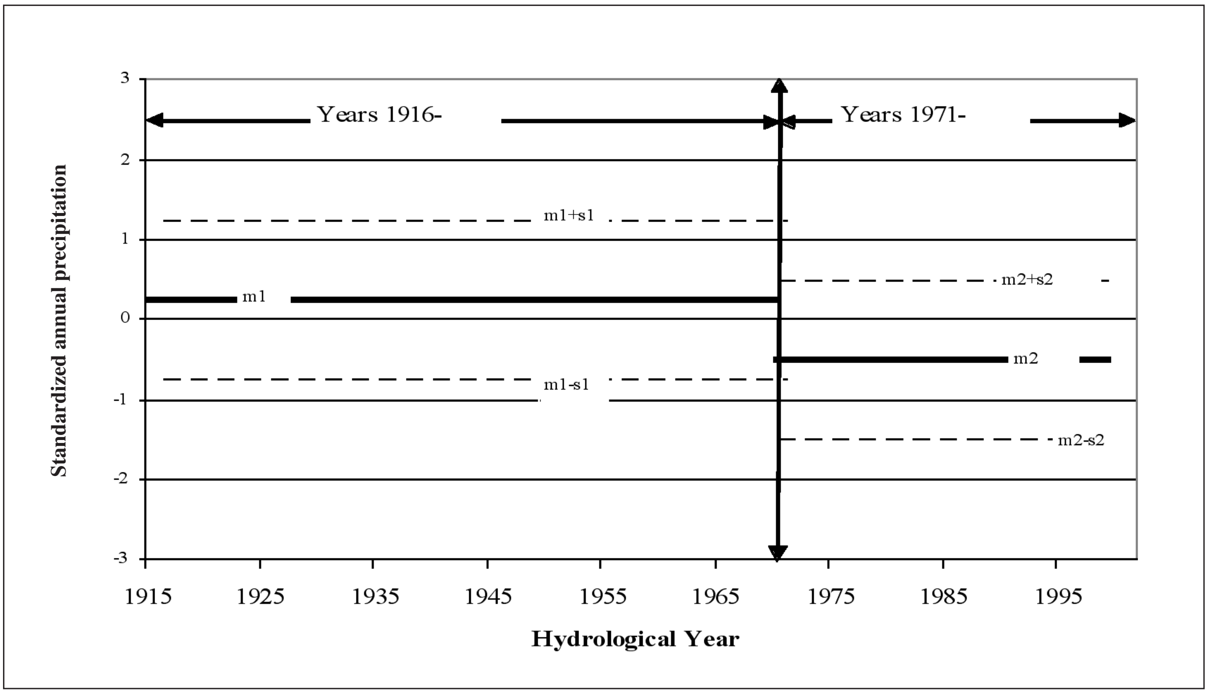


Fig. 6. Mean average precipitation. Steep reduction of precipitation after 1970. m: mean average precipitation; s: standard deviation.

Meteorological drought in the SCP

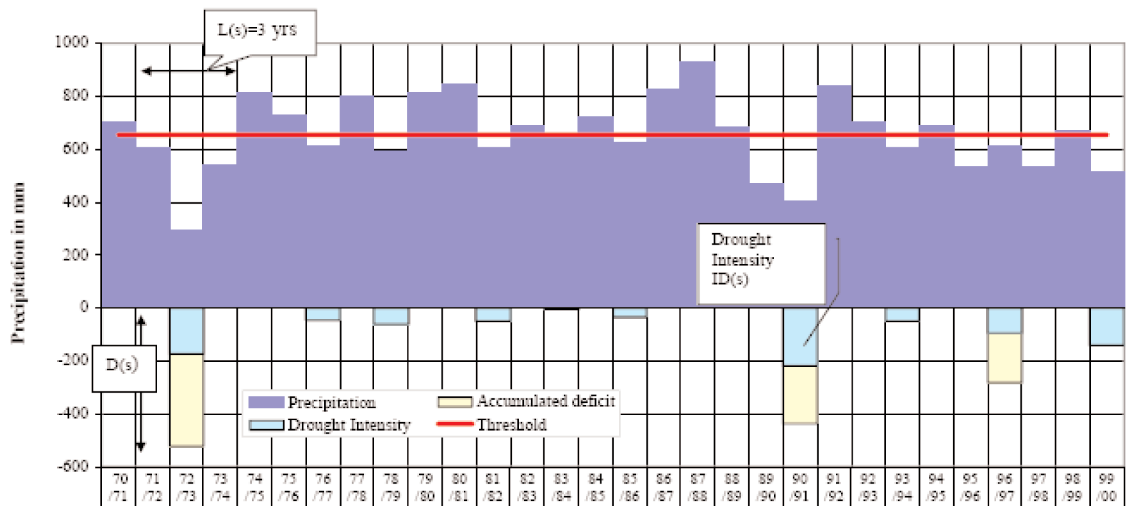
The Southern Conveyor Project supplies water to closely two thirds of the urban population and to one third of the irrigated land of the area under the Government control. Fig. 5 shows the average precipitation on the area under the control of the Government for the years of 1916-2002. Fig. 5 shows that there is a trend of reduction of precipitation with the average decreasing from 533 mm/year in the period 1940-1970 to 428 mm/year in the decade 1990-2000. On the same figure, it can be seen that the frequency of precipitation events being below the average has increased from 2.4 every 10 years to 8 out of 11 years in the period 1990-2000. Since no single indicator or index (Standardize Precipitation Index or Surface Water Supply Index or Deciles) based on the precipitation and other available data could be correlated with the hydrological drought periods or historical drought impacts, the water managers tend to rely on the precipitation, stream-flow and water in storage data variables to determine the onset and end of the water shortage situations.

Hydrological drought in Cyprus

The run analysis is an objective method for identifying the drought periods and for evaluating the statistical properties of drought events. According to this method, a "Drought period" coincides with a "negative run" defined as a consecutive number of intervals where a selected hydrological variable, in this case the precipitation, remains below a chosen truncation level or threshold. A threshold is very important since it can be chosen to be equal to the long-period mean or to a percentage of the average. The setting of threshold is based on the relationship between precipitation and runoff, which is roughly shown on Fig. 4.Three different thresholds were considered as follows: (i) drought occurs when the rainfall is below the average precipitation, (ii) drought occurs when the rainfall is equal or below 95% of the average precipitation, and (iii) drought occurs when the rainfall is equal or below 90% of the average rainfall. Based on these three thresholds, Table 5 shows the calculated number of drought events, the number of drought years, the minimum and longest period of droughts and the deficits and drought intensities for the period 1970-2000. An example of graphical presentation of the droughts identification for a threshold equal to the average precipitation is shown on Fig. 7.

Table 5. Hydrological series and drought characterization for the Kouris catchments area, for three thresholds: equal to the mean, equal to 95% and equal to 90% of the mean precipitation

	Mean	95% of the mean	90% of the mean
Droughts Characterization			
Length of analysis period (years)	30	30	30
No. of drought years	14	13	8
No. of drought events	9	8	5
Minimum duration of drought (years)	1.0	1.0	1.0
Longest period drought (years)	3.0	3.0	2.0
Average duration of drought (years)	1.56	1.63	1.60
Maximum accumulated deficit for one period (mm)	522.00	417.00	334.00
Average accumulated deficit (mm/year)	180.33	141.88	160.40
Maximum drought intensity (mm/year)	218.50	183.50	167.00
Average drought intensity (mm/year)	62.04	42.73	50.13
Percentages to mean annual precipitation			
Maximum accumulated deficit for one drought period	79.69%	63.66%	50.99%
Average accumulated deficit	27.53%	21.66%	24.49%
Maximum drought intensity	33.36%	28.02%	25.50%
Average drought intensity	9.47%	6.52%	7.65%
Percentages to length of period			
No. of drought years	46.67%	43.33%	26.67%
Longest period of drought (years)	10.00%	10.00%	6.67%



	70 /71	71 /72	72 /73	73 /74	74 /75	75 /76	76 /77	77 /78	78 /79	79 /80	80 /81	81 /82	82 /83	83 /84	84 /85
Precipitation	704	607	297	539	813	731.	609	797	593	813	847	604	687	650	723
Accumulated deficit			-522.				-46.5		-61.8	0.0	0.0	-51.1	0.0	-5.1	0.0
Drought Intensity			-174.				-46.5		-61.8			-51.1		-5.1	
Threshold	655	655	655	655	655	655	655	655	655	655	655	655	655	655	655

	85 /86	86 /87	87 /88	88 /89	89 /90	90 /91	91 /92	92 /93	93 /94	94 /95	95 /96	96 /97	97 /98	98 /99	99 /00
Precipitation	622	824	931	685	472	400	837	704	604.	692	535	614	534	671	514
Accumulated deficit	-33.2	0.0	0.0	0.0		-437.			-50.2			-282.			-141.
Drought Intensity	-33.2					-218.			-50.2			-94.1			-141.
Threshold	655	655	655	655	655	655	655	655	655	655	655	655	655	655	655

Year

Fig. 7. Drought identification using the run method.

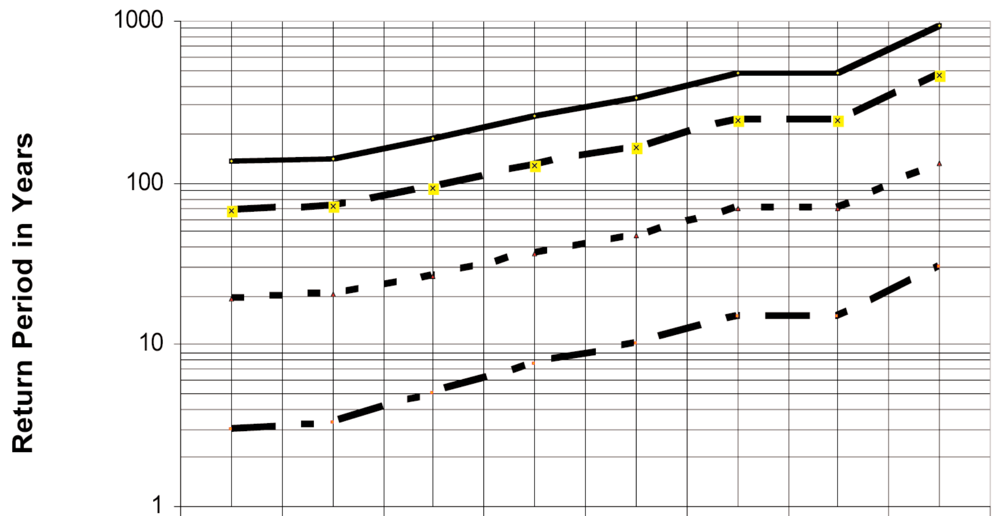
If we take a drought with a threshold equal or less than 95% of the average rainfall then the average number of drought events is eight (8) over a period of thirteen (13) years equivalent to 4.3 years every 10 years. The use of a comparatively high threshold value (very close to the mean rainfall) is due to the fact, that a meteorological drought of this intensity causes a relatively high hydrological drought as seen on Fig. 4, which shows the relationship between precipitation and surface runoff.

Probability distribution of drought characteristics and return periods

Since the probabilistic features of droughts characteristics cannot be properly carried out by fitting a parametric distribution to observed sequences of drought characteristics because of the limited number of drought events,an analytical derivation of the probability distributions of drought characteristics, based on the distribution of the hydrological series has been proposed by a number of researchers. Such analytical expressions have been derived for the marginal distribution of the accumulated deficit and for the bivariate distributions of duration and accumulated deficit and drought intensity.

The return period of droughts is defined as the expected value of elapsed time or inter-arrival time between occurrences of critical events. In evaluating the return period of multiyear droughts it is necessary to consider their duration and their severity, i.e. the accumulated deficit or intensity in order to derive analytical expressions for its estimations.

The probability of occurrence and the return periods of drought identified are shown on Table 6 and Fig. 8.



	0,0%	4,6%	7,6%	15,3%	30,5%	45,8%	61,1%	76,3%
One Year Duration Drought	19	20	27	37	48	69	69	133
Two Years Duration Drought	135	143	188	260	333	482	482	931
Three Years Duration Drought	68	71	94	130	167	241	241	466
Any Drought	3,00	3,33	5,00	7,50	10,00	15,00	15,00	30,00

One Year Duration Drought   Two Years Duration Drought

Fig. 8. Return periods in year of droughts deficit equal to or more than to a certain amount (percentage of mean average precipitation) and for drought duration of one, two or three years for catchments area and threshold equal to mean average precipitation.

Table 6. Drought characterization (Accumulative Deficit>Do and duration L = 1, 2, 3 years) and return periods probability of occurrence

Kouris catchment-Threshold equal to mean average								
Accumulated deficit mm	0-30	30-50	50-100	100-200	200-300	300-400	400-500	500-600
Percentage to mean average (Do)	0.0%	4.6%	7.6%	15.3%	30.5%	45.8%	61.1%	76.3%
Probability of occurrence of D>Do	33%	30%	20%	13%	10%	7%	7%	3%
Return period in years								
A.1: One year period drought	19	20	27	37	48	69	69	133
A.2: Two years period drought	135	143	188	260	333	482	482	931
A.3: Three years period drought	68	71	94	130	167	241	241	466
A.4: Totals	3.00	3.33	5.00	7.50	10.00	15.00	15.00	30.00
Kouris catchment- Threshold equal to 95% of mean average								
Accumulated deficit mm	0-30	30-50	5-100	100-200	200-300	300-400	400-500	500-600
Percentage to mean average (Do)	0%	5%	7.6%	15.27%	30.53%	45.80%	61.07%	76.34%
Probability of occurrence of D>Do	27%	13%	13.3%	13.33%	6.67%	6.67%	3.33%	0.00%
Return period in years								
B.1: One year period `drought	31	52	52	52	96	96	186	0
B.2: Two years period drought	153	260	260	260	482	482	931	0
B.3: Three years period drought	77	130	130	130	241	241	466	0
B.4: Totals	3.75	7.50	7.50	7.50	15.00	15.00	30.00	
Kouris catchment -Threshold equal to 90% of mean average								
Accumulated deficit mm	0-30	30-50	50-100	100-200	200-300	300-400	400-500	500-600
Percentage to mean average (Do)	0.0%	4.6%	7.6%	15.27%	30.53%	45.80%	61.07%	76.34%
Probability of occurrence of D>Do	16.7%	17%	10.0%	6.67%	6.67%	3.33%	0.00%	0.00%
Return period in years								
C.1: One year period drought	72	72	111	161	161	310	0	0
C.2: Two years period drought	108	108	167	241	241	466	0	0
C.3: Totals	6.00	6.00	10.00	15.00	15.00	30.00		

The calculations of the probability distribution of drought characteristics and return periods were carried out as outlined in Tsiourtis (2005b).

The probability of occurrence of any drought event with accumulated deficit greater than zero (threshold equal to mean average precipitation) is 33.3%, with recurrent period 3 years.

The probability of occurrence of any drought event with accumulated deficit greater than zero (threshold equal to 95% of mean average precipitation) is 26.67%, with recurrent period 3.75 years.

The probability of occurrence of any drought event with accumulated deficit greater than zero (threshold equal to 90% of mean average precipitation) is 16.67%, with recurrent period 6 years.

The return period of a drought event with accumulated deficit greater than zero (Threshold equal to the Mean Average Precipitation) and drought period duration equal to 3 year is 68 years.

Generally the return period for any drought with accumulated deficit above zero is 3 years, for accumulated deficit above 7.6% of the mean is 5 years, for accumulated deficit above 15.3% of the mean average precipitation is 8 years and so on. Fig. 8 shows in graphical form the return periods for any drought and for specific droughts.

Conclusions on model validation

Threshold is set arbitrarily or can be based on the observations and findings the selected hydrological or meteorological variables have on the droughts. In the case of rainfall it was observed that even a small reduction causes a big reduction in stream flow and in the groundwater recharge. This is due to the typical Mediterranean climate with relatively high potential evaporation, and high potential transpiration. The resulting surface runoff is not directly proportional to the rainfall reduction but reduces drastically with small reduction of the rainfall this being the result of satisfaction first of the relatively constant evaporation and transpiration demand. The precipitation-runoff relationship has been studied in the Re-Assessment Study of Water Resources and Demand in Cyprus (Klohn, 2002) for the Kouris Dam and it is shown on Fig. 4. A reduction of 13% of the precipitation causes 35% deduction of the average of the runoff. Therefore an annual precipitation below the average precipitation is always a drought condition since the runoff is reduced drastically. In view of the above the threshold should be fixed equal to the average mean annual precipitation.

Impacts of drought

Droughts have adverse impacts on agriculture, on the water supply economy, on the environment and on the social life. A number of potential impacts, for each sector, were identified and ranked according to their importance, from five down to one. The drought impacts selected were characterized taking into account the area extent, the social distribution, the public priority, the historical trend and where possible the estimated cost of damage. The characterization of impacts is made for each of the years 1990-2000, for each of the project areas (catchment, Akrotiri area and Kokkinochoria area) in a qualitative (see Table 7) and quantitative manner (Tsiourtis, 2005b, Tsiourtis, 2005c).

Correlation of drought indices with impacts

The Standardized Precipitation Index (SPI) and the Surface Water Supply Index (SWSI) were calculated on a yearly base for the years 1970-2000 and were correlated with the economic impacts identified and ranked in the Risk Analysis Study carried out by the MEDROPLAN project. From the analysis, some conclusions, that follow, can be issued (Tsiourtis, 2005c).

There is a high correlation between Standardized Precipitation Index (SPI) and the Surface Water Supply Index (SWSI), ranging from 0.75 to 0.887.

There is a high correlation between SPI and the gain/loss in the rainfed agriculture, which varies from 0.6306 in the Akrotiri area to 0.7124 in the Kokkinochoria Area. Kokkinochoria area is the most representative area since it covers the largest part of the area under rainfed crops. This relationship is

Table 7. Checklist and ranking of potential impacts

No.	Impact	Rank	Remarks
	ECONOMIC: AGRICULTURE		
A.1	Loss of farm income	5	Mainly for rainfed
A.2	Decrease in Farm Income	4	This includes crop and livestock
A.3	Decrease in crop production	4	Valid only on crop production
A.4	Decrease in livestock feed quantity and quality	3	Valid only for livestock
A.5	Increase of farm subsidies	3	This concerns Government subsidies
A.6	Increase of unemployment of the agricultural sector	3	Affects both family farm and hired workers
A.7	Decrease in pasture production	2	This is affected by meteorological drought
A.8	Decrease crop quality	2	Mainly on crop production
A.9	Increase in crop prices because fixed costs remain the same	2	Due to reduced supply of crops and
A.10	Loss of income of industries dependent on agriculture	2	Because of less product available
A.11	Loss of income from agricultural exports	2	Because of less product available
A.12	Losses in financial institutions related to agricultural activities	2	Because the lending capacity of the farmers decreases where their needs increase
A.13	Increase in crop imports	1	To cover needs not covered by local production
A.14	Increase of soil erosion	1	Due to the loss of plant roots and the winds
A.15	Loss of Value Added Tax	1	Less product, lower value, lower VAT
	ENVIRONMENTAL		
B.1	Biodiversity loss in land based ecosystems	4	Less moisture, less vegetation
B.2	Biodiversity loss in ecosystems associated with water	3	Less water or lack of water in water systems, animals and fish migrate to other areas
B.3	Deterioration of visual and landscape quality	3	Wetlands, riparian animals and plant life are displaced or die
B.4	Groundwater depletion	3	Water levels drop because of less recharge and over pumping
B.5	Increase stress to endangered species	3	Endangered species are very vulnerable to droughts
B.6	Increase in number and severity of fires	3	Drier land and mountain slopes increase vulnerability of the forest
B.7	Water quality effects (salt concentration in soil)	3	Less quantities of infiltrating water to groundwater and seawater intrusion due to falling water levels
B.8	Groundwater quality deterioration	3	Same as above plus higher waste water infiltration
B.9	Decrease in reservoir and lake levels	1	Less inflow from rivers
B.10	Increase erosion of soil by wind	1	Less moisture less roots
	ECONOMIC: WATER SUPPLY		
C.1	Decrease revenues of water supply firms	4	Less water to sell
C.2	Decreased revenues of Government	4	Less water to sell
C.3	Additional cost of supplemental water infrastructures	3	Construction of emergency water projects
C.4	Increase in water treatment costs	3	While fixed costs remain the same treated Water volumes decrease

C.5	Additional cost of water transport	2	Water has to be transported from long distances
C.6	Increased cost of groundwater extraction	2	Water levels are falling, yields are decreasing, water is pumped from deeper levels and from more boreholes
C.7	Reduced service quality	2	Lower pressure, lower flow rates do not serve All consumers
	SOCIAL		
D.1	Conflict between the Government and affected groups	5	The inability to provide full supply of water
D.2	Deterioration of the overall well-being of rural people	5	Less water input less product lower income
D.3	Social inequality	5	Social inequality deepens since rural inhabitants suffer most
D.4	Danger to public safety from fires	4	Fires are more frequent because of droughts
D.5	Increase migration from rural to urban areas	4	Less work opportunity in rural areas People move to towns for work
D.6	Public health related problems	3	Reduced water supply, with reduced water quality may endanger public health
D.7	Conflict in decision-making by different government authorities	2	Because of water scarcity and different priorities set by different departments
D.8	Decrease in the visits to recreational areas	2	Because of deterioration of the environment
D.9	Damage in cultural heritage sites	1	Not in Cyprus
D.10	Decreased nutrition quality in rural areas	1	Not in Cyprus

correct since rainfed agriculture production depends entirely on the precipitation falling during the year of growth and production. Soils in Cyprus are not such to carry over year moisture.

There is no high correlation between SPI and irrigationor water supply dependent activities economic impacts. The correlation varies from -0.164 to -0.334 for the SPI in the catchments area, from -0.4099 to -0.422 for the SPI of Akrotiri and around -0.3 for the Kokkinochoria SPI.

There is no correlation at all between SPI and the losses of financial institutions and industries dependent on irrigated agriculture. It is also seen that the correlation is slightly high in the opposite direction which means that in cases of drought events these institutions do not suffer from losses but instead increase their activities.

The correlation of SWSI with the different impacts is the following:

– Losses in crop production: Correlation coefficient -0.6627

– Losses of water supply firms: Correlation coefficient -0.6354

– Losses of Government from domestic water: Correlation coefficient -0.6959

– Losses of Government from irrigation water: Correlation coefficient -0.5689

– Extra cost to Government in water treatment: Correlation coefficient -0.5307

– Total economic cost: Correlation coefficient -0.6810

– Rainfed crop gain/loss: Correlation coefficient 0.9002

– Water supply: Correlation coefficient 0.2228

From the above the following can be concluded:

(i) The Surface Water Supply Index reflects in a more representative manner the relationship between droughts and economic impacts

(ii) The SPI index correlates highly with the rainfed agriculture losses, which indicates that the meteorological drought affects directly the rainfed agriculture.

(iii) There is no correlation between the SWSI and SPI with the water supply quantities. In both cases this is because of the role the reservoirs play in the water supply management. The role of the surface, over-annual storage reservoirs is to regulate the greatly varying inflow to the reservoirs to a steady outflow thus providing a dependable safe annual supply, which is based on the overall average yield of the reservoir. With the right management of the reservoirs, it is possible to achieve satisfaction of the basic water demands even under severe drought conditions something, which happened in Cyprus during the years 1990/91, and 1996/2000. The uniformity of water supply achieved by the proper use of the over-annual storage reservoirs definitely distorted the correlation coefficient and finally showed that there is no correlation between SWSI and water supply volumes, which under normal conditions should be very high.

A study aiming to estimate the economic effect of drought from the reduction on agricultural production was carried out by the Economics Research Unit of the University of Cyprus within the framework of the MEDROPLAN Project (Soteroulla *et al.*, 2005). For carrying out the study, the agricultural production was divided into seven categories for which data could be found on all variables of interest for the years 1975-2000, which categories are: potatoes, grapes, citrus, fruit, vegetables, olives and wheat. Wheat and grapes are the only products, which depends solely on rainfall. The aim was to estimate the effect of drought, measured with the annual or semi annual or as a moving average Standardized Precipitation Index (SPI) and the regressions are estimated for the standardized production of each agricultural product, since SPI is a standardized variable.

From the mentioned analysis the following can be summarized:

(i) There is no clear relationship between potatoes production and SPI. This is due to the fact that groundwater has been used extensively to supplement the deficient surface water supply, where surface reservoir reserves were used to compensate supplies during drought periods. The potatoes are winter crops and under normal conditions most of their water demands can be satisfied from the rainfall. In case of drought a relatively small supply of water from surface reservoirs or from groundwater can secure full production. The role of surface reservoirs and groundwater aquifers is very important in eliminating water shortages during droughts if used properly.

(ii) There is clear relationship between grapes production and SPI. This is because grapes are fully rainfed and SPI expresses the meteorological drought.

(iii) There is clear relationship between wheat production and SPI. This is because wheat is fully rainfed and SPI expresses the meteorological drought.

(iv) The relationship between citrus and SPI is varying, being originally negative and then becoming positive. This can be explained by the fact that during the 1970's 1980's droughts there was an alternative water supply from groundwater to compensate the short supplies from surface water. However with repeated droughts and with the continued over-pumping, the groundwater reserves have been adversely affected thus at the end not being able to supplement the surface water supplies. Ground water depletion and increased water demand on the surface water sources, and acute water shortage on the surface water supply system in drought events, result to the inability of the supply system to supply water to the citrus plants, indicating finally a direct relationship between SPI and citrus production.

(v) The relationship between vegetables production and SPI is similar to the one of citrus for the same reasons.

(vi) Generally there is a direct relation between rainfed agriculture and SPI although this sometimes depends on the rainfall distribution during the rainy season. Reduced rainfall in the winter months might not affect the rainfed crops but reduced rainfall in the autumn and spring months may have an adverse effect. With regard to the irrigated crops the relationship is not so direct because the surface and groundwater reserves play an important role in the supply of water. From the analysis carried out it can be seen that the duration of drought, expressed by SPI, starts to have an effect on irrigated agriculture since prolonged drought causes depletion of the reserves (surface or groundwater). Unfortunately not enough data was available to examine the relationship with the Surface Water Supply Index.

Operational component

The great variability of rainfall during the decade 1990-2000 with two periods of drought one lasting for two years and the other for five years, have created acute shortage of water. During these periods the Government was forced to change its water policy and to implement a number of drought mitigation measures thus avoiding devastating effects on the economy, on the social life and on the environment. The short and long term measures were aiming to increase the water availability, to reduce the demand and to minimize the impacts. The best measures under the prevailing hydro-meteorological, social, economic and environmental conditions were the water rationing, the raising of the public awareness and education of the consumers on how to use and save water at the consumers' level, the introduction of desalination and the use of improved irrigation systems for irrigation. Cyprus does not have the necessary legal framework for the preparation of drought preparedness plans of the risk management type and all the drought mitigation plans that were implemented were of crisis management type.

Permanent monitoring

The basis for the drought management plans in the past during the decades 1970-2000 was the selection of actual meteorological data, the hydrological data (inflow and outflow from dams) the actual use of water by sector and by user and the actual amount of water in storage in real time. Early before the commencement of the hydrologic year (in August) an assessment of the available water resources (surface, groundwater and other) was made, and the projected demands and most probable inflows were estimated in an effort to prepare a balance sheet of the water resources by the end of the coming hydrological year. This exercise was continuously updated through the winter months until the end of March, at the end of the rainy season. By analyzing the results of the water balance sheet, the water situation was initially forecasted but as time was passing by, the situation whether a drought was coming or not was becoming clear. The monitoring was not based on any index but clearly on meteorological, hydrological and water demand data that were collected on a daily basis and utilized to run water supply simulation models to establish water deficits if any.

Fig. 9 shows the actual water supply, the normal water demand and the deficit that occurred during each of the years 1987-1999 of the Southern Conveyor Project. The figure shows acute water shortages in the years 1991-1993 and the years 1996-2000 created by the drought events of the years 1990/91 and of the years 1996-1999 (one year drought and a four year duration droughts).

Examples of drought management

The drought events in the early 1970's and 1980's were easier to mitigate because the level of water utilization was lower and the water demand was lower. Their adverse effects were avoided by mobilizing non-mobilized water, by transferring water from non-developed river basins and by accelerating the rate of project construction and to a lesser extent by imposing small water cuts. However the droughts of the 1990's were very difficult to mitigate and the only way to mitigate them was by water rationing to both domestic and irrigation consumers and by cutting water supplies by more than 20% to domestic users and up to 70% to the irrigators. The inability of the water managers to mitigate these droughts was caused by the fact that all natural water resources were developed and the water demand has reached a level equal to the average annual supply. It is obvious that the only way to minimize the adverse impacts on the economy, the social life and the environment, generated by the water shortages caused by droughts, is through a Drought Preparedness Plan.

Cyprus adopted and applied practices which were chosen from a variety of practices available or proposed at the time. There are long term, medium term and short term measures, and each measure

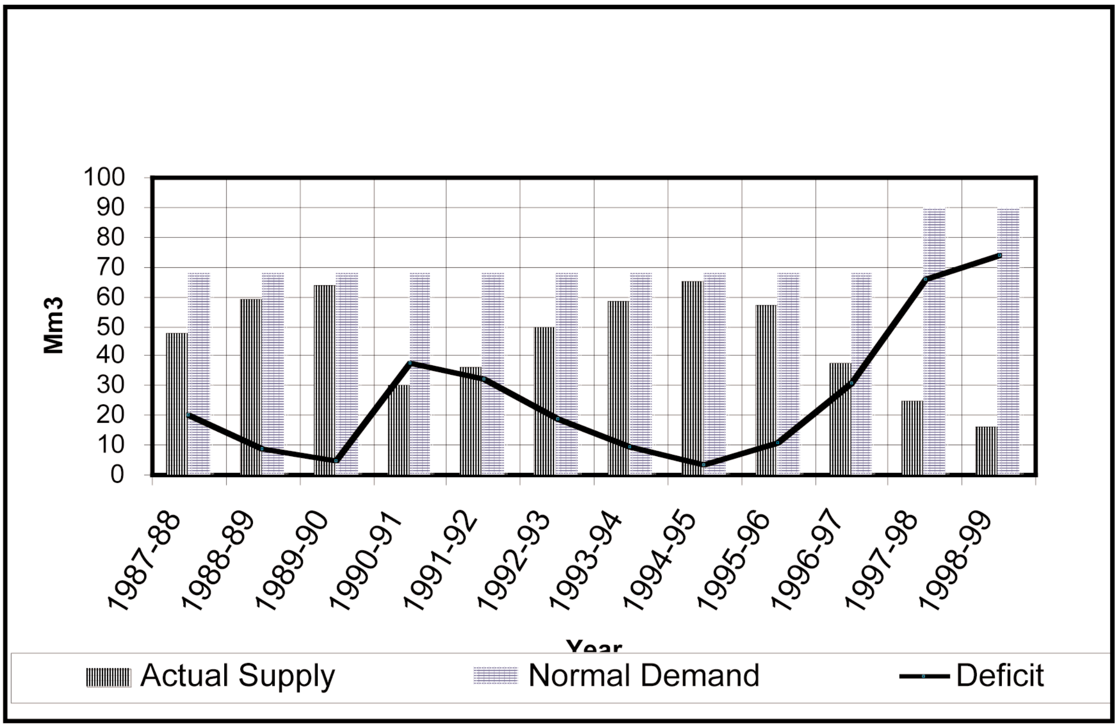


Fig. 9. Southern Conveyor Project water supplies, normal demand and observed deficit (dams only).

includes a number of practices. It has been found out that the best practices are those that are very effective and efficient (give results), are just and simple, are understood by the affected consumers, give immediate results and are applied as long as they are needed.

From all the measures adopted and applied the following can be considered as the best practices.

Water rationing

Although it is a painful measure, it is the most effective since it generally enables the water mangers to overcome the great water crisis. There were difficulties to find the golden rule as to how much water should be rationed to the individual irrigators and how to achieve equal distribution to the domestic consumers. This measure was effective (reduction in water consumption, reduction in wasteful use) and a lot of water was saved. It requires cooperation and understanding from the side of the consumers and generosity, patience and quick action from the part of the water managers. The water rationing was imposed by water cuts but its success is based on the acceptance and cooperation of the users.

Water saving

The consumers were "educated how to use water" and how to avoid over-consumption and were assisted to achieve this by the provision of the means (modernization of on-farm irrigation systems, toilet flashing water saving mechanisms, flow regulators in taps, avoid use of hoses for car and floor washing and cleaning, etc.). Domestic water distribution systems improvement, by the use of leakage detectors and repairs and the installation of high accuracy water meters were also very effective.

Use of brackish water

The use of second quality water for gardening and flashing is a common best practice.

The Government subsidized the drilling of boreholes, installation of pumping units and connection to the toilets in urban areas, thus enabling the saving of almost 50% of the domestic consumption. In some areas without groundwater the Government subsidized the installation of grey water treatment and recycling water systems.

Desalination

This measure is very efficient and effective since it increases the water availability, increasing the system reliability, and it gives results within short time compared to other alternatives which require longer periods to materialize and are dependent in many case on the weather conditions and the will of the consumers.

Awareness

Creating water awareness and, promoting the education of the consumers on water was effective and efficient directly and indirectly since it helped the population to accept the measures and also to save water.

Compensations

The provision of compensations to the most affected solved a socioeconomic problem and on the other side it helped the population to be responsive and accept the implementation of the drought mitigation measures.

Improved irrigation systems

Since agriculture consumes more than 70% of the total water resources a small saving on water for irrigation is contributing a lot in the effort to save water. The Government of Cyprus started very early in the 1960's to promote the use of modern efficient on farm irrigation systems, with efficiencies around 85-90%. Now almost 100% of the irrigated area is served from pressurized distribution systems are irrigated with modern on-farm irrigation systems.

Stakeholder analysis

Five stakeholders were interviewed to validate the organizational and operational mental model and to enhance the understanding of droughts and water scarcity problems in Cyprus. Below is a summary of the role each stakeholder plays in water and the information provided in the interviews relevant to the drought definition and understanding and to the validation of the reactive model applied in Cyprus during the period 1990-2000.

The five stakeholders were the following: Water Development Department, Meteorological Service, Department of Agriculture, water boards and farmer union organizations.

Water Development Department

This Department is the technical adviser to the Ministry of Agriculture, Natural Resources and the Environment and to the Government in general and contributes mainly to the formulation of the Government's water policy. This Department is also the main contractor who under the direction and authority granted by the Council of Ministers undertakes to plan, design, construct the waterworks and implements in general the Government's water policy.

Meteorological Service

This Service is a Government Department belonging to the Ministry of Agricultural, Natural Resources and the Environment and it is in charge of collection, processing and storing of all the meteorological data and preparing the weather forecasts for the civil aviation, travelers, agriculture and for any other users.

Department of Agriculture

This Department belongs to the Ministry of Agriculture, Natural Resources and Environment and it is responsible for the implementation of the Agricultural Policies of the Government. It also participates to the formulation of the policies.

Water Boards

These are semi-governmental organizations charged with the responsibility of distribution of domestic water in towns and cities. A Board of Directors made of a varying number of members, three of which are appointed by the Government and the rest being elected members from the municipalities govern the Water Boards.

Farmers Union Organizations

The farmer's union organizations are non governmental organizations whose objectives are to promote and protect the interests of the farmers. There are four such organizations in Cyprus representing the various political fractions of the constituent.

Summary of the interviews with stakeholders

(i) *Drought definition.* Droughts constitute a permanent feature of the Cyprus climate and are recognized by all by the lower than normal precipitation, lower flow in rivers and inflows to dams, and by reduced moisture in the plants root zones. No indices or other specific parameters are used to identify drought. It is also recognized that Droughts cannot be avoided but can be mitigated through proactive planning and actions.

(ii) *Water value.* Water is a socioeconomic good and as such it must be valued and priced accordingly. Although almost all water belongs to the Government, the irrigators' and other users' rights to use the water cannot be totally removed. In cases of droughts water is reallocated according to the priorities set by the Government. The Government through its agencies monitors the climatic and hydrological parameters and keeps records enabling its agencies to intervene in cases of droughts.

(iii) *Trends.* During the last 30 years it has been observed that droughts are occurring more frequent with longer periods than before. It is also recorded that there is a climate change with reduction in rainfall by 1 mm/year and increase of the ambient temperature by 0.5° C. per 100 years. During the 1990-2000 decade Cyprus has faced successfully the 5 year severe drought, because the measures adopted were accepted by the public and were just and not one sided. The Government also provided limited compensation to those that were severely affected.

(iv) *Management.* Cyprus is very vulnerable to droughts because it has developed most of its natural water resources and the existing legislation does not provide for drought preparedness plans and no specific actions for drought mitigation. The exiting Agricultural insurance plan against droughts is inadequate and cannot be considered as a drought mitigation measure. It does not cover losses suffered by the irrigated agriculture due to droughts and in case of rainfed agriculture it provides cover for a very limited type of crops.

Acknowledgements

The drought identification and the risk analysis studies were carried out on meteorological and hydrological data of the Southern Conveyor Project, which supplies domestic and irrigation to more than 60% of the population of Cyprus, using the procedures outlined in the Terms of Reference of the MEDROPLAN Project. A lot of data and information were provided by the Water Development Department, the Meteorological Department and the Agricultural Department to whom we express our sincere thanks and gratitude.

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Annex 1. Data and information systems

For the preparation and implementation of water development and water management plans, including drought management plans, it is necessary to collect record, process and provide accessibility to a number of variables of Biophysical and Socioeconomic nature. Table 1.1 outlines the type of data, the Institutions that collect record and process the data, how the data is acquired, the accessibility, the data reporting and the data users. Most of the information and data on drought can be acquired by request from the Departments that collect and use it, where a smaller portion can be required from published statistics or census reports.

Table 1. Characteristics of the biophysical and socio-economic data and information in Cyprus

Type of Data	Data and information System Description
Climate	Supplier: Meteorological Service Governmental Office Acquisition: Meteorological Stations manned or unmanned spread all over the island. Data include precipitation, temperatures (min, max, average), humidity, wind speed, evaporation, solar radiation, etc. Accessibility: Hard Copies, free of charge Reporting: Not published. Data kept in database Files in soft or hard copies Users: Civil Aviation, Department of Water Development, Dept of Agriculture and other organizations
Soils	Supplier: Department of Agriculture Acquisition: Surveys and investigations, soil type, soil potential, soil classification Accessibility: Purchase of Maps from Land and Surveys Department Reporting: On Maps by the Land and Surveys Department Users: Department of Agriculture, Town and Rural Planning Department, Farmers, Others
Water	Supplier: Water Development Department Acquisition: Continuous measurement of stream-flow, and water levels in aquifers Accessibility: Official request to the Water Development Department. Hard copy, digital form Reporting: Not published. Data kept in database Files in soft or hard copies Users: Water Development Department
Land	Supplier: The Land and Survey Department is responsible to register all lands in Cyprus Acquisition: Compulsory registration of land ownership Accessibility: Purchase of the Land Registry Maps Reporting: Land Registry Maps Users: Government Offices and Individuals

Agriculture	Supplier: Department of Agriculture, Department of Statistics Acquisition: Surveys, Census and Investigations Accessibility: Purchase of Agricultural Statistics Publications of the Department of Statistics from Government Printing Office Reporting: six monthly, yearly statistics Users: Government Offices and others
Water Supply and Use	Supplier: Water Development Department Acquisition: Continuous measuring of sales of water to communities and individuals. Accessibility: Requesting data Reporting: Hard copy upon request Users: Water Development Department
Land Use	Supplier: Department of Agriculture Acquisition: Land use surveys or by Agricultural Census Accessibility: Purchasing of Census Reports or Agricultural Statistics Reports from Printing Office Reporting: Annual Statistic Reports or Census Reports Users: Department of Agriculture, Water Development Department, Land Consolidation Department
Water Demand	Supplier: Water Development Department Acquisition: Measuring consumption by various users Accessibility: Requesting Data Reporting: Hard copy upon request Users: Water Development Department
Economic Indicators	Supplier: Department of Statistics Acquisition: Department of Statistics on a regular basis Accessibility: Purchasing Economics Statistic Publications from Government Printing Office Reporting: Official Government Statistic Publications Users: Ministry of Finance, Economic and financing Planners in general
Demographic Indicators	Supplier: Department of Statistics Acquisition: Ministry of Interior vital statistic Department Accessibility: By purchasing Demographic and Population statistics of the Department of Statistics fro the Printing Office Reporting: Hard Copy Users: Economic and social Planners