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

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Chapter 22. Application of the Drought Management Guidelines in Tunisia

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SUMMARY – This Chapter summarizes the analysis of the Tunisian organizations and institutions related to drought. First, the Chapter provides an overview of the rainfall and water resources in Tunisia. Second, mapping of the different National organizations and institutions involved in water management and drought mitigation, and also those not working on water management but, due the emergency of drought circumstances and regarding the importance of their contribution, they are associated when the drought is upon. The International organizations working on water resources management in Tunisia and eventually on drought mitigation are also described. The Chapter analyses the interaction between the different organizations and institutions involved in the process of the water management and drought mitigation as well as in the linked data and information collection and processing system. The Chapter includes a description of the water resources data and information systems, which have an important role in the water management and drought mitigation. The Tunisian water resources and drought policy and the related legislation are described. Finally, the drought preparedness and management system in Tunisia and its coping with drought proficiency is outlined.

Key words: Institutions, legislation, risk analysis, reservoir, Siliana, drought management.

The planning framework

Tunisia is located in the South of the Mediterranean basin, therefore climatic conditions and consequently the rainfall, the origin of renewable water resources and principal factor for rainfed (dry) farming systems, are influenced by the Mediterranean climatic perturbations from the north and also by the desert effects from the south. In other hand, in Tunisia, drought periods could be restricted for one or some regions and could be generalized. The drought duration could be one season or one year and more, but with a variable intensity. The probability to have 3 successive dry years is so small (one time in the north and 2 to 3 times in the centre and the south during 1 century), like the drought occurred during 1999-2002.

According to FAO (1994), especially the southern Mediterranean countries are among those that will face severe water resources scarcity in the near future. Regarding the demographic evolution of those countries, the great challenge for the coming decades will be the task of increasing food production with limited water resources, and unfortunately under global climatic changes (Sakiss *et al*., 1994). For this reason, Tunisia focused its policy on the water mobilization, that is conceived with inter annual volume regulation approach and with inter-basins and within-basin water transfer system, and implemented an integrated water resources management system (IWRM). In the Tunisian IWRM process, the drought is considered as a climatic reality, which is taken in to account in Development Plan Programs. The planning for drought for moving from crisis to risk management dates only from the end the eighties. Before, drought was erroneously considered for several years as temporary and rare climatic event, and consequently its management was "a forced reaction" to respond to immediate needs. A drought management system have been developed, used for the drought events occurred during 1987-1989 and 1993-1995, and showed the performance of the hydraulic system. In 1999, Tunisia elaborated its first drought mitigation guideline (Louati *et al.*, 1999). The later, applied during the drought upon during 1999-2002, were qualified as moderately sufficient, and could be improved; the lessons learned should be established in order to update the system (the guideline). The output and deliverable of MEDROPLAN will have certainly a high importance in the updating process of the drought management system in Tunisia.

Organizational component

Organizations and institutions

According to Article 2 of the updated Decree No. 2001-419 dated on 13 February 2001 (Journal Officiel de la République Tunisienne, JORT), the Ministry of Agriculture, and Water Resources (MARH, Ministère de l'Agriculture et des Ressources Hydrauliques) is entrusted with the water management. The MARH duties are carried out by its different directions and departments defined in the updated Decree No. 2001-420 (13 February 2001, JORT).

The complexity of the Tunisian water system results in an intricate institutional water management framework, where the water competencies and responsibilities are spread among several organizations and institutions. Consequently, all those institutional bodies are linked to drought mitigation processes. Moreover, several departments in the MARH and in other Ministries, which are not working in water management, are associated in the drought management (Table 1).

The principal organizations and institutions, which are involved in the water mobilization, management and planning as well as in the drought management are the MARH, especially the BPEH (Bureau of Water Planning and Hydraulic Equilibriums, Bureau de la Planification et des Equilibres Hydrauliques) department, the central directions, and the regional services (Departments). In addition the organizations supervised by MARH, such as the NGOs (Collective Interest Associations/Groupement d'Intérêt Collectif, GIC), which are professional and users associations. Finally, the are some institutions non relevant to MARH.

BPEH (Bureau de la Planification et des Equilibres Hydrauliques: Bureau of Water Planning and Hydraulic Equilibriums)

BPEH is directly attached to the cabinet (departmental staff) of the MARH Minister. The competencies assigned to this bureau are:

(i) Mapping the conventional and non conventional water resources.

(ii) Identifying the different socio-economic water needs (demands).

(iii) Collecting the available and exploitable water resources information.

(iv) Collecting and analysing all data related to the water demand.

(v) Proposition of plans and programmes on the water resources allowance for all users, according to the supply and demand.

Regarding its important role within the MARH, the BPEH is continually in relation with all organizations and institutions involved in water resources management in the country. Consequently, an important database on the water resources is continually collected and updated.

Central Directions of MARH

Central Directions, that have extensive competencies in the water resources management field, are the General Direction of Dams and Large Hydraulic Works (DGBGTH, Direction Générale des Barrages et Grands Travaux Hydrauliques), the General Direction of Water Resources (DGRE, Direction des Ressources en Eau) and the General Direction of Rural Engineering and Water

Table 1. Organization and institutions involved in water resources management and/or drought mitigation in Tunisia (see text below for acronyms)

Ministry	Institution	Water Management	Drought Mitigation Phases
MARH	BPEH (Cabinet)	X	(1-2-3)
MARH	DGBGTH	X	(1-2-3)
MARH	DGRE	X	(1-2-3)
MARH	DGGREE	X	(1-2-3)
MARH	DGACTA	X	(1)
MARH	CRDA (Water Departments)	X	(1-2-3)
MARH	CRDA (Vegetal and Animal Departments)		(1-2-3)
MARH	BIRH (DGRE)	X	(1)
MARH	SONEDE	X	(1-2)
MARH	SECANDENORD	X	(1-2)
MARH	IRESA	X	(1-2-3)
MARH and other Ministries	CNE	X	(1-2-3)
Advised by MARH	NGO association	X	(1-2-3)
MESD (Environment and Sustainable Development)	DGEQV	X	–
MESD (Environment)	ONAS	X	–
MESD (Environment)	ANPE	X	–
MESD (Environment)	CITET	X	–
MTCT (Meteorology)	INM	X	(1-2)
MPH	DHMPE	X	(2-3)
MARH	DGPA	–	(1-2-3)
MARH	DGSV	–	(1-2-3)
MARH	DGPCQPA	–	(1-2-3)
MARH (Budget)	DGEDA	X	(2-3)
MARH (Budget, Finance)	DGFIOP	X	(2-3)
MARH	DGF	–	(1-2)
MARH	OC	–	(2-3)
MARH	OEP	–	(2-3)
MARH	AVFA	–	(2-3)
Prime Ministry	Media	–	(2-3)
NGO	UTAP	–	(2-3)
Ministry of Finance	Ministry	–	(1-2-3)
Ministry of Economic Development	Ministry	–	(1-2-3)
Ministry of Public Health	Ministry	–	(1-2-3)
Ministry of Interior	Ministry	–	(1-2-3)
Ministry of Commerce	Ministry	–	(1-2-3)
Ministry of Communication Technologies and Transport	Ministry	–	(1-2-3)

Exploitation (DGGREE, Direction Générale du Génie Rural et de l'Exploitation des Eaux). On the other hand, the General Direction of Planning, Management and Conservation of Agricultural Lands (DGACTA, Direction Générale de l'Aménagement et de Conservation des Terres Agricoles) is involved in the natural resources evaluation and preservation as well as in the hydrological and hydro geological aspects linked to the water resources. Those directions have their legal framework defined in the updated Decree No. 2001-420 dated from 13 February 2001 (JORT).

DGBGTH

Responsibilities in water resources planning and management are shared by DGBTH through the following competencies:

(i) Elaboration of the hydraulic studies.

(ii) Elaboration of mastering surface water resources planning.

(iii) Elaboration of water mobilizations studies.

(iv) Making up the dams and lakes building studies.

(v) Elaboration of important water planning studies for surface water resources mobilization (big dams, water transfer…).

(vi) Control and maintenance of dams.

(vii) Realization of the planning and large hydraulic works related to the rural and agricultural zones protection against floods.

(viii) Ensuring a platform to encompass all the areas of flood prevention and disaster management.

(ix) Supervising the drought management system.

DGRE

The DGRE is responsible for:

(i) Setting up and managing of measurement and observation networks related to all country water resources components (water data and information system and flood early warning, etc.).

(ii) Elaboration of basic and applied studies on the water resources evaluation and setting their general balance.

(iii) Drawing the principal and specific methods for the water resources management, according to the supply and the demand.

(iv) Promotion of the research and experimentation activities related to the conventional and non conventional water uses.

(v) Finalizing and perfecting the different ground (basics) of water mobilizations planning and their exploitation.

BIRH

The Hydraulic Inventory and Research Bureau (BIRH, Bureau de l'Inventaire et des Recherches Hydrauliques) was created by the Law No. 80-100 (31 December 1980, JORT), has a financial autonomy and it is under the DGRE administrative authorities. BIRH participates, by using advanced technological instrumentations, in the mounting and management of measurements and observations networks related to all country water resources components (surface and ground water). BIRH is loaded by the realization of the following duties:

(i) Establishment and updating of the national surface and groundwater resources inventories and development of prospecting for new water resources identification.

(ii) Mounting and management of measurement and observation networks related to all the country water resources components (surface and ground water).

(iii) Realization of pumping operations in order to determine the technical aquifers characteristics.

(iv) Computation and optimization of water information and data base management.

(v) Dissemination of water data and information recorded and analysed, by publishing bulletins and technical yearbooks (annuaires).

DGGREE

The attributions of the DGGREE are:

(i) Realization of strategic studies and elaboration of political plans related to rural engineering and agricultural water exploitation.

(ii) Attending and evaluation, planning, equipping, soil sweetening and drainage of irrigated areas, management of irrigation water exploitation, maintenance of hydraulic works and equipments, and conceiving the appropriate technical and economic management of the irrigated areas.

(iii) Optimizing the water use and valorisation of the reclaimed used water, attending all NGO (GIC), and implementing the management and the balance of the water demand and supply in the agricultural sector.

(iv) Coordination of rural and urban domestic (drink) water programmes, and elaboration of water supply planning and projects and attending them.

(v) Coordination of rural infrastructures and basic equipments, and studying the technological and economic aspects related to the agriculture mechanization promotion.

DGACTA

DGACTA is involved in the natural resources management by realizing the following missions:

(i) Elaboration of plans and orientations related to natural resources (soil, plant and water).

(ii) Proposition, elaboration and promotion of measures ensuring the optimization of natural resource utilization.

(iii) Soil resources evaluation (vocation and agricultural aptitude). The GIS and remote sensing technique are used.

(iv) Realization of research on soil sciences, using advanced techniques and equipped soil and water analysis laboratories.

(v) Control of soil evolution under the different exploitation modes, and their protection against salinity, degradation, and desertification.

(vi) Coordination between all parties working on the soil and water conservation.

(vii) Elaboration of the basins planning, and drawing out the anti-erosive studies and implementing them.

(viii) Control and attending the soil and water conservation projects realization.

(ix) Evaluation of the soil and water conservation planning and programmes.

(x) Setting and promotion of approaches targeted on the natural use optimization and preservation and associating all operators in the preservation process.

(xi) Ensuring the valorization and exploitation of the soil and water conservation infrastructures and planning works realized.

DGPA

The General Direction of Agricultural Production (DGPA, Direction Générale de la Production Agricole), is a central direction and is responsible for the promotion of agricultural production (cereal, forage, horticulture, arboriculture, fruit and olive trees particularly, industrial crops, biological agriculture, animal production). This DG is subdivided into 5 directions:

(i) Direction of Cereal and Forage Crops.

(ii) Direction of Fruit and Olive Trees and Horticultural Crops.

(iii) Direction of Agricultural Production Diversification (biologic agriculture, production diversification).

(iv) Direction of Forage Resources and Rangelands.

(v) Direction of Animal Production and the Livestock Promotion (meat, milk, productions, genetic amelioration, etc.).

DGPA is not involved in water management but it is associated in the drought mitigation system and contributes through its central and regional services ("Arrondissements") in the CRDAs in the different steps of drought management.

DGSV

The General Direction of Veterinary Services (DGSV, Direction Générale des Services Vétérinaires) defines the national programmes and policy in the animal health sector and all components related to the livestock preservation and safeguard. This General Direction is associated in the drought mitigation process by its central directions and regional services in the CRDAs.

DGPCQPA

The General Direction of Agricultural Products Quality Control and Protection (DGPCQPA, Direction Générale de la Protection et du Contrôle de la Qualité des Produits Agricoles), has several attributions related to the sustainability and the promotion of the agricultural quality production. It controls the quality of several products and attests their conformity with the norms: (seeds, plants, chemical treatment products, the imported and exported agricultural products, etc.). This direction establishes the products quality control when the importation programme is scheduled.

DGEDA

The General Direction of the Agricultural Studies and Development (DGEDA, Direction Générale des Etudes et du Développement Agricole), has to realize the following duties:

(i) Realization of studies and analysis for the agricultural development.

(ii) Elaboration and attending the development plan execution with the collaboration of the different MARH departments.

(iii) Identifying the agricultural development plan components and evaluation of related programmes and projects.

(iv) Elaboration of the MARH budget, realization of economics-related research topics, establishing statistical data analysis on the agricultural activities for future utilization in the economic planning programmes.

(v) Attending the evolution of the agricultural circumstances, notably during the drought events.

(vi) Elaboration of economic analysis related to the agricultural development policy.

By its Directions (Studies and Plans, Statistics and Agricultural Circumstances, Development Programs and Projects), DGEDA contributes on drought management by analysing its different phases and evaluating the social and economic impacts.

DGFIOP

The General Direction of Financing, Investments and Professional Institutions (DGFIOP, Direction Générale du Financement et des Investissements et Organismes Professionnels) prepares the MARH budget with the collaboration of DGEDA, and draws up all operations related to the financial support for the agricultural activities as well as for the drought management.

DGF

Forest General Direction (DGF, Direction Générale des Forêts), is not involved in water management but contributes in the forest lands management and acts against forest fire, especially during drought events. DGF manages several rangelands that are open for farmers during drought. DGF has numerous forest lands data and maps containing numerous water resources information.

DGAJF

The General Direction of Juridical and Land Property (DGAJF, Direction Générale des Affaires Juridiques et Foncières), within its duties, ensures the legal advisory service for the MARH, notably in water legislation field.

Regional Commissaries of Agricultural Development or Regional District Department of MARH (CRDA, Commissariats Régionaux au Développement Agricole)

Within the framework of the Tunisian decentralization policy, the MARH central direction, involved in all the agricultural activities (natural resources, food production, vegetal and forestry domains, economic aspect…) are represented in each governorate (24 governorates), by regional services or district departments. It is an administrative and technical structure, called CRDA. The CRDAs are created by a law that was successively updated in March 1989 (Law No. 89-44, JORT) and in October 1992 and October 1994.

CRDAs are entrusted with numerous responsibilities targeted on the realization of all operations related to the regional agricultural development and natural resources valorizations, particularly:

(i) Application of the legislation and regulation related to soil protection, forest and water management, supervising plant protection, and caring for animal health.

(ii) Ensurance of forest resources development and protection, soil land water conservation and agricultural land and basin planning.

(iii) Regional hydraulic system and forest domain management. Conservation of the natural resources.

(iv) Realization of hydraulic planning and hydro agricultural infrastructure valorization.

(v) Hydro agricultural infrastructure management and maintenance. Achieving the water supply network management.

(vi) Encouraging farmers' initiatives for adequate structure creations that are targeted on the regional agricultural development process.

Each CRDA supervises the agricultural activities and their promotion by technical, administrative, legislative, and financial issues and by diffusion of new agricultural technologies enhancing the related regional domain. CRDA has technical and administrative services ("Arrondissement"), which are the representatives of the central directions and realize their duties at the regional level. The principal services "Arrondissements" involved in the water management and producing linked data and information are: (i) Water Resources Service (A/RE, Arrondissement des Ressources en Eau); (ii) Public Irrigated Areas Exploitation Service (A/EPPI, Arrondissement de l'Exploitation des Périmètres Publics Irrigués); (iii) Maintenance of Equipments Service (A/ME, Arrondissement de la Maintenance des Equipements); and (iv) Rural Engineering Service (A/GR, Arrondissement du Génie Rural).

On the other hand the Soil and Water Conservation Service (Arrondissement de la Conservation des Eaux et des Sols) that is relevant to the Afforestation and Soil Protection Division (Division de Reboisement et de la Protection des Sols), is linked to the water management process.

Institutions supervised by MARH

SONEDE

Created by the Law No. 68-33 (2 July 1968, JORT), the Water Exploitation and Distribution National Company (SONEDE, Société Nationale d'Exploitation et de Distribution des Eaux) is an autonomous institution under the umbrella of the MARH authorities, and ensures the management of the domestic water and also the industrial and other (non agricultural) uses in the country. Organized by several directions, SONEDE is responsible for the quantitative and qualitative fresh water management. It has to realize the water network exploitation, maintenance, transportation (transfer and canalization), and all activities related to the area of drinking water such as water treatments for normalized qualities (physical, chemical, biological and bacteriological) and its equitable distribution. SONEDE establishes the population water needs, realizes the infrastructure required, and draws up a statistical data related to the evolution of the domestic, industrial and tourist water demand, production and treatment operations required, and establishes the yearly fresh water provision for the different users. SONEDE collaborates with DGBGTH, DGGREE, DGRE and SECADENORD.

SECADENORD

The Company of Exploitation, Canalization and Adduction of the Northern Canal and Waters (SECADENORD, Société d'Exploitation du Canal et des Adductions des Eaux du Nord), was created by the Law No. 84-26 (14 May 1984, JORT), has a financial autonomy and is under the MARH authorities. It ensures the management and maintenance of the North West part of the network of water transfer (pipes and channels) from the extreme North West to the users located in the North East, Centre and South of the country were there is a fresh water shortage. The water adduction and interconnection network hydraulic components are the following: (i) Canal Medjerda Cap Bon (from Laroussia to Belli); (ii) transfer of Sejenane and Joumine waters; (iii) Kalaat El Andalous hydraulic complex; (iv) El Herry hydraulic complex; (v) Nebhana hydraulic complex; (vi) Barbara dam waters transferring; and (vii) Sidi Barrak dam waters transferring.

The water quality is controlled by several analyses, and water pollution risk during transferring is monitored.

IRESA

Decree No. 90-72 (30 July 1990, JORT) assigned to the Agricultural Research and Higher Education Institution (IRESA, Institution de la Recherche et de l'Enseignement Supérieur Agricoles) the supervision of agricultural research and higher education institutes. IRESA has to sit up, to keep awake and to supervise the agricultural research programmes, and to promote the agricultural higher education in order to enhance the agriculture sector.

Decree No. 91-104 (21 January 1991, JORT), related to the organization and the attributions of IRESA, specifies the attributions of the Direction of the Scientific Information Processing (DTIS, Direction du Traitement de l'Information Scientifique). The DTIS is the linkage organ between the agricultural research and education institutions and the development departments, and ensures the internet service supply for the agricultural sector (Authorization No. 1002, 30 December 1997), by mean of AGRINET National network (www.agrinet.tn). DTIS is entrusted notably with conservation, elaboration, and processing of scientific databases (e.g. implementing of an information system on the agricultural water research, WATER 2000) for research and planning uses purposes, and also in order to establish a simplified Decision Support System (DSS). Moreover, DTIS identifies and manages the databases (national and international) connections.

Furthermore, IRESA establishes an international collaboration and cooperation related to its field of activities (notably with ICARDA, CIHEAM, FAO, IDRC, GTZ, ACSAD, IRD, EC, AIEA, foreign Universities and numerous other institutions and organizations). Actually, by using GIS, attending the irrigated areas project is in process and is conducted by DTIS and DGGREE and Italian cooperation. On the other hand, water management and drought mitigation are within the priority research programmes of IRESA.

CNE

According to the Tunisian Water Code, the National Water Committee (CNE, Comité National de l'Eau) is supervised by MARH (Law No. 75-16, 31 March 1975, JORT). The Tunisian Water Code attributes to CNE several competencies on water resources in the country. The CNE examines and evaluates the general issues related to the water planning and management. Data on supply and demand, population, natural characteristics, etc., are used in the evaluation process. The CNE is composed (Law No. 78-419, 15 April 1978) by the MARH Minister as President and as members are the representatives of the Ministries linked to water resources management (Justice, Interior, Finance, Equipment, Development and International Cooperation, Public Health, Industry Energy, and Communication Technologies and Transport), representatives of the MARH technical direction entrusted with water management, the directors of public water institutions such as SONEDE and the National Service of Used Water Cleansing (ONAS, Office National de l'Assainissement), representatives of several water resources users public and private bodies. The regional authority is associated when the subject discussed is related to its region.

OEP

The Animal Husbandry and Pasture Agency (OEP, Office de l'Elevage et de du Pâturage) is entrusted with the management of all tasks related to animal husbandry and pasture.

OC

The Cereal Agency (OC, Office des Cereals) is in charge of the promotion and the management of the cereal production.

AVFA

The Agricultural Extension and Training Agency (AVFA, Agence de Vulgarisation et de la Formation Agricoles) is responsible for the attending the farmers to promote agricultural practices and to transfer the new agricultural technologies.

GIC (Groupements d'Interêt Collectif, NGOs)

GIC associations are a group of users in the rural areas that have to manage their demand on water (domestic and agricultural use). They are created by MARH and advised by DGGREE. The number of drinking water associations is more than 1500 and they supply (with fresh water < 1.5 g/l) around 117,000 families (1.3 million inhabitants) and the several regional schools and hospitals. In the rural areas not covered by the national agricultural hydraulic system, 550 agricultural GIC (irrigation and agricultural land management operations) are organized around the waterholes, sources and intakes from dams, hill dams in order to irrigate their farms. They ensure the management of about 30% of the total irrigated areas (DGGREE, 2002).

The GIC associations have a legal framework defining their duties and their legislative code (several decrees and laws dated from 1985 until now, where the legal framework is continually updated and almost completed, depending on the water demand evolution).

UTAP

The Tunisian Farmers Association (UTAP, Union Tunisienne de l'Agriculture et de Pêche) is a professional association, which represents the Tunisian farmers and their interests, and is supported by MARH.

Environmental Institutions supervised by MESD (Ministère de l'Environnement et du Développement Durable)

Environmental institutions do not have any role in water resources and drought management but they are indirectly involved by their competencies and duties since they care and share the environment quality, were water quality is an important component.

DGEQV

DGEQV (Direction Générale de l'Environnement et de la Qualité de la Vie: General Direction of Environment and Life Quality) has to: (i) formulate the general political aspects related to the environment; (ii) coordinate and attend the state operations and measures for the environment protection; (iii) campaign against pollution and its nuisance; and (iv) improve the life quality. It is involved in environment aspects related to water resources.

ONAS

(i) Created in 1974, ONAS (Office National de l'Assainissement: National Service of Used Water Cleansing) is involved in water management by the following activities:

(ii) Avoiding water pollution in the urban, industrial and touristy zones.

(iii) Management, exploitation, maintenance and construction of the network town cleansing.

(iv) Realization of studies projects related to the individual rural water cleansing.

(v) Management of water purifying station (used water reclamation), and supplying the reclaimed water for the specified irrigation uses.

(vi) Collecting data on the rejected water and setting all information's about the industrial effluents. Information related to the mapping of the industrial unities are organized in "Cadrin" database.

ANPE

The financial and administrative organization of ANPE (Agence Nationale de Protection de l'Environnement: National Environment Protection Agency) is defined by the Decree N° 93 – 335 (8 February 1993, JORT).

Within its missions the ANPE realizes the environmental protection and preservation operations. ANPE controls the polluting throwing out (liquid and solid) in the natural systems and also their treatment stations, attends the legislation application, and sensitizes the population to environment protection and preservation. Every new project related to agricultural, touristy, industrial, urban fields is submitted to this agency in order to identify its environmental impacts. Data information on water, air and all environmental components are monitored by ANPE. In other hand, by a special PNUD support, the OTED (Observatoire Tunisien de l'Environnement et du Développement: Tunisian Observatory for the Environment and the Development) was created in 1994, just after the Rio de Janeiro conference held in 1992 were Agenda 21 was adopted.

CITET

CITET (Centre International des Technologies de l'Environnement: International Centre of Environment Technologies) dates from. March 1996 (Law N° 96 - 25).

The CITET activities are hinged on 3 axis:

(i) National and international trainings, notably on the urban cleansing, solid and liquid rejections management, industrial pollution control, urban management systems, environmental impacts studies, campaign against desertification.

(ii) Conducting a research related to industrial effluents treatments, and purifying water stations, air quality, etc. …

(iii) Technologies transferring, as desalinization of saline and sea waters and industrial water physical and chemical treatments.

Other Institutions not related to MARH

INM

Within the Ministry of Communication Technologies and Transport framework competencies, the National Institute of Meteorology (INM, Institut National de la Météorologie) was created in 1974 (Law No. 101-74, JORT). INM ensures the meteorological observations, particularly weather forecasting, climatology, and applied meteorology by managing the nationwide meteorological observation network that comprises synoptic, agro-meteorological, climatologic, rainfall, marine and upper-air observation stations. Its mission is namely:

(i) Meteorological observations.

(ii) Seismic recording and location.

(iii) Astronomic observation and calculation of ephemeris.

(iv) Weather prediction.

(v) To provide meteorological, astronomy, and geophysical data to various national economic sectors.

(vi) Technical coordination of all activities related to meteorological and geophysical aspects.

(vii) To do technical and economic studies relevant to its field of activities.

(viii) To conduct theoretical and applied research for the development of meteorological and geophysical sciences.

(ix) Preparation and implementation of international agreements related to matters of skill and technical cooperation with international centres and specialized organizations.

DHMPE

The Direction of Environmental Hygiene and Environment Protection (DHMPE, Direction de l'Hygiène du Milieu et de la Protection de l'Environnement) is relevant to Public Health Ministry (Ministère de la Santé Publique) and involved in the water management system by the control of drink water quality, attending the network town cleansing and campaigning against pollution. DHMPE database target on the qualitative aspects of drink, recreation, and reclaimed used waters.

Ministries associated in the drought mitigation system

Treasury or Finance Ministry (Ministère des Finances), Ministry of Economic Development and International Cooperation (Ministère du Développement Economique et de la Coopération Internationale), Public Health Ministry (Ministère de la Santé Publique), Ministry of Communication Technologies and Transport (Ministère des Technologie de la Communication et du Transport), Interior Ministry (Ministère de l'Intérieur) and Commerce Ministry (Ministère du Commerce) are involved in the measures for coping with drought.

Linkages among institutions

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

In every water management plan that is realized and supervised by one institution, numerous institutions are associated in the relevant study as well as in the realization process. Coordination is already consolidated by the representatives of the institutions linked by the water resources management programmed. On the other hand, linkages between institutions are shown in water resources information and data exchange. Figure 1 summarizes the linkages among the institutions.

Most of the communications between institutions are organized through a network supervised by IRESA which is the same time the Internet provider of MARH.

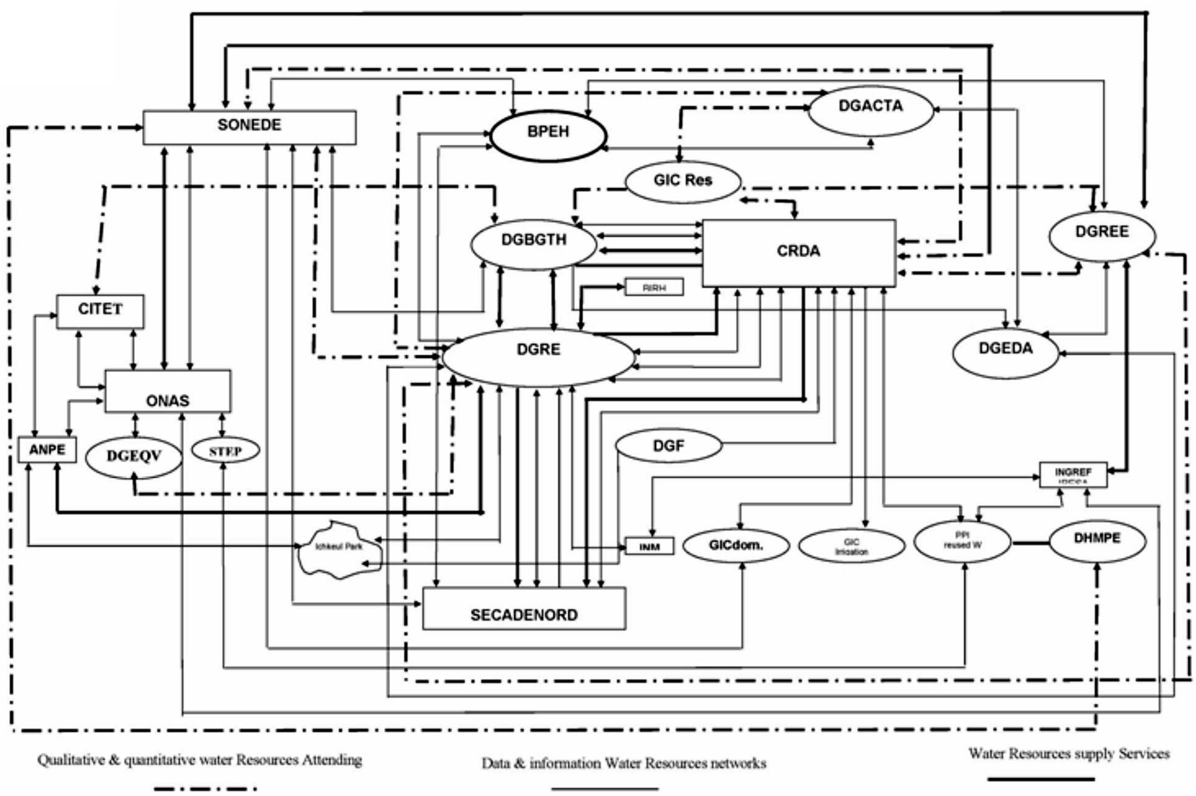


Fig. 1. Map of the organizations and institutions involved in water management in Tunisia.

International Organizations associated in water resources management in Tunisia

The Integrated Water Resources Management in Tunisia is continually viewed and updated by mean national studies and also by international cooperation programs. DGBGTH (1992) achieved the "Water 2000 project / EAU 2000" with the collaboration of KFW (German Bank). This project established planning study linked to water investment and mobilization until 2010. A study on the Natural Resources Management Policy was achieved and has as objective the sustainable natural resources management until 2025 (DGPDA, 1996; WB, 1997). In 1998, a long-term identification of water resources was defined (Khanfir *et al*., 1998). A Water sector study was elaborated in 1999, were diverse subject to water sector were analyzed as the demand, supply, cost, legislative and institutional water management system, pollution and different water origins and uses. Later, GEORE project has been achieved (DGBGTH/GTZ, 2001). GEORE Project is target on the establishment of an integrated Water Resources Management Policy.

By the World Bank support, the PISEAU project (Projet d'Investissement dans le Secteur de l'Eau: Water Sector Investment Project) is conducted in Tunisia. The objectives of PISEAU project are namely:

(i) The participative water demand management.

(ii) The integrated water resources management.

(iii) The sustainable natural resources management.

(iv) Enhancing the governmental structure capacities, promoting the NGO and (GIC) associations, and the private water users in order to sustain the water resources management.

(v) Promotion of the natural resources conservation and protection of the environment.

(vi) Training and research.

(vii) Establishment of a national information system on water resources (SINEAU).

Water resources and drought legislation

Water legislation history

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

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

(ii) During the Islamic empire, especially the Hafsides (1236-1574), the water was considered as "God's Gift", and consequently it was considered as public property and the free access was promulgated.

(iii) The French colonization period (1881-1956), that was characterized by the first water decrees targeted on favours attributed to the colonists. The Decree of 24 September 1885, defined the public surface water domain, without any reference to the groundwater resources. In 24 May 1920, a Water Committee was appointed. Decrees appeared in 1933, 1935, 1936 and 1938 instituted a water use regulation and fixed the dues for the water use; Decrees of 30 July 1936, 11 January 1945 and 17 March 1949 instituted the regulation related to the NGO organizations involved in water use.

(iv) The fourth period, started with the independence of Tunisia, is characterized by an evolutionary water legislation, that is related especially to the resources mobilization, exploitation by different users (urban, agricultural, industrial and tourist uses) and focused on water quality and environmental problems. In order to satisfy the different water demands, the socio-economic development national programs realized large hydraulic works. With the evolution of hydraulic planning, a legislative system was established, whose main objectives were to identify the competencies of all operators and users in the water field, to preserve the water resources and to ensure the equitable allocations. In 1975, all legislative water texts were updated and promulgated in the Water Code (Law No. 75-16, 31 March 1975).

Since 1975, the water code is continually updated by modification of some legislation and adding of new ones, that concern socio-economic development, the water demand evolution, and the environmental issues required to preserve the natural resources.

Water Code

Water Code goals

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

Water Code Clauses

The water code is composed by nine Chapters, which rule the water resources regulation.

Drought Circumstances Legislation

The drought management system in Tunisia is based on drought announcement and MARH Minister decisions to cope with drought and the duties loaded to the National Commission, which is charged by the supervision of the execution of all the operation actions related to the 3 drought management phases: (i) before –drought preparedness; (ii) during– drought management; and (iii) after –subsequent drought management–. This process has a strong collaboration of the regional and sectorial or specialized committees (details will be stated in the next section of the present report). The Minister of MARH, promulgates several decisions related to the different drought committees and the operations programme for the drought mitigation instead of its crisis management. The Tunisian Central Bank (BCT, Banque Centrale de Tunisie), delivers a circumstance circular establishing easiness in the credits delivery for farmers. Special decisions are taken in order to exempt the importation from the custom duties.

Methodological component: Drought characterization and risk analysis

Water resources in Tunisia

Rainfall in Tunisia is characterized by a spatiotemporal variability. Around 1500 mm/year is basically received in the northwest and dropped to less than 50 mm/year in the southern desert zone (Fig. 2), resulting in a wide spatial variability as illustrated in Table 2. Tunisia is submitted to drought periods that could be restricted for one or some regions and could be generalized. The drought duration could be one season or one year and more, but with variable intensity. Figure 3 points out the regional minimum rainfall observed during the 20th century in Tunisia.

Table 2. Water resources distribution and quality in Tunisia. Source: Ministry of Agriculture and Water Resources-DG/RE

Element	North Region	Center Region	South Region	Total Tunisia
Area of the region (%)	17	32	51	100
Rainfall (%)	41	29	30	100
Surface water (Million m^3)	2,190	320	190	2,700
Surface water (%)	78	38	19	58
Shallow aquifers (Million m^3)	395	222	103	720
Shallow aquifers (%)	14	26	10	15
Deep aquifers (Million m^3)	216	306	728	1,250
Deep aquifers (%)	8	36	71	27
Total water resources (Million m^3)	2,801	848	1,020	4,670
Total water resources (%)	60	18	22	100
Resources with salinity < 1.5 g/l (Million m^3)	1796	153	6	1955
Resources with salinity < 1.5 g/l (%)	82	48	3	72
Resources with salinity > 3 g/l (%)	37	49	86	
Sallow aquifers with salinity < 1.5 g/l (%)				3
Deep aquifers with salinity < 1.5 g/l (%)				22
Sallow aquifers with salinity 1.5-3.0 g/l (%)				11
Deep aquifers with salinity 1.5-3.0 g/l (%)				57

From the rainfall temporal variability results receiving 90,000 million m^3 during the wet year that could decrease during a drought event to only 11,000 million m^3/year. The global mean allows 36,000 million m^3/year (Khanfir *et al.*, 1998). Within this quantity, 2700 million m^3/year are the potential surface renewable water resources and represent the capacity of dams and lakes, and also a part that is collected by several traditional water catchment techniques (this volume was dropped to 780 million m^3 during the drought event of 1993-1994). 720 million m^3/year is the renewable water stored in the shallow aquifers. One part flowed out to the sea by runoff as well as lost by evaporation from bare soil and the rest allows the sustainability of the natural ecosystems and allocates rainfed farming systems, that cover around 93% of agricultural lands (total agricultural lands is 5 million ha). On the other hand, deep aquifer

Fig. 2. Rainfall Spatial distribution in Tunisia (Source: DGRE).

resources ensure around 1250 million m^3 of non renewable water. Hence the total conventional water resources are estimated at 4670 million m^3, of which about 90% is actually mobilized (Fig. 4 and Table 2). On the other hand, the percentages of water resources with less than 1.5 g/l are 72%, 3 and 22% respectively for the surface water resources, shallow and deep aquifers (Table 2).

The total area under irrigation by conventional and non conventional water covers actually 368,500 ha (7% effective agricultural are) and it's expected to rise to nearly 400,000 ha by 2010 (Table 3). This sector consumes about 80% (Table 4) of the total water resources and provides 32-40% of the mean value of the total agricultural production. In the near future, 50% of the agricultural production should be provided by this area.

The analysis of water resources in Tunisia situation shows the importance of rainfall in the irrigated and rainfed agricultural production systems and also in the water supply for the other sectors. The water resources spatial variability is so important that the ecosystems and their responses to drought are different. When drought is upon, the natural water resources availability displayed a substantial deficit, and consequently, the irrigated area as well as the rainfed lands are strongly affected, and the other water demands are evenly subjected to some restriction. For coping efficiently with the drought period, Tunisia established a drought management system which demonstrated its capacities in drought mitigation during 1987-1989 and 1993-1995. Latter, the first guideline of drought management "Guide pratique de la gestion de la sécheresse en Tunisie" has been elaborated by Tunisian competences (Louati *et al.*, 1999).

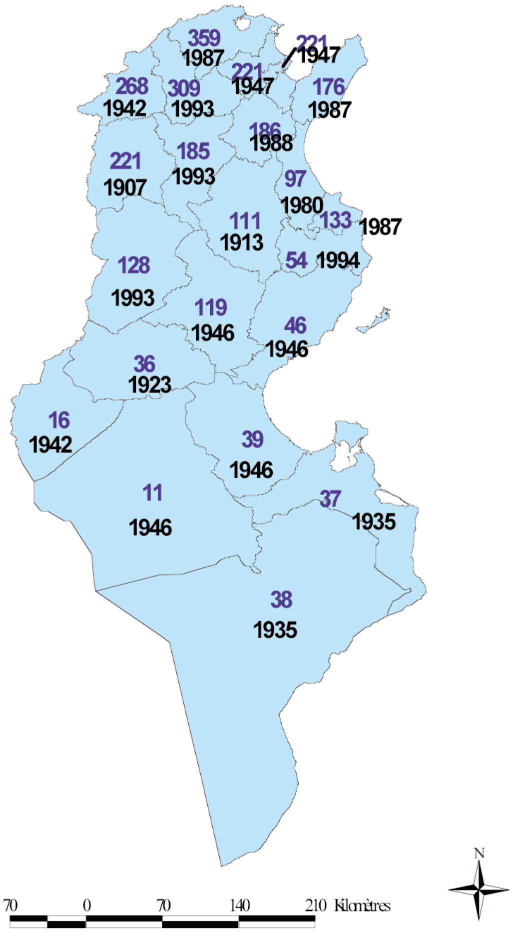


Fig. 3. Minimum regional rainfall during the 20th Century in Tunisia (Source: DGRE).

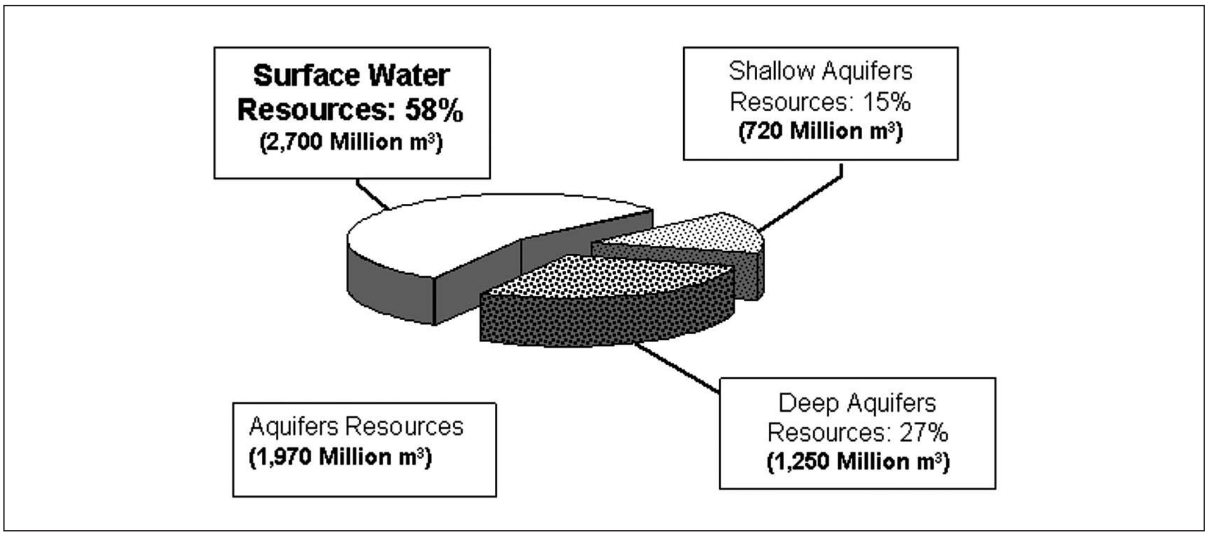


Fig.4. Water Resources in Tunisia (Total: 4,670 Million m^3).

Table 3. Irrigation schemes and water resources (2000) in Tunisia. Source: Ministry of Agriculture and Water Resources

Water resources	Area (ha)	%
Large dams & hillside-dams and lakes	127,000	34.5
Deep aquifers	85,000	23.0
Shallow aquifers	136,000	36.9
Springs and intermittent streams	14,000	3.8
Reclaimed Water (non conventional water)	6,500	1.8
Total	368,500	100

Table 4. Water demand in Tunisia. Source: Ministry of Agriculture and Water Resources – DGRE

Water Use	%
Irrigation	82
Domestic and Municipal	13
Industry	4
Touristy	1
Total	100

Water resources management units

In most Mediterranean countries, water management planning is based on "Waters Master Plans (Plans Directeurs des Eaux)". In Tunisia, these plans depend on basin boundaries. As a consequence, the water resources planning process has been compelled to balance between two main constraints. First, the target water use regions are generally different than those where mobilization has been realized, resulting in an imperative water transfer, that reaches 300 km. Second, water resource management planning is conducted on a basin scale contrary to their supply programmes which are planned, in the social and economic development national plans, depending on the administrative units (governorate and departments) (Fig. 5). Nevertheless, basins and administrative units did not have common boundaries. Consequently, the precise evaluation of Water Master Plans is hampered by such structural divergences.

In order to overcome the above constraints, the hydraulic units concept has been adopted as an approach in water resources planning and management. Since water resources (surface and aquifers) were identified, quantified, and mobilized or to be mobilized, their management became linked to "stocks management" and not as "random resources". This is the main strength of the water resources system in Tunisia. The management of each reservoir or a group of reservoirs could be realized in a normal period as well as with interaction with the remainder system components, particularly during extreme situations (drought or floods). The Geographical Information System (GIS) allowed the water balance establishment at administrative as well as at hydraulic unit scales. Every hydraulic unit is characterized by its own, imported and exported resources.

Challenges to risk management

Regarding the geographical position of Tunisia in the south of the Mediterranean Basin, climatic conditions and consequently the rainfall are influenced by the Mediterranean climatic perturbations from the North and also by the desert effects from the South. On the other hand, drought periods in Tunisia could affect one or several regions and could be generalized. The drought duration could be from one month or season to one year and more, with a variable intensity. The probability to have three successive dry years is too small (one time in the north and from 2 to 3 times in the center and the South during one century).

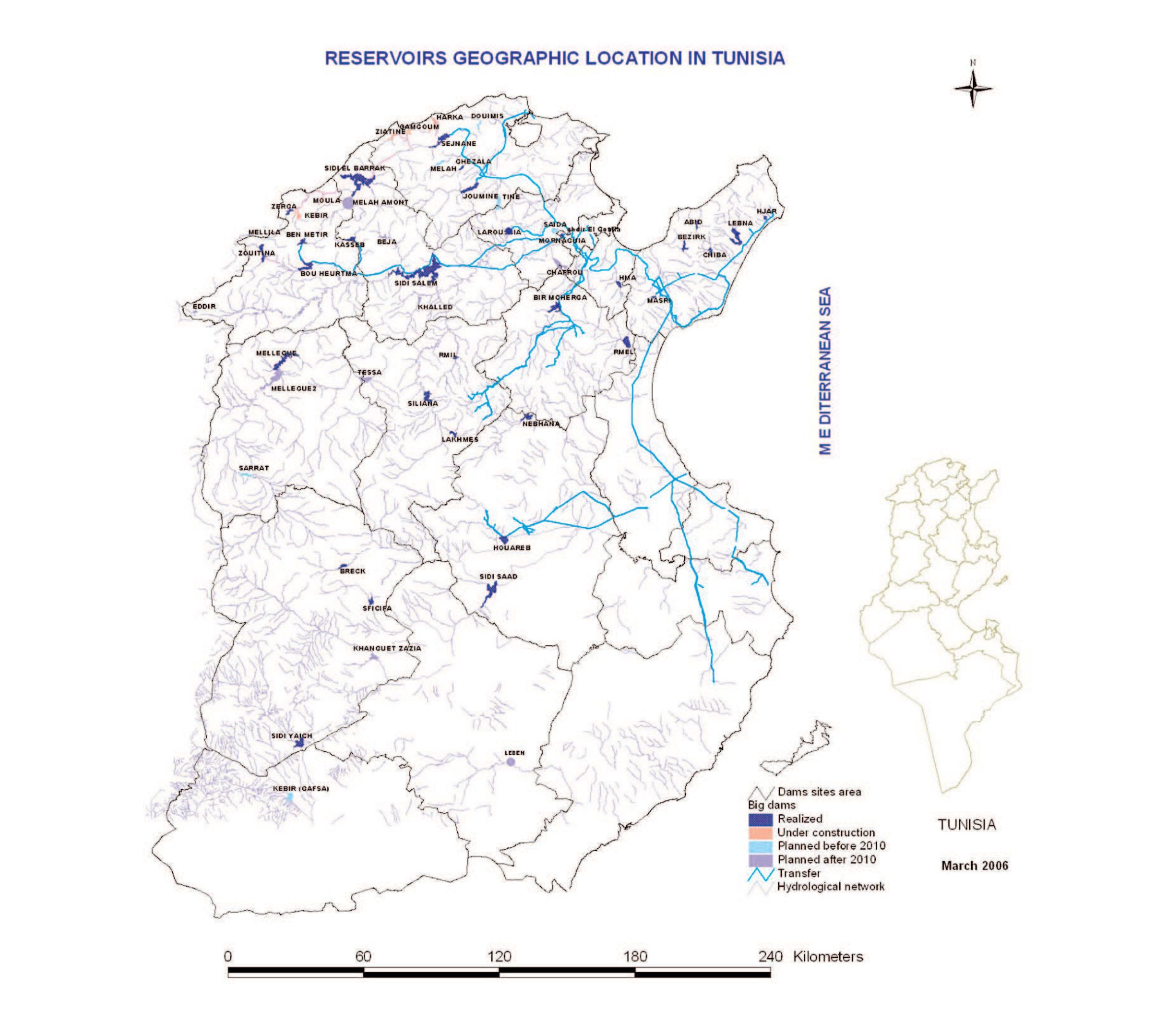


Fig. 5. Geographical location of dams in Tunisia.

There are considerable differences between the climate in the North and the South of Tunisia (Table 5). The North's climate is typically Mediterranean, with hot dry summers and mild wet winters. In the south, the proximity to the Sahara increases the aridity of the landscape, and makes an unpleasant summer climatic combination of high humidity and high temperatures.

Table 5. Rainfall distribution in Tunisia

	North	Center	South
Rainfall (%)	41	29	30
Area (%)	17	32	51

Source: Ministry of Agriculture and Water Resources – DG/RE, 1998.

Tunisia focused its policy on the water mobilization, that is conceived with inter annual volume regulation approach and with inter-basins and within-basin water transfer system, and implemented an integrated water resources management system (IWRM). In the Tunisian IWRM process, the drought is considered as a climatic reality, which is taken into account on the Development Plan Programs. The planning for drought for moving from crisis to risk management dates only from the end of eighties. Before, drought was erroneously considered for several years as temporary and of rare climatic event, and consequently its management was "a forced reaction" to respond to immediate needs. A drought management system has been developed and put into practice during the drought events occurred along 1987-1989 and 1993-1995 and showed the performance of the hydraulic system. In 1999, Tunisia elaborated its first drought mitigation guidelines (Louati *et al.*, 1999). The latter, applied during the drought during 1999-2002, was qualified as moderately sufficient, and could be improved; the lessons learned should be established in order to update the system (Louati *et al.*, 2005).

The Case study area: Siliana watershed

Siliana watershed, object of the case study, is characterized by a semi arid climate. The average rainfall is around 400 mm. Winter is usually wet, summer is hot and autumn is characterized by stormy rain with high intensity and short duration often causing floods.

Various structures were built (dams, hill dams, small lakes) to mobilize those resources. The total storage capacity in the region is around 80 Mm^3. To minimize water losses on one side and satisfy all the demands on the other side, the whole components are considered (watershed, hydraulic structures, irrigated areas) as a complex one which should be managed taking into account all stakeholders.

The case study for drought characterization and risk analysis is carried out according to the observed data in the region.

Land topography in the region presents high slopes and a low vegetative cover out of the rain period. Siliana watershed is crossed by an intensive rivers network (Fig. 6).

Drought characterization in Siliana

The system designed to alert of a drought situation depends on a complex set of interdependent and organized institutions. The drought is considered as an extreme climatic event and qualified as natural risk. However, the prolonged drought entails a water shortage in some regions, being so much heavy of consequences on a local zone than for a whole region. The capacity to manage the impact of the drought also varies from a region to another. To understand the vulnerability to drought, it is essential to protect the natural resources and to consider the policies that are linked with their management programs. In the present work, an analysis of meteorological drought in the semi-arid area of Makthar plain located in Siliana Basin in Tunisia is presented. Annual and monthly rainfall series observed at the station of Makthar were used to characterize droughts at a local scale by using run concepts (Yevjevich, 1967). The revealing drought indexes constitute the basis of the methodological approach presented in this case study. It is proposed to analyze the observed rainfall data and determine meteorological drought characteristics. (Bergaoui med. & al., 2001).

Rainfall

Hydrological phenomena can occur both at the local level and at a larger spatial scale. Drought is generally characterized by its severity, defined by its duration and the occurred deficit. Therefore drought varies in time. This temporal change is in part explained by the climatic changes due to atmospheric perturbations and environmental problems.

The rainfall records, which were collected and analyzed, were originated from the station of Makthar. Table 6 shows the main characteristics of the station, namely the location coordinates, the altitude and the corresponding area of influence. Data were obtained mainly from the hydrological services.

Table 6. Identification of the measuring site

Station	Latitude	Longitude	Altitude (m)	Area (km^2)
Makthar PF	N°:39G 84 00	E°:7G 63 00	910	483

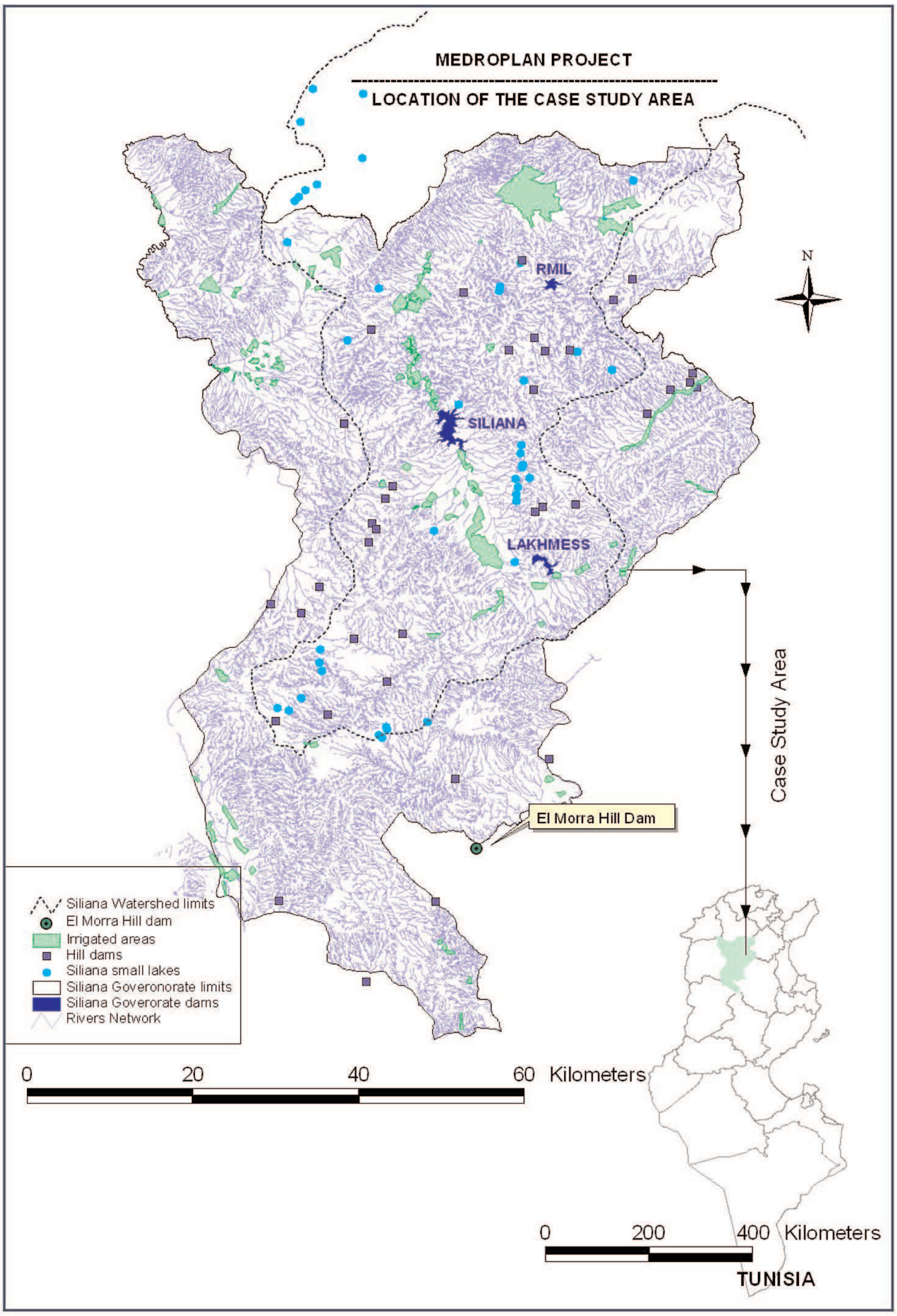


Fig. 6. Location of the case study.

The observation period for this station is ranged from 1972 to 2002; those 30 years series is believed to be long enough to reflect the validity of the analyzes to be carried out. The basic statistical characteristics of the annual and monthly rainfall series (location and dispersion parameters) are reported in Table 7. The location parameters (average and median) are quite different which indicates the presence of skewness in the series. The parameters of position and scattering show the existence of an important variability of rains quantities.

The coefficient of variation is equal to 0.22. It permits to appreciate the degree of variability in a set and the scattering of the values with regard to the average.

Table 7. Location and dispersion parameters

Characteristics	Sept	Oct	Nov	Dec	Jan	Febr	March	April	May	June	July	Aug	Annual
Average (mm)	45.9	42.2	49.9	43.6	58.0	49.3	57.3	45.5	41.0	18.2	8.6	25.9	485.4
Maximum (mm)	147.8	148.8	139.2	123.8	178.4	133.9	225.2	110.8	124.0	86.8	73.5	72.1	810.6
Minimum (mm)	0.0	2.5	0.0	0.0	5.0	0.0	4.0	8.5	0.0	0.0	0.0	0.0	317.0
Median (mm)	37.7	34.5	41.1	37.0	47.9	49.5	50.5	38.9	32.1	13.6	0.0	22.0	472.0
Standard deviation	34.7	31.8	37.5	34.0	45.3	33.3	39.5	28.7	30.8	19.4	16.5	21.9	109.7
Coefficient of variation	0.76	0.75	0.75	0.78	0.78	0.68	0.69	0.63	0.75	1.1	1.9	0.85	0.22

Stationary analysis

A time series is considered as stationary if there is no systematic change in mean (no trend), if there is no systematic change in variance, and if strictly periodic variations have been identified. The time series analysis is important both to describe data and to help in formulating a prevision or prediction model. A visual examination of a time series graphic is sufficient to see that it is not random. It is recommended to test the stationary time series for randomness. Several tests exist for this purpose and they are described by Kendall (1973). For details see (Rossi G. *et al*., 2003).

The stationarity analysis of the series was carried out for Makthar station and applied to the catchment's area, considering calendar year, hydrological year and monthly time scales. Three tests have been applied, namely the student t-test for linear trends, and the Kendall t-test and the turning points test for randomness. The results of the three tests for the analysis of the observed rainfall series at study station are given.

Series aggregated at calendar year and hydrological year generally present a negative linear trend, with the significance level of 5%. For Kendall test, the null hypothesis is accepted, by using the test of the turning point, the null hypothesis is accepted with the significance level of 5%.

Drought identification and characterization has been carried out by means of run concepts, using the software REDIM (DICA, 2000). The drought characteristics are identified by using two annual time scales (hydrological year and calendar year) and monthly time scale. Further, two thresholds have been selected, namely the average and the median. It can be concluded that using the calendar year, the number of drought periods is equal to or higher than that found while considering the hydrological year as a time scale.

On the other hand, deficits and drought severity are generally higher when hydrological year time scale is applied. Also, the characteristics of the drought periods, identified by considering the mean as threshold, are higher than those found for the median threshold, as expected due to the difference of the two thresholds (see Tables 8, 9 and 10).

Table 8. General characteristics of drought periods; Makhtar station

Calendar year	Mean	Max	Min
Duration (years)	2	4	1
Cumulated deficit (mm)	182	440	30
Drought Intensity (deficit/years)	96	185	30

Table 9. Characteristics of drought periods

Hydrological year	Mean	Max	Min
Duration (years)	2	4	1
Cumulated deficit (mm)	194	434	34
Drought Intensity (deficit/years)	64	108	17

Table 10. Characteristics of drought periods

Time Scale: month	Mean	Max	Min
Duration (months)	2	10	1
Cumulated deficit (mm)	50	354	0
Drought Intensity (deficit/months)	19	51	0

An analysis of rainfall series observed and covering the period from 1972 to 2002 in Makthar station is presented. In particular stationarity analysis of the series has been carried out by means of three statistical tests. Stationarity analysis indicates a significant decrease of precipitation in the last years, both at calendar and hydrological year time scale. The results of general characterization of drought periods are affected by the time scale adopted. In particular, when hydrological year is applied, drought characteristics duration, deficit and intensity or severity are generally higher that those computed by applying calendar year time scale.

The normal precipitation

The objective of this analysis is to visualize the yearly rains versus the normal of 30 years observations. During the period of 01/09 to 30/10 the variation of rain is normal. The period ranging from 01/11 to 30/03, can be considered as rainy period. The total yearly precipitation is greater than the normal. There is 220 mm more than the normal. Thus, the analysis of rains for one year given in relation to the normal allows the identification of the dry or wet periods as well.

The comparison of the cumulated monthly rain for a year scale, during 2002-2003, with the normal shows that this year (2002-2003) is wet, since the cumulated value was grater than the normal one (Fig. 7). This method shows a good accuracy to identify the dry or the wet periods with a finer time scale.

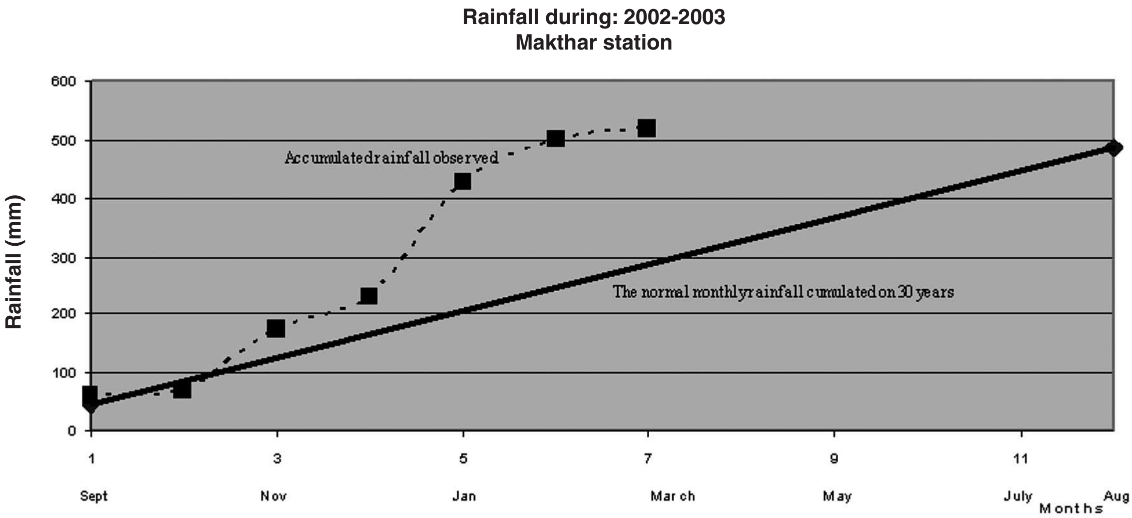


Fig. 7. Cumulated rainfall observed during the hydrological year (2002-2003).

Scale impact on drought characterization

Time scale is an important issue that needs to be accounted for when characterizing drought. Depending on the objectives of the study it will be interesting to use one scale or the other. The following examples show the importance of an analysis at a monthly scale due to the differential effects of precipitation distribution along the year for agricultural purposes.

Figure 8, for example, shows a deviation around (- 200 mm) during 1993: Consequently the year is considered as dry, however, during 2002, deviation reaches (+ 200 mm): Consequently the year is considered as wet.

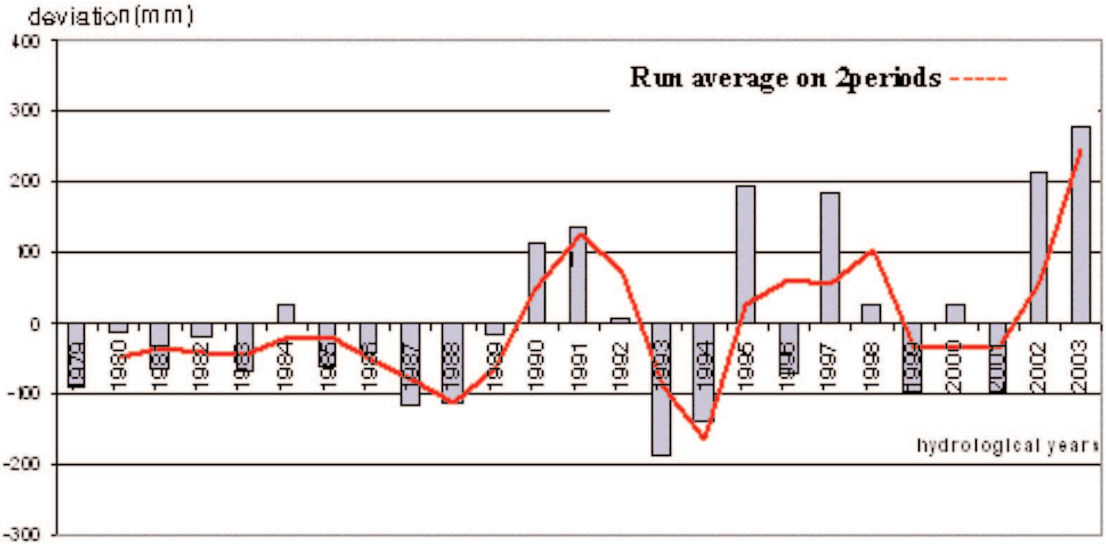


Fig. 8. Variation of the mean deviation of the annual precipitation.

Figure 9 shows that during 2002, March was significantly dry, although the year 2002 has been characterized as wet year as shown in Figure 8.

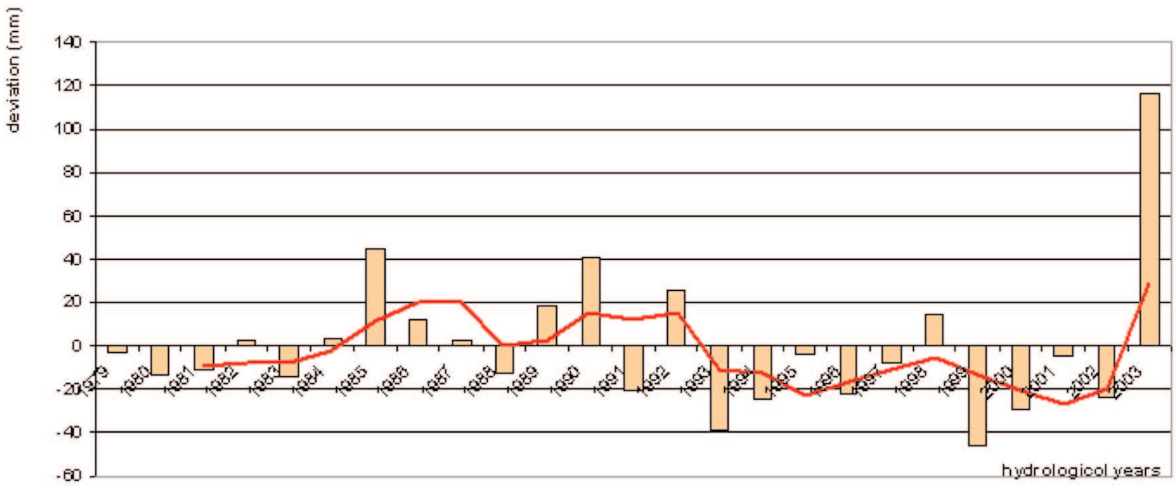


Fig. 9. Deviation of monthly mean during March in Siliana station.

The drought characterization method based on the mean deviation allows identifying the percentage of dry years. The current case study shows 60% of dry years. Drought characterization is more precise when the monthly scale is taken in account in the identification. This is illustrated by the case of Siliana region where drought characterization showed that the year 2002 was wet when the yearly scale was applied. March of the same year (2002) appears as dry month. This is very important since March rainfall is critical for agricultural production.

Risk analysis of the El Morra reservoir in the Siliana watershed

El Morra Reservoir (hill dam) is located at the boundary of Siliana watershed. Its main objective is to supply an irrigated area.

In average, the inflows are sufficient to satisfy agricultural demands, but the inter-annual variability is very high. The agricultural demand is less than the average inflow but we can observe a risk of dryness in the summer when the highly water consuming cultures of melon and watermelon are very developed (Fig. 10). The reservoir is developing a double function as agricultural water supplier from March to August, and also as a flooding regulator during autumn and spring. Therefore there is a conflict between keeping enough water for agricultural productions and having enough regulating capacity for eventual flooding.

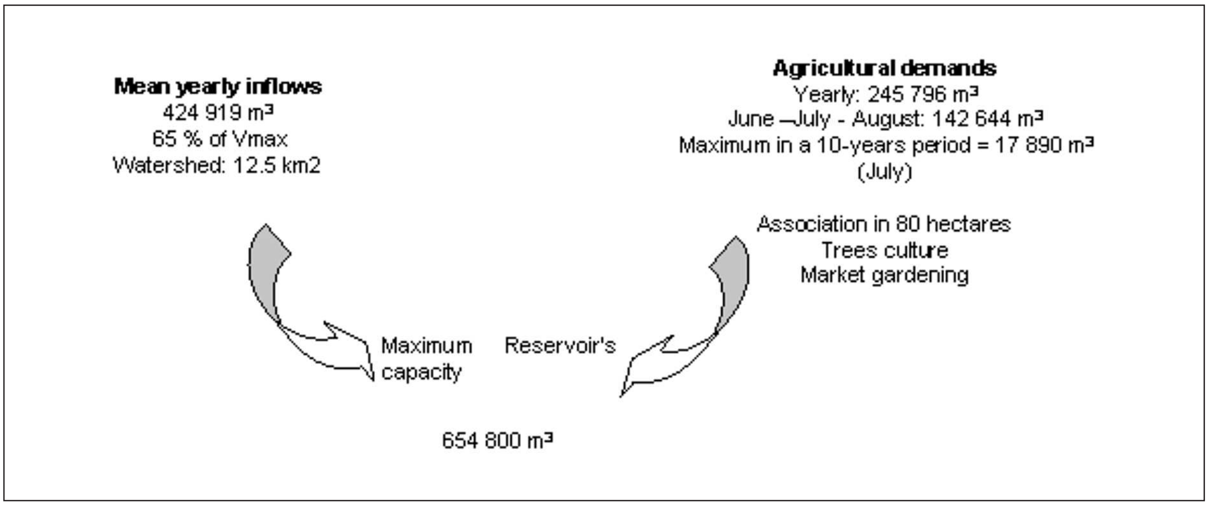


Fig. 10. El Morra reservoir characteristics.

Water balance in the reservoir

A run off-rainfall station was installed in the reservoir in March 1996 to collect daily evaporating data, rainfall and water levels in the reservoir.

Height-volume and height - surface curves

Only one bathymetry was done to the reservoir during its construction in 1992. The surface of the reservoir was deducted from the height (H) by the linear interpolation between two values. The volume (V in m^3)-height (H in m) relation is fixed by order 3 polynomial smoothing:

$V = 87.7*H^3 + 2882.1*H^2 + 22429*H + 52000$

Balance equation in the reservoir assessment: In a given period of time, the general equation of water balance is formulated as:

$$\Delta V = (V_r + V_{ecs} + V_p) - (V_{ev} + V_d + V_{inf} + V_u)$$

ΔV: the storage variation is known from the gauging records data.

V_r: inflows by streaming. It's the first variable unknown of the assessment because there isn't a gauge station controlling the gate. Its estimation is based on the floods' reconstitution.

V_{ecs}: inflow coming by underground's run off. It's the third unknown of the assessment.

$V_{p:}$ inflows are known from pluviometer saved data and the height-surface curve in the reservoir.

V_{ev}: evaporation is estimated from the daily saved backs' data and the mean surface in the same day. This estimation contains some errors due to the corrective coefficient from back evaporation to reservoir evaporation.

V_d: the spilling (the reservoir didn't spill yet).

V_{inf}: seeped volume, which is in function of the reservoir's hydraulic charge and the stored volume. It's the second unknown of the assessment.

V_u: bottom discharge, known from reading levels before and after operation.

Inflows reconstitution

In semi arid climate, the floods are violent and occur in a short duration. With a daily time step (the streaming still exist), the infiltration and evaporation are too slight compared to the streaming. The water balance formula is then simplified. Volumes records are smoothed for controlled floods.

Evaporative flux reconstitution

The evaporation in the area of the reservoir is estimated from the Colorado back in situ, taking into account a corrective coefficient equal to 0.8 (windy zone). The evaporative flux is deducted from an observed time series set with daily average during three years. These values are correlated to the stored volume (V) in the reservoir using a linear expression:

$$V_{ev} = a V + b.$$

Infiltration reconstitution

It can be estimated by droughts reconstitution, so we have:

$$V_{inf} = \Delta V - V_{ev}$$

In order to optimize the operating rules, a long set of inflows is needed to apprehend better the hydrological risk. Considering rainfall, inflows are reconstituted by using a GR3 rain fall-run off model from CEMAGREF. This software is calibrated on the basis of inserting three years measures on the site. An inflow generation is made to extend a 24 year's set of rainfall to a long one reconstituted from bordering stations and the rainfall-run off model.

The operation reconstitution is realized on three years-observation on the reservoir and gives good results for 10-years periods (Fig. 11).

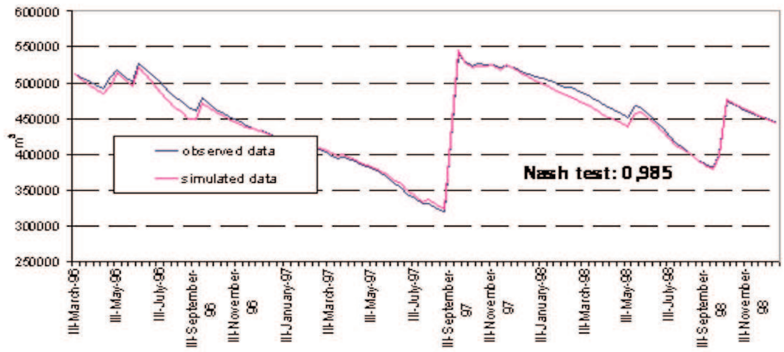


Fig. 11. Reservoir volume simulation per decade.

Operating reservoir rules optimization

Optimization of operating reservoir rules is based on the assessment of water balance equation which reflects the real hydrologic system behavior. The model's development is based on the state variables identification, decision variable and on the formulation of hydraulic constraints and the objective function. The optimization model formulation is defined by:

System states

The state variables concern the water balance variables (inflow, evaporation, etc.) and reservoir storage at the beginning of all the operating period.

The commands

The decision variable is the release executed at t time which is L(t).

Evolution function

It depends on time and use the water balance expression in the reservoir, taking in account L(t). It expresses the dynamic operation character.

Constraints

It presents the maximum and minimum values of the reservoir storage and the transit capacity of release.

$$V_{min} \leq V(t) \leq V_{max} \quad \text{and} \quad L_{min} \leq L(t) \leq L_{max}$$

The objective function

While the optimization operating rules optimization, the criterion formulated is applied, with low-objectives weighting. It consists on a simultaneous and weighted minimization of the deficit with regard to the target storage and the deviation from the water demands. That means a part of the criterion consists on storing water during a maximum of time in the reservoir and the other part consists on the satisfaction of water demands on the downstream side of the reservoir. The mathematic formulation is written as:

$$MIN\sum_{t=1}^{11}\left[\alpha(\frac{S_{t+1}-S_{consig}}{S_{max}})^2+(1-\alpha)(\frac{u_t-B_t}{B_{max}})^2\right]$$

S_{t+1}: Final storage at the end of each operating period.

S_{max}: Maximum exploitable storage (useful reservoir's volume).

S_{consig}: Target storage.

a: Weighting coefficient between 0 and 1.

u_t: Release to be optimized between i and (i+1).

B_t: Water demand presented at the beginning of an operating period.

t = 0: It corresponds to the beginning of September.

Therefore it doesn't mean to conduct the optimization from of economic benefit point of view, to respond automatically to the operator desire. The compromise to realize is based simply on the distribution of relative weight of each objective (demand satisfaction downstream of the reservoir and the guarantee of security storage for exceptional events). This operation is simulated by using synthetic series, we compare the optimal rules for each a value (weighting of each objective) and to choose the acceptable values according to the operator desire (expressed by the objective function and the constraints).

Pareto diagrams are drawn to represent performance indicators corresponding to the damageable events that could exist during time. This facilitates the optimal a value selection, which gives a better compromise between the two-operating objectives.

The operating model is naturally stochastic and the inflows are not known for each time step. Thus, for each storage level at a time (t+1) corresponds an inflow and an occurrence probability for this value. And thus for each storage level at a time (t), the system evolutes at least to "n" final states, with n, the number of the possible inflows values. According to MORAN, a simple scheme of storage levels and inflow classes' distribution, in a finite number of n equal classes, permits to apply optimization algorithms such as stochastic dynamic programming.

Optimization by stochastic dynamic programming (SDP)

Optimization process by SDP is based on a recursive equation presenting the possibility to optimize the objective criterion defined before taking in account inflows probabilities for a given time horizon:

The horizon time chosen for computation is the year because the reservoir does not have a sub-year regulation function.

The time step for computation is 10 days. It is the minimum period to simulate correctly the reservoir operation and where the different 10-days inflows are independent (Wald-Wolfowizt autocorrelation test).

The inflows and the volumes stored in the reservoir are distributed in 3000 cubic meters classes. This volume corresponds to the minimum agricultural demand per decade which is considered as base unit for calculation.

For each iteration and in the optimization procedure, the optimal desired winning is calculated for each state of the system. When the winning becomes constant from a period to another, the convergences criterion, by function stabilization increases, is fulfilled (Louks *et al.*, 1981) (Fig. 12).

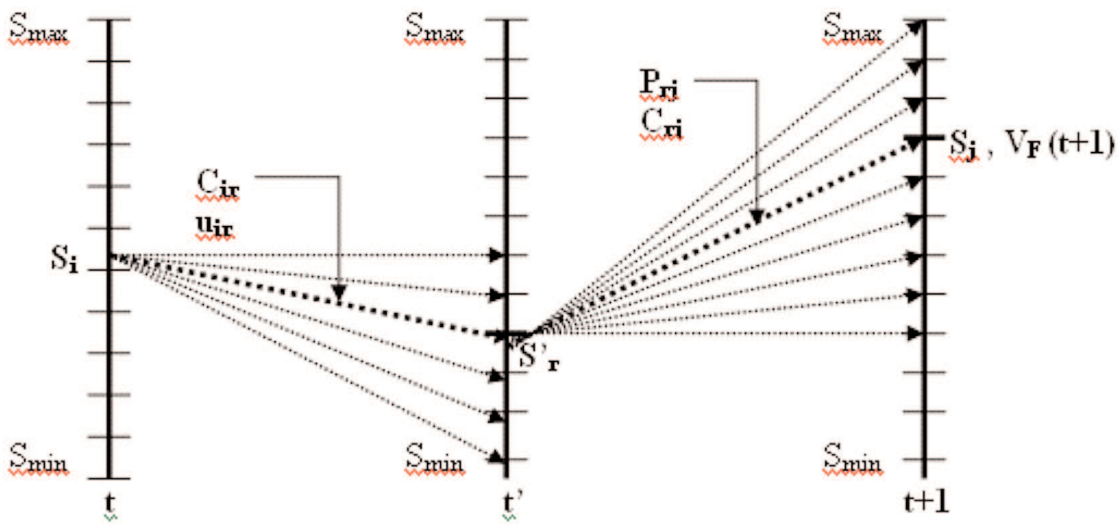


Fig. 12. Optimization scheme decision / hazard. C_{ir}: Cost of the transition between S_i and S_j. P_{rj}, C_{rj}: transition probability from S_i to S_j and C_{rj} is the transition value.

Incidents definition and selection - System performance indexes

By defining a damageable event and performance indexes, it is possible to judge the opportunity of an operating rule based on the same parameters. Incidents linked to storage shortage are also taken in account.

It is important to separate an objective weighted with a minimum of filling or a target storage to reach at each end of operating period, from eventual damageable event occurrence, when climatic conditions can't satisfy the objective indicated for the selected operating rule. The events are probable and real and can be integrated one by one into the reservoir operation. These ones are amounted when the optimal operating rule selected for a fixed a and they are used in the measure of the operating rule performance.

(i) Storage shortage: before the end of the operating period, the reservoir is empty. This situation depends on hydrologic risks and the water management policy selected until that date (Parent, 1992).

(ii) Demand not satisfied: for a given time, the available storage in the reservoir can't satisfy different partial objectives.

(iii) Spilling: it is not really an incident but it's a useful parameter, because it's the logical complement for the first incident.

For each of those incidents, and for a given operating rule, different performance indications are associated. These indicators are:

(i) The risk: it is the probability to realize, for a given time, the indicated event.

(ii) Resilience: it means estimation for medium time in which the system returns to a normal state when an incident has occurred (Fig. 13).

(iii) The vulnerability: it measures risks fullness. That means the medium importance of an incident for the resources' users (Fig. 14).

(iv) Duration of staying into a failure state.

(v) The steady probability of being in a failure state.

(vi) The time of the first transit to a failure state.

(vii) The average time between two states: full satisfaction and failure.

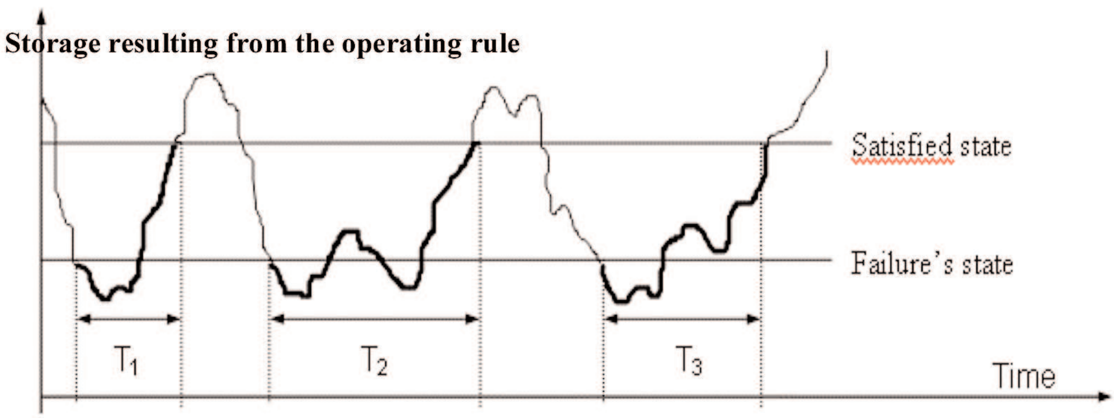
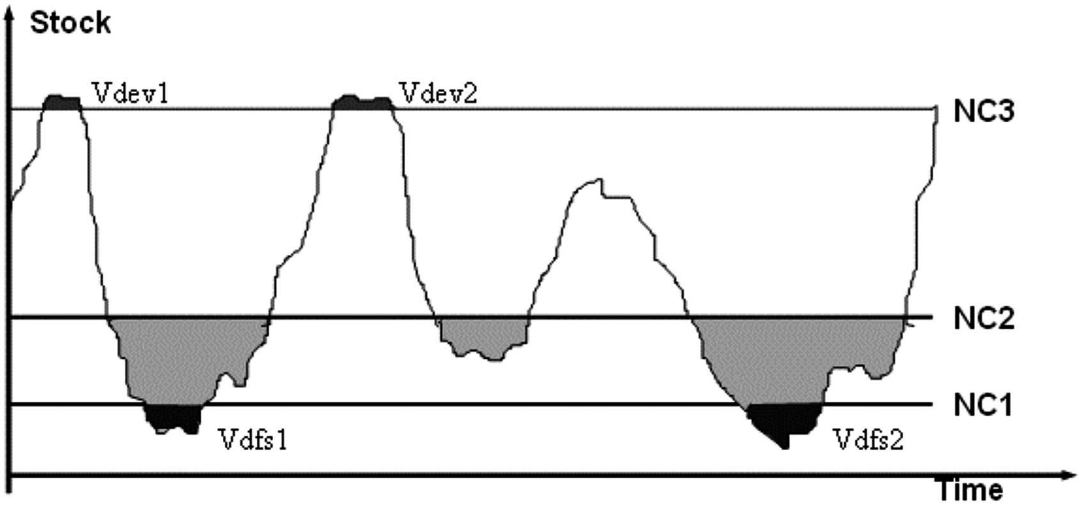


Fig. 13. System's resilience representation.

According to the resilience definition, we can write:

$$\text{Resilience} = \frac{T_1 + T_2 + T_3}{3}$$

Figure 14 represents the system's evolution in relation to time:



$$Vdfs = \frac{1}{N}\sum_{t=1}^{n}\left(S(NC1) - S_t\right) \qquad \text{for } S_t \leq S(NC1)$$

$$Vbns = \frac{1}{N}\sum_{t=1}^{n}\left(S(NC2) - S_t\right) \qquad \text{for } S_t \leq S(NC2), \text{ N: number of simulation's years and}$$

$$Vdev = \frac{1}{N}\sum_{t=1}^{n}\left(S_t - S(NC3)\right) \qquad \text{for } S_t \geq S(NC3)$$

Fig. 14. Vulnerability or deficit representation.

The performance of an operating rule with regard to another is estimated by a comparison between values of the same performance indicator calculated for each rule, and for two damageable events.

Simulation by criteria for risk analysis

In this case study, the following indicators are selected by simulation of optimal rules on 24 years of generated hydrological data (Fig. 15):

(i) Risks of failure (RDF), spilling (RDV), and the non demand satisfaction (VBN).

(ii) Vulnerability of failure (VDF), spilling (VDV) and the non demand satisfaction (VBN).

(iii) Resilience of failure (RESDF), and spilling (RESDV).

(iv) Overshooting (unused volumes): VSUP.

All the indexes are normalized between 0 (very good performance) and 1 (very bad performance) by an acceptation threshold and they are grouped as the following:

Normalized index = (index – acceptable threshold) / (unacceptable index + acceptable threshold).

In order to simplify the results interpretation, the following graphic (Fig. 16) presents: alpha, the indexes and their values. When the rule has a normalized index > 1, it is rejected. Therefore two optimized rules are acceptable in regard to the fixed indexes thresholds (alpha = 0.2 and 0.3).

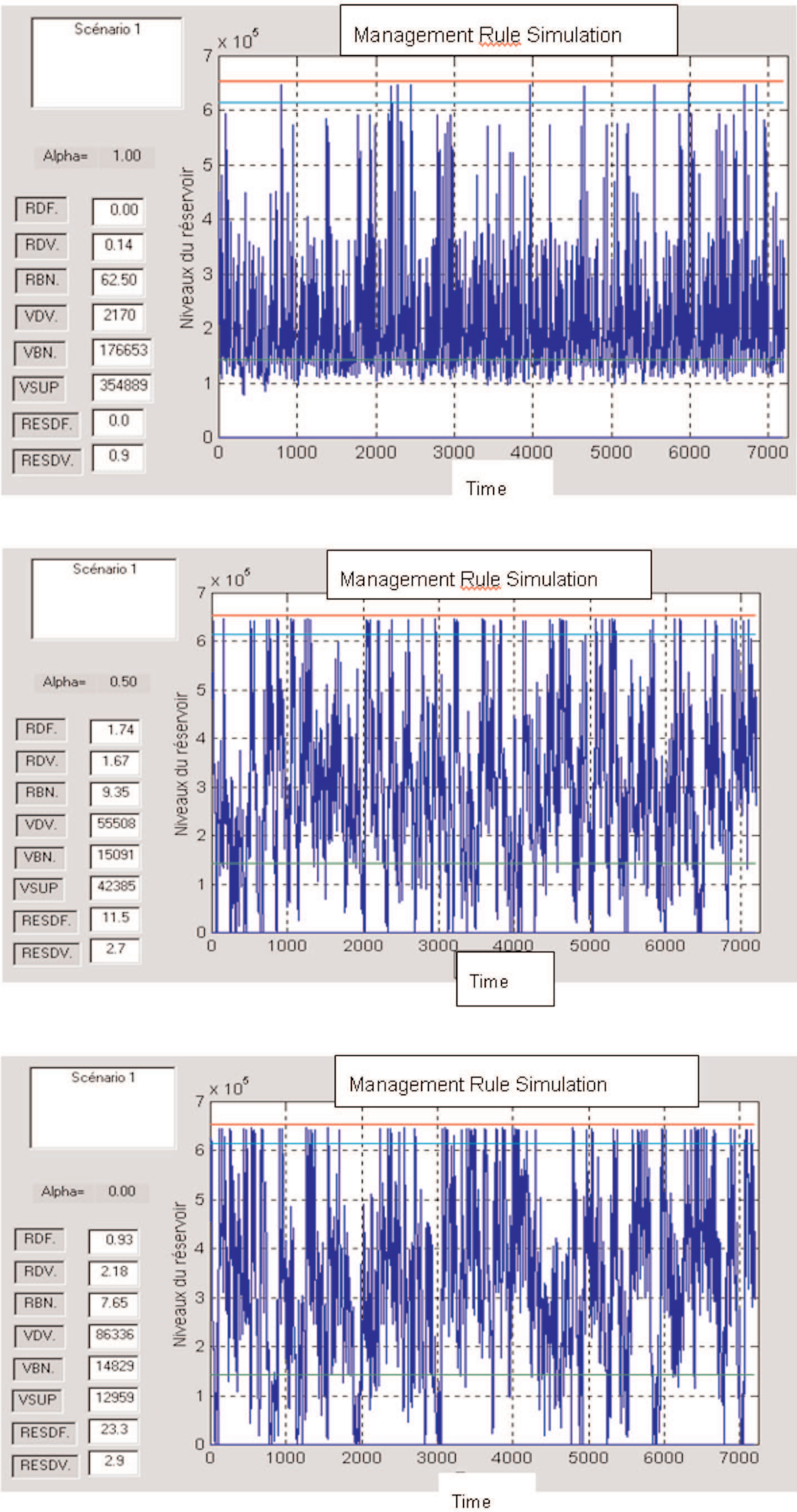


Fig. 15. Managements rule simulation.

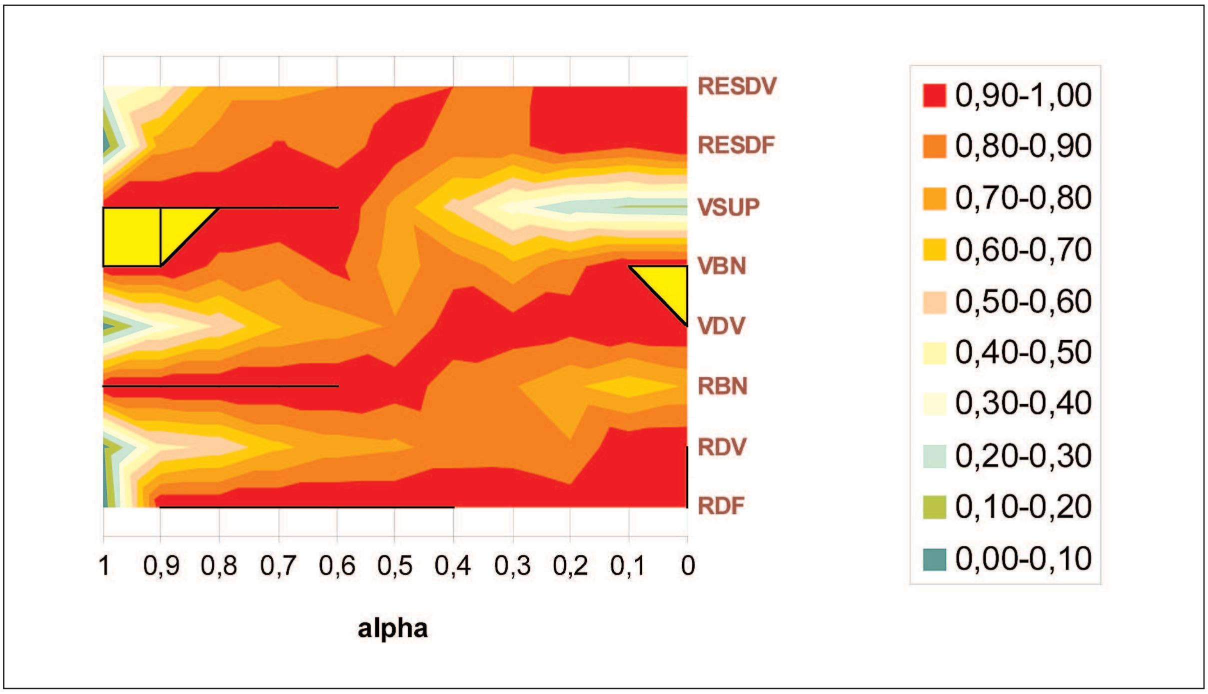


Fig. 16. Alpha values.

Results and perspectives

According to these results, the operator has in hand only a few possibilities to avoid events judged unacceptable (alpha = 0.2 and 0.3) (Fig. 17).

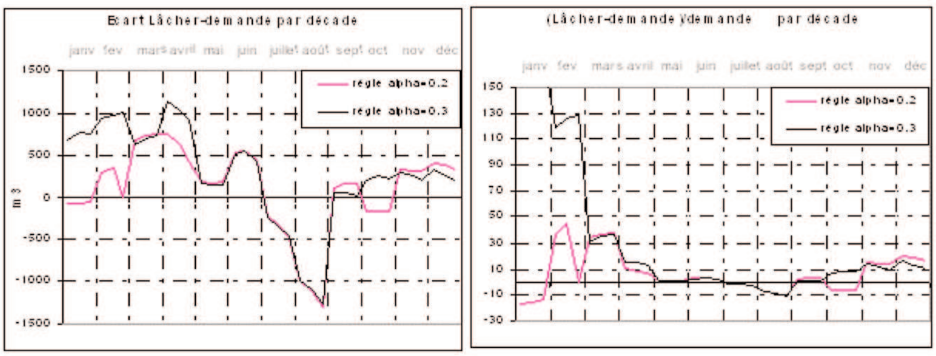


Fig. 17. (Release – Demand) deviation per decade.

In the two cases, the failures of supply are slight and the selection of those coefficients shows that the operator should give a preference for the agricultural demands to satisfy the double objectives already fixed. From May to August, the two operating rules (a = 0.2 and a = 0.3) satisfy the demand by the same way. But from January to April, the rules are different. The rule (a = 0.3) gives always exceeded volumes (overshooting), except for the dry months (July, August). The (a = 0.2) rule gives a near from a null deficit (less exceeded water) and presents a little deficit in October. However, this deficit has a slight absolute value (≤ 300 cubic meters per decade), that is 12.5 cubic meters per hectare and per day, so 0.125 mm per day (≤ limit of demands water values precision). The choice between the two rules is not trivial. We should be oriented to rule which presents less penalties (less deficit per decade, sum of minimal normalized indexes). It means the (a = 0.3) rule.

The fulfillment curve determination

The selected operating rule (Fig. 18) is based on an objective function giving a weight of 0.3 to the guarantee of a minimal storage in the reservoir (213000 m^3) and a weight of 0.7 to the demand's satisfaction. The inflows and storage distribution make the releases having a class unit equal to (3000 m^3). When the release is null and the storage level is greater than the fixed objective level to 50% of the inflow's median (23000 m^3), a correction should be operated to bring the release to the slight values of water's volumes eventually demanded. This correction is omitted when the storage level is lower than the minimum one corresponding to the demand volume of the peak period (142600 m^3). Thus, the matrix corresponding any decade to the stock level for an out let decision's value makes an objective's line (called fulfillment matrix) which delimits the storage levels per decade in which the demand is totally satisfied.

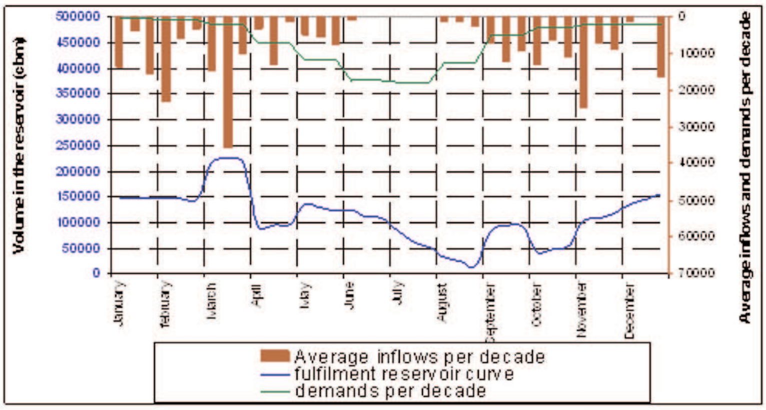


Fig. 18. Optimized operating results for El Morra reservoir.

The maximum risk of failure is 1.41%, the spilling risk is 2.12% and the unsatisfied demand risk to a 60% height of a value of 11.1%. The maximum release vulnerability is 70000 m^3, the unsatisfied demand vulnerability is 6000 m^3 and the unused releases vulnerability is 42000 m^3.

In these results there are some errors of data's incertitude caused by: reconstituted inflows with errors' tolerance, estimated demand's water fixed per decade, the optimization and the operating rules simulation.

All these approaches are concentrated either on the production and the water resources constitution or on its variability. However the demands are considered as data determined by scenarios already made and usually almost satisfied.

When the deficit offer/demand is structural, the resource operating becomes dryness operating and in this case, the proposed solutions previously calculated are no more available even in the domain of water agriculture's demand.

Operational component

Overall strategies

In most Mediterranean countries, water management planning is based on "Water Master Plans". These plans depend on basins boundaries, and as a consequence (in Tunisia), the water resources planning process has been compelled to balance between some constraints as:

(i) The target water use regions are generally different than those were mobilization has been realized, resulting in imperative water transfer, that reached 400 km.

(ii) Water resources management planning was conducted in the basins scale contrary to their supply programs which are planned, in the social and economic development national plans, depending on the administrative units (governorate and departments). Nevertheless, basins and administrative units didn't have common boundaries.

In order to overcome the above constraints, the hydraulic units concept has been adopted as approach in water resources planning and management. Since water resources (surface and aquifers) were identified, quantified, and mobilized or to be mobilized, their management became linked to "stocks management" and not as "random resources". This is the headmaster strength in water resources system in Tunisia. The management of each reservoir or a group of reservoirs could be realized in normal period as well as with interaction with the remainder system components, particularly during extreme situations (drought or floods). The Geographical Information System (GIS) allowed the water balance establishment at administrative as well as at hydraulic unit scales. Every hydraulic unit is characterized by its own, imported and exported resources.

Generally, drought is upon in Tunisia once every 10 years. In order to reduce the resulting effects of the drought in Tunisia, a related management system was developed and adopted for the drought events occurred during 1987-1989, 1993-1995 and 2000-2002. During 1999, Tunisia published the first guideline of drought management "Guide pratique de la gestion de la sécheresse en Tunisie" (Louati *et al.*, 1999). The guideline was elaborated by referring to the drought management system and by analyzing the data and information recorded during the drought periods of 1987-1989 and 1993-1995. This guideline, consisting on methodological approaches, identifies the principal drought indices, describes the drought preparedness and management process, and maps the intervening parties.

The drought management system in Tunisia process in 3 major successive steps (Fig. 19):

(i) *Drought Announcement.* Referring to meteorological, hydrological and agricultural indicators as observed in the different regions affected by drought and transmitted by the agricultural, economic, and hydrologic districts relevant to MARH, a drought announcement is established by mean a circumstance memorandum.

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

(iii) *Action implementation*. The National Commission is loaded by the supervision of the execution of all the operation actions, with strength collaboration of the regional and specialized committees. The National Commission supervises also all operations when the drought is over.

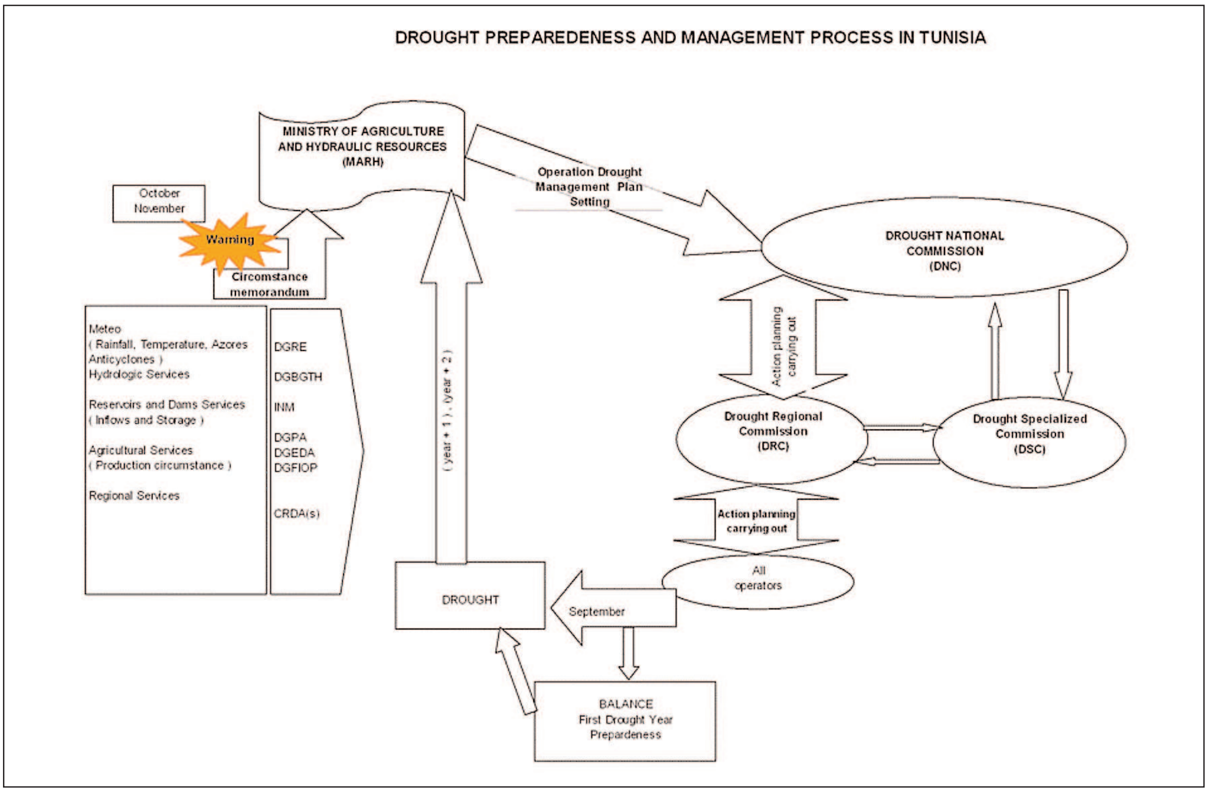


Fig. 19. Drought management plan in Tunisia.

Phases of the drought management system

The drought management system in Tunisia is based on three phases: (i) Before drought (preparedness and early warning); (ii) Drought management (Mitigation when drought is upon); and (iii) Subsequent drought (when drought is over). During each of the three phases different measures are applied and carried out (Louati *et al.*, 2005)

The Drought Management Phase is characterized by the execution of the planning programs of drought mitigation. Depending on the type, intensity and duration of the drought event, different scenarios are adopted.

The year is considered dry when the precipitation deficit is beyond 50% of the mean historically established value. The probability to have a dry year is 7 to 23% in the North and between 25 to 30% in the Centre and the South. From such situation results a substantial shortage in the available water resources, a production falling and range shortage, and some problems related to the domestic water supply appear in the drought sensitive regions. Livestock sickness could be observed, because of diet change and unbalanced nutrition regime. In order to attenuate those problems a mitigation program is executed:

(i) For Livestock safeguard, the identification of the animal nutriments stocks is established and an importation planning is fitted in order to gap the deficiency.

(ii) Prevision of vaccination campaigning on the livestock against the sickness related to drought.

(iii) To satisfy the domestic water demand, in urban as well as in rural areas, a program of aquifers uses is adopted, the use of the surface water resources is avoided or minimized. Particular attention is given to water transportation until the rural drought sensitive regions.

(iv) Establishing reservoirs' water management plan regarding the evolution of the climatic conditions. The eventuality of a second dry year is specially taken in account.

(v) Intensification of the preparedness operations related to the next year up going (short loans, soil tillage, seeds distribution, etc.).

(vi) Subsequent Drought Phase.

When drought is over, several measures are taken:

(i) Intensification of the vulgarization program related to the soil tillage and farming practices in order to maximize the valorization of the precipitation coming during the subsequent drought wet year.

(ii) Available water resources evaluation. (reservoirs and aquifers).

(iii) Reconstitution of the aquifers water reserves by the artificial recharging.

(iv) Evaluation of the mitigation program efficiency and estimation of their cost.

Analysis of historical drought periods: 1987-1989 and 1993-1995

The hydrological drought

During 1987-1989 and 1993-1995 drought was characterized by "two subsequent dry years". The drought management system that is described above has been applied. It was based on reactive decisions. Data and information related to the drought incidences were recorded and used in the elaboration of the drought management guideline in Tunisia (Louati *et al.*, 1999).

The hydrological drought in Tunisia, including the water resources reservoirs management under drought and the resulting water supply conditions, is presented in this report section.

Firstly it is important to underline that water resources reservoirs management involving the application of water supply rationing depends on water storage at 30 April. Rainfall deficit during the period between the 1st September and 30th April is an important index indicating the water resources availability situation. This period is the most determining of the hydrological drought and its impact on the reservoirs storages.

During 1987-1989 drought was severe in the whole country, where NE, CW, SE and SW were the more sensitive regions. During this period the water catchments (input) in the reservoirs has been less than 50% of dams capacity.

During 1993-1995 drought was similar to the former event described above. Rainfall deficit was ranged between 33 to 56% and was around 35% on the national scale. During this drought, data on the water catchments recorded in 8 dams within the 18 that were under exploitation in this date (actually 26 dams are already realized) are presented in Table 11.

Table 11. Minimal water input recorded in the 18 dams under exploitation in Tunisia.
Source: DGBGTH, 1996

Dams	Use starting date	Minimal water input (Mm^3)	Year
Mellegue	1954-1955	36.6	1993-1994
Joumine	1983-1984	17.9	1993-1994
Ghezala	1984-1985	0.5	1993-1994
Siliana	1987-1988	3.5	1993-1994
Bir M'Cherga	1971-1972	3.4	1993-1994
Nebhana	1967-1968	3.1	1993-1994
El Houareb	1989-1990	7.5	1993-1994
Bezirk	1961-1962	0.2	1993-1994

Statistical study on the dams (since their use starting), showed that the minimal water input has been recorded during 1993-1994, in 8 dams within the 18 under exploitation (Table 11).

Tables 12 and 13 show that 1993-1994 and 1994-1995 were characterized by a severe hydrological drought. Consequently, the water volumes stored in the dams were strongly affected as shown in Table 11. In January 1995 the stored water volumes were in their minimal quantities.

Table 12. Water catchments (inflows) in dams in Tunisia between 1st September and end of August (Mm^3)

Dams	Mean	1992-1993[†]	1993-1994	1994-1995
North West (10 dams)	1108.1	566.1	318.3	466.2
Centre (4 dams)	210.8	119.4	36.7	132.5
North East (4 dams)	23.1	19.2	23.3	7.0
Total (volume)	1342.0	704.6	378.3	605.7
Total (%)	100.0	56.7	30.4	45.1

[†] 1992-1993 could be supposed with satisfactory water resources availability since water storages since the precedent year had not been affected by drought.

Table 13. Water volumes stored in the dams during 1992-1993, 1993-1994 and 1994-1995 in Tunisia. Source: DGBGTH, 1996

Dams	1992-1993		1993-1994		1994-1995	
	Volume (Mm^3)	Filling rate (%)	Volume (Mm^3)	Filling rate (%)	Volume (Mm^3)	Filling rate (%)
North West	864.8	81.7	698.7	66.0	403.3	38.1
Centre	307.3	84.0	287.2	78.5	194.8	53.3
North East	36.7	71.5	29.9	58.2	26.0	50.6
Total	1208.8	81.9	1015.8	68.8	624.1	42.2

Reservoir management during 1992-1995: Decision Tools

The decision tools used for water management were based on the measurement instrumentation spread in all the water supply locations, information and data transfer to the Central Direction (in Tunis) for decision taking, the filed database, specialized software and simulation models related to the water management optimization.

The water management policy established has been highly proficient since the following results were obtained:

(i) The drinking water supply (for domestic, tourist and industrial use as well) has been ensured without any restriction during the successive years 1992-1993, 1993-1994 and 1994-1995.

(ii) The agricultural water demand was satisfied during 1992-1993 and 1993-1994. A restriction plan was prepared for 1994-1995. This plan was applied in March 1995 and adapted in July 1995 regarding the water resources situation which was improved by the exceptional rainfall of June 1995 (in Mellègue). For all the irrigated areas, the restriction has been about 50% (with normal year as reference). This restriction ranged from 19.5 to 27.5% referring to a dry conditions year (1993-1994). Therefore during this year (1993-1994), in spite of the dry conditions all agricultural demand was satisfied (Table 14). Farmers adopted some "self modifications" in their farming systems to adapt them to drought situation.

Table 14. Agricultural water supply restriction during 1994-1995 in Tunisia before and after the "Restriction Plan" adaptation. Source: DGBGTH, 1996

Regions	Water demand during 93-94 (Mm^3)	Water supply ensured during 94-95		Restriction rate % (93-94 water demand as reference)	
		Before	After	Before	After
North West	272	170.1	199.2	37.7	27.5
Centre	35.7	25.9	25.9	27.5	27.5
North East	44.3	27.0	35.7	39.1	19.5
Total	352.0	223.0	260.8	36.9	26.2

Lessons learned during the 1992-1995 drought (Hydraulic management exercise)

From all the previous drought management events, actions related to agricultural production (crop systems and livestock care) were well monitored. It is from the practical decisions taken during 1992-1995 drought events that tools decisions linked to water reservoir management were tested. Some conclusions that are related to the improvement of the water system could be drawn:

(i) Improving the water storage dam capacity. Existing dams have to be heightened or new dams should be built in order to maximize the valorization of the wet years rainfall.

(ii) To follow and reinforce the maintenance improvement of hydraulic infrastructures to reach their maximum performances.

(iii) To interconnect the regional hydraulic systems (surface and ground water) – integrated and combined management of the resources.

(iv) To adopt an adequate irrigation system.

(v) To give responsibilities to the water users by the implementation of associations of collective interest.

(vi) Strengthen the knowledge in water resources management control subject to the climatic changes.

(vii) Set up a database of measurements and observations which can constitute a reference for the future.

(viii) Dams conceived for inter annual regulation played their role completely in the satisfaction of demand during normal periods.

(ix) Reservoirs conceived for inter annual regulation are, in case of drought, subject to sensitive deficits. These deficits should be filled by supplements of water from the north waters network as is the case of Bezirk, Nasri and Chiba dams, or from direct pumping in the "oued" (river) as is the case for Lakhmess.

Plans and actions for coping with the 1999-2002 drought (Guideline approach application and lessons learned)

Drought has been upon Tunisia during 3 consecutive years (1999-2002). This drought was characterized by different types: regional, global, seasonal and annual. In this section a brief description of the drought events is presented. The lessons learned are identified. The updating mitigation system necessity is underlined.

Rainfall during 1999-2002

From the precipitation data, observed in the different regions in Tunisia and presented in Table 15 the following conclusions could be drawn:

(i) Rainfall during summer has no importance in the cropping systems or in the water resources mobilization process. Such precipitations are generally small quantities and occur with hot weather, consequently they are totally evaporated. The global drought index related to the cumulated rainfall during the effective seasons – autumn, winter and spring is more significant than the yearly values.

(ii) During 1999-2000 the autumn was safe, but the winter and spring were severely dry in the Centre and South. In the effective season’s level, the water deficiency ranged on about 80%. The droughts during this year have been seasonal (winter and spring), and moderate in the North and severe in the South and the Centre. This situation has created awareness on the decision makers as well as on the water users. Hence, a preparedness programme, for eventual subsequent dry years, was in the mind of all.

(iii) During 2000-2001, the drought has been generalized in the country, expect the North side.

(iv) Unfortunately, 2001-2002 was dry in the whole country, so it could be considered as the third year of drought. This situation is generally rare but it occurred in Tunisia. The drought was severe and generalized during the autumn and the winter and moderate during the spring in the North, Centre, and SW of the country. A severe drought occurred in the SE regions.

Table 15. Rainfall [Pm: historical mean (mm); P: measured (mm)] and drought index (DI = P/Pm * 100) during 1999-2002 (autumn, winter and spring) in Tunisia

Regions	Autumn-winter-spring			Year		
	Pm	P	DI (%)	Pm	P	DI (%)
1999-2000						
NW	587	436	74	619	504	81
NE	467	418	90	489	437	89
CW	283	235	83	320	252	79
CE	305	296	97	317	335	106
SW	116	82	71	124	116	94
SE	172	125	73	175	125	71
2000-2001						
NW	587	599	102	619	625	101
NE	467	436	93	489	455	93
CW	283	178	63	320	189	59
CE	305	156	51	317	158	50
SW	116	55	47	124	56	45
SE	172	53	31	175	54	31
2001-2002						
NW	587	371	63	619	468	76
NE	467	262	56	489	308	63
CW	283	176	62	320	229	72
CE	305	185	61	317	201	63
SW	116	82	71	124	87	70
SE	172	86	50	175	87	50

Drought mitigation operations during 1999-2002

All operations described above were realized. It is important to mention that the hydraulic system was highly efficient, since during the third dry year no significant restriction in the water supply was applied. The restriction was around 10% for drinking water and about 30% on agricultural uses. All media and extension services contributed in increasing public awareness on the drought event and sensitization for the saving water.

(i) During 1999-2000, principal measures were localized in the sensitive regions. A preparedness programme, for eventual subsequent dry years, was in the mind of all.

(ii) During 2000-2001, the principal measures were related to the livestock nutrition providing subsided prices and also free barley quantities were attributed to 170,000 small farmers. Circumstance decisions were taken by exempting the importation from taxes and customs charges. Livestock vaccination was operated. On the other hand, the farmers were advised in the soil tillage (dry farming operations) and in the trees pruning. Priorities were attributed to water transportation by tank track in order to irrigate fruit trees, especially the young ones and to protect the trees, particularly the olive tree, against insects and diseases. A water management programme for satisfying the demand was realized: water transportation, new artesian wells creation and maintenance of the shallow wells. In the national level, markets were supplied by sufficient quantities of principal products. The cost was estimated by 19,550 millions of Tunisian Dinars, scheduled in two stages and supported by a presidential special attention.

(iii) During the third dry year 2001-2002, that was general for the whole country, all measures listed above were intensified and evaluated with a cost of 33,172 millions of Tunisian Dinars that were also scheduled in two stages.

Proactive and reactive measures

All drought mitigation actions undertaken before 1999 in Tunisia are basically characterized by being "adaptation measures" that are linked to emergency interventions, rarely integrated and overloading the State budget. The intervention measures consist particularly of: (i) free vaccination of animals; (ii) distribution of free livestock nutrition products for small farmers who are the most financially affected by drought; (iii) subsidizing forage product prices; and (iv) attribution of yearly credit for farmers in order to cope with drought. Such interventions were not planned before 1999. But today drought is considered as a climatic reality and is taken into account in the national development plans (e.g. the tenth plan 2002-2006) as well as in the State annual budgeting.

Although the four mentioned measures conducted during drought are really reactive, regarding their importance in securing the farmers, they tend to be proactive measures since they approach an insurance system.

Strengths and weakness of drought management system

The drought plan or the drought management system has not been analysed deeply until now in Tunisia. Actually, a wide-spreading study is in process (since 2003). The study entitled "The Climatic Changes and their Impacts on the Agricultural Sector and the Ecosystems" is actually in its first phase, and diagnostic and evaluation of the drought mitigation plan in Tunisia would be realized in the near future.

Strengths

(i) A high Presidential interest and support is devoted to the drought mitigation system in Tunisia.

(ii) The approach based on three drought management phases (before, during and after drought process), is a very important strategy and relevant to the basic elements of drought management theory.

(iii) Productive capital sharing and preservation.

(iv) Sustainability of farmers incomes.

(v) Integrated and optimized water resources management in Tunisia, especially during drought depending on its intensity and duration.

(vi) Water saving is a national policy not only related to drought.

Weaknesses

(i) The financial incidences are supported by the State budget because of the absence of insurance systems linked to droughts, and the private sector contribution is limited.

(ii) Updating the drought mitigation plan until 2003 was based on simple note taking and observation findings, without any wide-spread evaluation study. The latter would be realized by in process studies "The Climatic Changes and their Impacts on the Agricultural Sector and the Ecosystems".

(iii) The deficiency in the relations between the different information data stakeholders, which should be resolved by the establishment of the Unified Water Resources National Information System "Système d'Information National des Ressources en Eau (SINEAU)" in the near future.

Conclusions

Rainfall in Tunisia is characterized by a spatiotemporal variability and it has a high importance in the irrigated and rainfed agricultural production systems and also in the water supply for the other sectors. For this reason, Tunisia focused its policy on the water mobilization with inter annual volume regulation approach. From Tunisian water system complexity results a complex water management process, where diversified organizations and institutions are involved in water resources data and information system, in water management and consequently in drought mitigation process.

The integrated water resources management system in Tunisia considers the drought as a climatic reality that is taken into account in the development plan programmes. The planning for drought moving from crisis to risk management dates only from the end of the eighties. Before, droughts were erroneously considered for several years as temporary and rare climatic events, and consequently the drought management was "a forced reaction" to respond to immediate needs. When drought is upon the country, irrigated areas as well as the rainfed lands are affected, and the other water demands are also subjected to some restriction. For coping efficiently with the drought periods, Tunisia established a drought management system which has been used for the drought events occurred during 1987-1989 and 1993-1995. In 1999, Tunisia elaborated its first drought mitigation guideline. The latter, has been applied during the drought during 1999-2002.

Finally the following points could be underlined:

(i) The performance of the Tunisian hydraulic system is demonstrated during the water shortage.

(ii) A consolidation of the interaction between the different organizations and institutions that are involved in the water and drought data collection and between those related to the drought mitigation process is required.

(iii) The Unified Water Resources National Information System "Système d'Information National des Resources en eau (SINEAU)", which will be established in Tunisia in the near future, will be useful for several situations of water resources management, particularly during drought.

(iv) The drought management system could be qualified as moderately sufficient, and has to be improved; the lessons learned should be established in order to update the system (the guideline and its approach).

(v) The partners of MEDROPLAN project experience in the water and drought mitigation, when identified, could enhance the Tunisian system. The outputs and deliverables of MEDROPLAN will have certainly a high importance in the updating process of the drought mitigation system in Tunisia.

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Practical Guidelines for drought management in Tunisia

Generally, drought is upon Tunisia 2 to 3 times every 10 years. It is considered as a reality and not as a rare and random event. In order to reduce the resulting effects of the drought in Tunisia, a related management system was developed and adopted for the drought events occurred during 1987-1989 and 1993-1995. In 1999, Tunisia published its first guideline of drought management "Guide pratique de la gestion de la sécheresse en Tunisie" (Louati *et al.*, 1999). The guideline was elaborated by referring to the drought management system and by analysing the data and information recorded during the drought periods of 1987-1989 and 1993-1995. The American and Australian drought mitigation systems were overviewed and explored in order to adapt some approaches to the Tunisian natural conditions. This guideline, consisting of methodological approaches, identifies the principal drought indices, describes the drought preparedness and management process, and maps the intervening parties.

Drought Indices

Precipitation Deficit

The principal drought indices adopted in Tunisia are related to the quantification, for a given period of time, of the percentage of precipitation deviation from the mean historically established values. According to the experience in Tunisia, when precipitation quantities are ranged between 70 to 50% of the historical mean value, drought is declared and when they are less than 50%, a severe drought is declared. Yearly, the first kind of drought is predominant, but the second one is rare in the North and frequently occurred in the Centre and the South of the country.

The delay of the first autumn precipitation (September-October) is a pertinent index relevant to the meteorological conditions during the remaining year. The rainfall data analysis showed that during the last century there was a highly correlated relation between autumn rainfall quantities and the yearly precipitation amount. Around 70% of the autumnal drought cases are generally followed by an annual drought event. This percentage is 78 and 90% respectively for the North and both the Centre and the South. Precipitation during autumn is very important since it is representing 40% of the mean annual quantity.

On the other hand, if the drought persists during the beginning of the winter, especially from 13 January to 2 February (called in the agricultural local language the black night), the drought is confirmed. The March precipitations are impatiently awaited. Such precipitations are very important; they are a great weight off of farmers' minds since they save their crops, especially the cereal and the young trees. The importance of that precipitation appears in the popular proverb: "rain of March is pure gold.

The Azores anticyclone

There are other drought indices related to the Azores anticyclone coming from the West of the country. This results in a rise in temperature that could reach 30 to 35°C and an outstanding SW wind that hampers the NW atmospheric disturbance, characterized by rainfall events. During the drought events occurred on 1987-1988 and 1994-1995 the Azores anticyclone was observed.

The drought committees

Because of the importance of the committees' work, they are nominated by Ministerial Special Decisions. In order to ensure an efficient drought management, three types of committees are established:

The Drought National Commission (DNC)

This DNC regroups representatives of MARH, Interior, Economic Development, Finances, Commerce, Transport, and Public Health. It has principally: (i) to keep track of the drought circumstance; (ii) to elaborate the measures and provisions against the drought situation (intensity, duration, etc.), according to regional and national indices analysis; and (iii) to coordinate the execution of drought mitigation operation programmes. This commission is supported by the Specialized Sectors Commissions (DSC) at the national level and by the Regional Commissions (DRC) in each province (Governorate).

The Drought Regional Commissions (DRC)

Tunisia has 24 Governorates. For each one there is a DRC. The members belong to the Regional Departments of all Ministries involved in drought mitigation. The UTAP (United Farmers Organisation) is associated. The main task of DRCs is to present the situation of the different sectors and inform the national authorities about the necessary measures for drought management if observed in their regions. They work in strong collaboration with DNC and DSC.

The Drought Specialized Commissions (DSC)

The DSC(s) are responsible for the preparation of the drought indicators observed in each field. They propose an operation planning and scenarios for mitigation of the different eventual drought events. The DSC(s) are as following:

(i) Water Resources Management Committee. This Committee regroups representatives of all departments involved in the water management in MARH. The INM (relevant of Ministry of Transport) and the Ministries of Interior and Public Health are also associated in this committee. Referring to the data collected by the DRC, this committee has to analyse the water resources situations, to establish the drought indicators related to water resources and to elaborate diverse water management scenarios that should be adopted. The DSC submits a measures programme to the approbation and decision making by DNC.

(ii) Livestock Safeguard Committee. Organizations and institutions not involved in water management, but that are associated in drought mitigation, are represented in the Livestock Safeguard Committee. The latter is formed by representatives of organizations and institutions that are involved in the animal husbandry within MARH. The UTAP is associated in the activities of this committee, and the Ministries of Commerce, Transport, Interior, Finances and Economic Development. In collaboration with the DRC, the committee identifies the forage stocks and reserves, analyses the fodder crop fields and fits the livestock health situation. Depending on the drought intensity, this committee has to elaborate an intervention programme and to establish the eventual importations needs in order make up the eventual forage deficit.

(iii) Cereal Sector Management Committee. This committee is organized by the cereal sector intervening parties. Its members are representatives from different departments of the MARH that are working in the cereal field. The UTAP is associated and also the Ministries of Finances and Economic Development. This committee has to quantify the cereal production stocks and seeds reserves, to propose a programme in order to promote the irrigated cereal production, to enhance the production collecting, with a principal preoccupation of satisfying the seeds demand for the next year. In the case of insufficiency in cereal an importation programme is elaborated.

(iv) Arboriculture Sector Committee. The members of this committee work in the arboriculture departments of MARH and are concerned with the situation of all trees and aim the arboriculture heritage (patrimony) safeguard. The UTAP is associated.

Phases of drought management system

The drought management system in Tunisia is based on three phases: (i) Before drought (preparedness and early warning); (ii) Drought management (mitigation when drought is upon); and (iii) Subsequent drought (when drought is over). This could be resumed by "Before, during and after". The drought management system in Tunisia process in 3 major successive steps:

(i) Drought Announcement: Referring to rain fall, hydrologic and agricultural indicators as observed in the different regions affected by drought and transmitted by the agricultural, economic, and hydrologic districts (services) relevant to MARH, a drought announcement is established by mean a circumstance memorandum.

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

(iii) The National Commission is loaded by the supervision of the execution of all the operation actions, with strength collaboration of the regional and specialized committees. The National Commission supervises also all operations when the drought is over.

Drought Preparedness

During this phase different organizations and institutions involved in the data collection systems, and also the universities, the research institutions, the extension organization (AVFA), the water management NGOs and the UTAP are associated. During this phase the following actions are realized:

(i) The climatic and hydrologic data are analysed in order to predict the hydro climatic situation.

(ii) A water management programme is established. This programme adopts the use of aquifers water resources during the scarcity periods.

(iii) Equipment of water points for domestic use when the drought has set in.

(iv) Contributing within the National Programme of Water Saving by a growing public awareness on the drought event.

(v) Ensuring sufficient quantities in forage and cereal seeds.

(vi) Fitting the reserves on forage and cereal in order to preparing a programme of an eventual importation.

(vii) Identifying the drought sensitive farmers.

(viii) Forecasting a financial supply for undertaking the farmers' drought disasters.

(ix) Preparing research topics related to drought mitigation.

Drought management

The drought management phase is characterized by the execution of the planning programmes of drought mitigation. Depending on the type, intensity and duration of the drought event, different scenarios are adopted:

Scenario 1 – Dry autumn

At the national level, around 70% of dry autumn cases are generally followed by an annual drought event. Nevertheless, this percentage is 78 and 90% respectively for the North and for both the Centre and the South. Precipitation during autumn is very important since it is representing 40% of the historical mean annual amount. Under such conditions the drought affects the cereal fields especially in the Centre and South and the forage crops in the north as well as the rangelands. Some mitigation and preventive operations are conducted:

(i) Identification of affected and sensitive zones.

(ii) Enhancing of the irrigated cereal programme, especially in the Centre and the South.

(iii) Evaluation of animal nutrition stocks and prevision of the eventual importation.

(iv) Supply the drought damaged regions by barley and other forage products.

(v) Establishing dams management plan according to the climatic conditions evolution.

Scenario 2 – Dry winter

Winter rainfalls are very important, particularly in the North where they contribute with about 41% of annual precipitation. They influence the cereal production, and have an impact on water collected in the dams and also on natural aquifer recharge. The mitigation programme is focused on:

(i) Identification of drought affected regions, in order to establish an intervention programme.

(ii) Evaluation of dams, water reserves and fitting a management plan regarding the available water.

(iii) Encouragement of the cereal complementary irrigation, especially in the seed production areas.

(iv) Prevision of priority products importation.

(v) Supplying the farmers with the livestock nutrition with a strong control of the distribution network.

Scenario 3 – Dry spring

The spring precipitation has an influence essentially on cereal yields, arboriculture fields, olive trees particularly, rangelands and surface water resources. Several operations are undertaken against any undesirable effects:

(i) Enhancing of the cereal complementary irrigation, in order to ensure the identified minimum production.

(ii) Evaluation of the rangelands, in order to fill the gap related to the livestock nutrition deficiency.

(iii) Predicting the cereal production and establishing an importation programme in order to remedy the eventual shortage.

(iv) Stored water evaluation and demand identification. A water resources management process is consequently adopted.

Scenario 4 – Dry year

The year is considered dry when the precipitation deficit is beyond 50% of the mean historically established value. The probability of having a dry year is 7 to 23% in the North and between 25 to 30% in the Centre and the South. Such a situation results in a substantial shortage in the available water resources, a fall in production and range shortage, and some problems related to the domestic water supply appear in the drought sensitive regions. Livestock sickness could be observed, because of change and unbalanced nutrition regime. In order to attenuate those problems a mitigation programme is executed:

(i) For Livestock safeguard, the identification of the animal nutrition stocks is established and an importation plan is applied in order to make up for the deficiency.

(ii) Prevision of vaccination campaigning on the livestock against the sickness related to drought.

(iii) To satisfy the domestic water demand, in urban as well as in rural areas, a programme of aquifer use is adopted, the use of the surface water resources are avoided or minimized. Particular attention is given to water transportation to the rural drought sensitive regions.

(iv) Establishing dams' water management plans regarding the evolution of the climatic conditions. The possibility of a second dry year is taken especially into account.

(v) Intensification of the preparedness operations related to the following year (short loans, soil tillage, seeds distribution, etc.).

Scenario 5 – Second dry year

A successive second dry year occurs with a probability of 3% in the North and 10% in the Centre and the South. Although classified as generally infrequent, this situation involves problems and constraints on water management and agricultural production. It requires an intensive importation planning in order to adapt to the shortages. This situation has unfavourable effects on the natural ecosystems. The major problem is to attempt to balance competing interest in a charged atmosphere by establishing awareness among the farmers, especially the small ones. For all these reasons, the Tunisian Government anticipates those inevitable problems by adopting several mitigation operations to dealing with drought:

(i) Since during this period the water resources are at their minimum level, a careful water management programme is established in order to balance the different demands and the limited available water resources.

(ii) The aquifers exploitation is intensified in order to alleviate the demand on the surface water resources.

(iii) Intensifying the measures taken during the first year essentially for the drinking water, which has a priority in the Tunisian legislation (Water Code).

(iv) Promoting the irrigation of the cereal crops, and those having small water requirements.

(v) Encouraging of the reclaimed water use for the specified forage crops.

(vi) Contributing within the National Programme of Water Saving through growing public awareness on the drought event and sensitization to the water saving in all usages.

(vii) Importation of products for the livestock nutrition and distribution to the farmers with subsidized prices.

(viii) Intensification of the livestock husbandry programme.

(ix) Organization of the products distribution networks.

Subsequent drought

When drought is over, the principal measures taken are:

(i) Intensification of the extension programme related to the soil tillage and farming practices in order to maximize the valorization of the precipitation coming during the eventually subsequent wet year.

(ii) Establishing a scheme of delaying the credit payment, and facilitate the obtaining of post drought loans.

(iii) Programming the distribution of cereal and forage seeds.

(iv) Evaluation of the available water resources (dams and aquifers).

(v) Reconstitution of the aquifers water reserves by the artificial recharging.

(vi) Evaluation of the mitigation programme efficiency and estimation of their cost.

(vii) Updating the drought mitigation programmes with reference to the identified deficiency. Such evaluation is conducted on the different aspects: economic, commercial, social, hydraulic and agronomic. All organizations and institutions involved in the drought management are associated in the evaluation process.

(viii) Associate the research institutes and universities in the development of research programmes related to drought mitigation, referring to the lessons learned by the past drought periods.

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Annex 1. Data and information systems

The current water information system

Water resources in Tunisia, as described above, are classified as surface, groundwater and non conventional resources. Tunisia devoted a high attention to the Data Information System on Water Resources (quantity and quality), in order to satisfy equitably the different water demand. The natural resources sustainability and the socio-economic approach are maintained as a policy basis. There are several stakeholders water information data institutions, that have diversities of objectives uses, but they are complementary (Table 1). Since the Tunisian water system is complex, the water data system includes eight major components:

(i) Precipitation (rainfall).

(ii) Surface Water (hydrometric data, reservoirs data –dams, hill dams, lakes–, water transfer by network connection, etc.).

(iii) Aquifers (management and artificial discharge).

(iv) Non conventional water (desalinized and reclaimed used water).

(v) Water quality monitoring network.

(vi) Water demand, cost and pricing.

(vii) Soil sweetening and drainage.

(viii) Demography (population).

Table 1. Summary of the principal institutions and organizations involved in water and drought data collect and processing

Institution	Data	Type of Data	Frecuency	Transmission mode
DGBGTH	Dams Data	Location, Capacity, Year of creation, Silting & Life Duration	Monthly &Yearly	Report
	Basin Hydrologic and Dams data Management	Water quality and quantity in dams, Daily water harvested, Rainfall, Rainfall management, Dam control, Management of hydrometric and hydrologic measurements, Volume used	Daily	48 radio VHF, 39 mobile transceivers, 60 walkie-talkies, Phone modem, Fax, Telemetry system for rainfall and hydrometric data every 30 minutes
	Dams Simulation and Statistical Analysis	Transfer, Losses, Exploitation	Monthly & Yearly	Report
	Dams Management	Annual volume, Annual hydrologic situation, Water losses in dams, Water dams balance, Water demand	Yearly	Report
	Water exploitation	Dams balance, Hydrologic studies, Statistics studies, Water demand	Monthly	Report
	Flood Early Warning	Instantaneous hydrologic situation	Instantaneously	Phone modem, Fax, Radio
DGRE & BIRH	Rainfall	Observation and Measurement Weather Station	Daily Monthly Yearly	Phone modem, Fax, Radio, Satellite, Report

Table 1. Summary of the principal institutions and organizations involved in water and drought data collect and processing (continuation)

Institution	Data	Type of Data	Frecuency	Transmission mode
	Hydrometric	Basin data, Oued (River), discharge, Stations, Maps, Water quality	Instantaneously, Daily, Monthly and Yearly	Magnetic support
	Flooding	Discharge of flood, Initial and final date and hour, Runoff	Instantaneously	Magnetic support
	Aquifers Supervision	Shallow and deep aquifers quantitative and qualitative situations and exploitation	Continually supervision and yearly data compilation	Report
	Shallow aquifers	Artificial recharging	Yearly	Report
	Aquifers Water Supervision	Quality and Quality (BIRH)	Yearly	Report
DGACTA-IRD	Rainfall	Observation and measurement around hill lakes	Instantaneously	Telemetry, ARGOS System
	Water Reservoir Hydrologic Balance	Volume, Evaporation, Runoff, Overflow, Emptying	Yearly	Report
	Strong Rainfall Characteristics	Intensity, Volume, Qmax	Instantaneously	Telemetry, ARGOS System
	Overflowing Risk	Spillway Maximum Discharge, Instantaneous Maximum Discharge, Dyke Overflowing	Instantaneously	Telemetry, ARGOS System
	Water Quality	pH & Salinity	Half-yearly	Report
	Water Reservoir Silting & Life Duration	Creation date, Initial and final volumes, Estimation of life duration	Yearly	Report
	Hill Lakes Exploitation	Water quantities, Irrigated areas	Yearly	Report
DGGREE	GIC Associations	Number, Water resources, Water quality, volume and cost	Yearly	Report
	Public Irrigated Areas	Surface, Intensification rate, Water resources, Water quality, volume and cost	Yearly	Report
	Rural Domestic Water Prevision	Statistics data: Supply & Demand evolution	Yearly	Database using GIS, Report
INM	Rainfall	Quantity and Intensity	Daily, Weekly, Decadal, Monthly, Yearly	Bulletins, Report, Web site
	Weather Observations and Prediction	All Weather observations	Continually	Bulletins, Report, Web site
	Weather Observations	Meteorological, Astronomy and Geophysical data	Continually	Bulletins, Report, Web site (for various national economic sectors)
	Seismic recording	Recording and Location	Instantaneously	Fax, Magnetic Support, Report, Web Site
	Climate Data	All Weather Historical Observations Data Base	Continually updated	Storage and filling (Technical Documents, Magnetic Support)

Rainfall

The DGRE has an important precipitation stations network (1,157 stations). Moreover, DGRE has 67 pluviograph stations distributed in the different regions. The data analysis is realized by the PLUVIOM Software.

The INM, Institut National de la Météorologie (National Institute of Meteorology), is the main precipitation data network in Tunisia. The first rainfall station measurement dated from 1873, and actually the INM network allows the management of 234 stations, were 26 are synoptic (principal stations), 31 agro meteorological, 59 climatic and 208 merely pluviometric. The database facilitates use by means of periodically structured applications namely:

(i) Acquisition of recent data and feeding the database tables.

(ii) Control of data quality.

(iii) Interactive management allowing visualization and updating.

(iv) Data computing by means a computer programs.

(v) Storage and filing of all climatic data.

(vi) Information provision, regular editing and dispatching of climate tables and statistics and preparation and worldwide distribution of "CLIMAT" messages.

(vii) Use of methods that combine climate data and socio-economic and physical data to meet the requirements of planners and decision makers.

In other hand, weather forecasting consists on collecting, analyzing and interpreting the different observations products, direct measurements or from remote sensing sources, as well as the products of the models of numerical weather prediction. It proceeds 24 hours a day, 7 days per week, and weather forecasts are provided in the form of bulletins, directives, or files in various communication supports. Different economic sectors are interested in forecast bulletins and other INM output (aeronautical and marine services, agriculture, environment, industry, energy, and tourism) and also other fields like health, sports, recreation, and media. INM has its WEB site *(www.meteo.tn)* where weather general information is supplied; specific data could be obtained by subscribing.

The DGACTA/DGRE has a network of meteorological stations located at the 30 hydrologic stations, 4 installed by DGBGTH nearby the hill dams and supervised by DGRE and the remaining 26 are equipped with telemetry systems realized in collaboration with IRD.

The DGBGTH includes a station network localized on the dams' sites. Every day, at 7h 30 am the precipitation quantities are recorded with other data related to dam situation.

The CRDA has a network in each district (Governorate), where the DGRE has a precipitation measurement post, that is managed by A/RE (the regional department of DGRE).

Surface water

Three institutions form a hydrologic measurement network: DGRE, DGBGTH and DGACTA.

Data are collected by the Hydrometric Network and by the Flood Early Warning Network. The Hydrometric Network includes a hydrometric station in each basin. There are 52 principal stations. The oldest is in Medjerda Basin were data are available for 80 years, and the newest are located in the Centre and the South, which have been in place since 14 years ago. DGRE analyses the data by mean HYDROM Software.

The Flood Early Warning Network started in 1970. The DGRE network focuses on the short term prevision of flood by the principal oueds (rivers). The objectives are the hydraulic system protection and the population preservation. Information is communicated by phone modem, and/or by mean 26 radio systems. The DGRE system is enhanced by the DGBGTH Flood Early Warning Network witch is based on 48 radio VHF communication system, vehicle mobile 39 transceivers, and 60 walkie-talkies.

Groundwater: Management and artificial recharging

Shallow and deep aquifers data are insured by DGRE and CRDA (A/RE). Quantitative and qualitative data's are recorded and published in special technical issues (Annuaires). Hydro geologic information on the deep aquifers are well mastered and simulated by mean numerical models. Shallow aquifers data are target on the quantitative and qualitative information, were artificial recharging is monitored.

Non conventional water

Until 2002, there were 60 stations of water used purifying that could reclaiming about 150 M m^3/year, and they were managed by ONAS. The reclaimed water use is restricted for the municipal activities and for the irrigation of golf courses and some forage crops (listed by legislation texts). Data on the production and uses of reclaimed water are supplied by ONAS, CRDA, DGGREE and Touristy services.

Desalinized water is produced especially for regions (Gabès, Zarzis, and Djerba and Kerkennah islands) which suffler fresh water shortage. SONEDE is the institution that is in charge of by this operation as well as of supplying information on the production quantities and the demand evolution.

Water quality attending network

Water quality is followed up by DGRE-BIRH for the aquifers and surface water quality is supervised by two groups of operators. Firstly DGRE-BIRH, DGBGTH, DGACTA, INRGREF, SECANDENORD, SONEDE, CRDA, and ONAS could be listed. The second group, formed by the regional departments of Health Ministry and the ANPE institution, is responsible on the health effect of water quality with respect of the OMS norms. Several laboratories assure water analysis that are relevant to DGRE-BIRH, DGBGTH, SONEDE, DGACTA, CRDA, ONAS, CITET, INRGREF, Sciences Faculty, Pasteur Institute, and numerous private laboratories.

Water quality information and data related to aquifers resources and the surface water resources are disseminated by BIRH (institution linked to DGRE).

Water demand, cost and pricing

Domestic (as well as industrial and touristy) water demand is established by SONEDE, GIC (NGO), and CRDA Department of DGGREE. For the irrigation needs, the quantities required are identified by CRDAs and GIC organizations.

Soil sweetening and drainage

The soil drainage supervising network is insured by DGACTA, DGGREE and INRGREF by mean a target studies and permanent measurement. The Geographic Information System is associated in the database of the soil description and analysis. Soil sweetening and drainage data are regularly published by mean annual reports, specific studies and technical bulletins.

Population data

Demographic information is provided by INS (Institut National des Statistiques: Statistics National Institute) through periodical national census (every 10 years), which includes several informations on the population pyramid age, and the different economic activities (active people and their domain, school-attending, etc.).

Strengths and weakness of the current water information system

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

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