



NOSTRUM-DSS

Network on Governance, Science and Technology for Sustainable Water Resource



European Commission, FP6, Specific measures in support of international co-operation
Mediterranean Partner Countries (MPC), 2004-2007



NOSTRUM-DSS

NATIONAL REPORT

PART II

***EXPERIENCES OF DECISION MAKING PROCESSES FOR WATER
MANAGEMENT***

TUNISIA

GROUNDWATER MANAGEMENT OF A PROTECTED AREA - JEFFARA AQUIFER SOUTHERN TUNISIA

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1. Institutional profile and stakeholders' identification

1.1 Regulative and Legal Background in the field of Water Resources

Since the independence (1956), the Tunisian public administration plays a major role in all domains and notably in hydraulic domain. In Tunisia, the domain of water is a prerogative of the state. The “Code des Eaux”, promulgated in 1975, constitute the legislative basis text that governs all interventions in the water sector. The responsibility of the application of the laws on water, the scheduling, the realization of the big hydro-agricultural amenities, the development of management strategies is confided to the Ministry of agriculture, environment and Hydraulic Resources.

The different water management strategies adopted by Tunisia during its history evolved as follow :

Until years 1960, water resources in Tunisia were under-used distinctly due to the weak development of irrigated agriculture and to limited demand of the population. The problem of water management really arises since the end of years 1960, not in global resource terms but rather in terms of regional deficit.

From years 1970, Tunisia opted for a politics of big hydraulic works, aiming to supply cities and to develop irrigation. The objective was to mobilize the maximum of surface waters by the big dams, to transfer water toward deficit regions and to achieve a real interconnection at national level. In spite of the massive investments during these years, the aridity of the climate marked by a strong summery drought generates dramatic situations of hydric stress. Indeed, these climatic conditions conjugated to the administrative difficulties to control resources exploitation directly resulted in an intensive exploitation. The end of years 1980 marked a change of orientation in the Tunisian hydraulic politics. Of a first tendency characterized by a central place of the State and by an important investment in the infrastructure, the policy passed to a tendency centred on the management of users demand.

In 1990, a decennial strategy of water resource mobilization (1990-200) was setting up. The objective of this strategy is to satisfy the demand of the different sectors and foresees the growth of water resource exploitation. The aim was to optimise the management of existing water by avoiding situations of intensive exploitation and by having recourse to alternative resources (brackish water desalination, re-use of drainage waters, artificial recharge of aquifers,...), but also to control water demand.

To the middle of years 1990, in the setting of the application of the Agricultural Structural adjustment Plan elaborated in 1986, the State tried to decentralize some tasks. The old services being a matter for the central administration are transformed on autonomous public establishments. Thus, the distribution of water to farmers has been confided to regional institutions; the regional commissions of agricultural development (CRDA), responsible of public perimeters of irrigated agriculture.

The hold of decisions in the domain of water is defined in the “code des eaux” that consider water as Hydraulic Public Domain and as offered natural resource whose utilization must respect rules of rational management of the national natural heritage.

It has been completed by national « Agenda 21 » elaborated in 1995 that defines the following objectives for rational management and utilization rational and lasting of water resources of the country:

- Enhanced and integrated water resources management
- Assessment of water resources
- Protection of water resources, of water quality and aquatic ecosystems,;
- Supply drinking water and purification;
- Guaranteed of resource in sufficient quality and quantity, for the purpose of food lasting production,
- Adaptation to extreme situations, droughts, flooding and climatic changes.



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All strategies of water management in Tunisia are elaborated to the national ladder and remain a prerogative of the state. Stakeholder's contribution is only introduced at the level of the application of these strategies and is considered as a tool to improve the management of water demand.

Table 1 : List of Main National Laws related to the Water Sector

Reference	Focus	Content	Implementation Status
Article 1	Water rights	Define the hydraulic public domain (shores, lakes, waterfalls, rivers, dams, hydraulic structure used for public use...)	Implemented
Article 9-10	Water rights and abstraction	Emphasizes modality of groundwater abstraction : no authorisation is needed for drilling wells of depth less than 50 m, interdiction to catch water from artesian springs even on private land.	Implemented
Article 11	Sanctions	The execution without authorization of works aimed in the article 10, is penalized by the tenth of the evaluated cost of executed works. The works can be suspended either suspended or definitely stopped by M.A.	Implemented
Article 12, 15	Water quantity & quality	Protected zones or Interdiction perimeters can be created in areas where water qualities or water quantities are put in danger by existing resource exploitation	Implemented
Article 13, 17	Water allocation	In protected zones or interdiction perimeters, all hydraulic equipments are forbidden without MA authorization.	Implemented
Article 22	Water quantity	Water right gives to its owner the possibility of using an annual abstraction volume from any type of water resources.	Implemented
Article 24	Water quantity	Water right can be revisited according to global water resources, and to real demand and according to valorisation of water.	Implemented
Article 26	Water tariffs	Equipment costs are covered by the Government while equipments exploitation are covered by users.	Implemented
Article 28	Water allocation	Water rights must be revisited each year.	Implemented
Article 37	Water Quality	Wastewaters coming from urban use supplied by the institutional water manager can be routed by pipeline to collection and purification equipments under the same conditions and reserve that those concerning supplying of these waters.	Implemented
Article 57	Water quantity	The administration has the right to limit the debit, whose use is allowed either conceded, to the really necessary volume for the program of utilization adopted.	Implemented
Article 73	Water quantity	The minister of agriculture can proceed to the closing of water holds using a superior water quantity to the one authorized, and holds of water not authorized and without right.	Implemented
Article 81	Water quality	The administration takes procedures aiming to protect water destined to supplying upon activities that can compromise the quality of waters.	Implemented
Article 86	Water quantity & quality	The state manages endowments of necessary water to ensure quantity and quality of drinking water of the population.	Implemented
Article 87, 88		Indicate procedures to be taken in the case of water transfers between hydrographic basin.	Implemented
Article 89	Water quantity	Determine conditions to be imposed for the construction and maintains of public or private networks in order to avoid the wasting of water	Implemented



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Article 90	Water quantity	Indicate appropriated procedures followed by the administration in the case where the existing use of water leads to a wasting.	Implemented
Article 91	Sanctions	The administration can suspend the supplying of the irrigation water to warn wasting, the execution of the irrigation works, in case of wasting and in absence of demand made for the repair of works.	Implemented
Article 92	Water tariffs	Quantities of water for domestic use consummated beyond norms give place to a increasing progressive ratification.	Implemented
Article 94	Water allocation (Industrial use)	Industrial users of water must justify in their demand of facilities that the foreseen arrangements are those that permit to save in maximum the quality of water used, to preserve the quality of it and to limit to the maximum pollution.	Implemented
Article 95	Water allocation (Industrial use)	Industrial users of water must proceed for their needs to the retraining of water used, all times that this retraining is possible.	Implemented
Article 96		The administration can grant financial and technical helps for works having the tendency to reduce water wasting.	Implemented
Article 98	Water quality	Drinking water must satisfy to conditions and norms that are fixed by decree.	Implemented
Article 99		Indicate procedures that must be followed by collectivities or public and private establishment that can have their own system of water supplying.	Implemented
Article 100	Water quality	Indicate appropriated procedures followed by the Ministry of public health in case that distributed water characteristics defers some prescribed norms.	Implemented
Article 103	Water quality	Waters uses for agricultural ends must be done in conditions as features of soils and the ascent of the water plan in the perimeter remain compatible with an exploitation of the soil of the perimeter without irrigation.	Implemented
Articles 105, 106	Water quality	Waters used for irrigation mustn't constitute a source of illnesses. In any case water reuse, even treated, for the irrigation of garishness is forbidden.	Implemented
Articles 107 à 138	Water quality	Present some interdictions to fight against water pollution in order to satisfy to following requirement : drinking water supply, public health, human activities of general interest and conservation of water out-flow.	Implemented
Article 139	Sanctions	Presents necessary sanctions in case of infringements to the previous interdictions (articles 107 to 138)	Not implemented
Articles 140 à 152		Indicate suitable procedures to fight against flooding.	Implemented
Articles 158	Sanctions	All infraction to "Code des Eaux" are penalised by 50 to 1000 DT penalties and by an imprisonment of 6 to 9 months.	Not implemented

The application of laws edited on the "Code des Eaux" takes two global ways: direct measures of regulation of the water utilization, and indirect measures aiming the voluntary behaviors (financial incitation, programs of sensitization of the public...).

The sensitization of public is made through television spots showing water saving behavior and explaining water scarcity and importance in socio-economic development. However, the impacts of these spots are quite limited. So, even if water is recognized as a "precious" good which everyone has to save and protect, access to water is considered as a right and not as a privilege.



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The necessity to preserve the hydraulic resources, the increasing costs of production equipments and of water transport, the increase of drinking water supply for urban and rural populations of weak economic and social conditions and national strategy to promote irrigated agriculture, are elements that are basis of renewed interest for the tariff system utilization as privileged instrument of optimal management of the resource in water. However, the increasing price of water seems to reach a threshold beyond of which its impact on consumption is very weak. This is due to two facts :

For the first class of consumers (rural and urban domestic use), water remains a vital element that can't be replaced so, even if the cost of water increases, the total consumed quantities reach the lowest possible level. That's why the first step of consumption is supplied to domestic use with a cost under the real cost of water products.

For other uses, national strategies encourage all projects that can contribute to socio-economic development by increasing products or by creating employments. Important financial incitations are given to all types of projects, even if it is a great consumer or a great pollutant of water.

1.2 Stakeholders' identification

In Tunisia, the institutional framework for water management has three level :

- Decision making level : Prime ministry and concerned ministries, mainly ministry of agriculture, Environment and Hydraulic Resources and State Secretariat to Hydraulic Resources;
- Executive level : Governmental organizations under ministries;
- Users level : governmental organization concerned by water sector (maintenance as well as exploitation of projects).

Ministry of Agriculture, Environment and Hydraulic Resource (MAEHR) : This ministry manages water resources that belong to the State (code des eaux – law n°75-16 of 31 march 1975) that means, it manages the hydraulic public domain, it is responsible of the scheduling of studies, the follow-up and the hydraulic project assessment, the realization of dams and big hydro-agricultural amenities, and of water management in the big dams.

State Secretariat to Hydraulic Resources : It is in charged of the scheduling, the coordination and the supervision of activities for water development.

General direction of water resources : It is in charge of the management of measurement networks, the application of the legislation, and of the promotion of research and the experimentation.

General direction of dams : It is in charge of the survey and the construction of dams and of water transfer.

Direction of equipments and big hydraulic constructions : It is responsible of the resource scheduling, of the technical studies, of the working and of maintenance of dams.

General direction of rural engineering : It is in charge of dinking water supply in rural zones, of planning and management of irrigated perimeters and of the promotion of the AIC.

Regional Commissariat to Agricultural Development : They are charged of water resources prospecting, of regional irrigation and water drinking projects realization and management and they are responsible of direct management of big irrigated perimeters.

National Water committee : It has for mission to give opinions on the relative general questions to the planning and the scheduling of waters, on projects of planning and distribution of waters at national as well as regional level. Besides, it can be consulted on all question concerning conservation and protection of waters. It can make all necessary general investigations for the programming of domestic, industrial or agricultural water uses as well as for the protection against harmful effects of water (Article 19 of “ Code des Eaux”). It arbitrates conflicts of water uses.



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National office of purification (Office National d'Assainissement - ONAS) : It is a financially autonomous public organism. This organism is charged of the management and the exploitation of purification works. It has for mission the protection of hydric environment, the development and the realization of projects carrying on the treatment of used waters, pluvial waters and domestic garbage.

National society for the exploitation and the Distribution of Waters (SONEDE) : It has been created in 1968 (law of the 02/07/68). It's role drinking water supply for all the urban population and agglomerations of more than 2500 inhabitants.

Society of channel exploitation and adductions of the waters of the North (SECADENORD) : It is an autonomous public organism under the agriculture ministry. It is in charge of the exploitation of transfer infrastructures.

National Agency of the environment protection (ANPE) : It was created in 1988 (law N°88-91) and has the same statute that the ONAS. It has a double mission : On the one hand, analyse the state of the environment of the country and follow its evolution in order to fight against all sources of nuisance and deterioration of the natural habitat and the setting of citizen life. On the other hand, the ANPE has for mission to participate in the government's general politics concerning protection of the environment against pollution and to propose to concerned authorities procedures of implementation for national strategies on the subject.

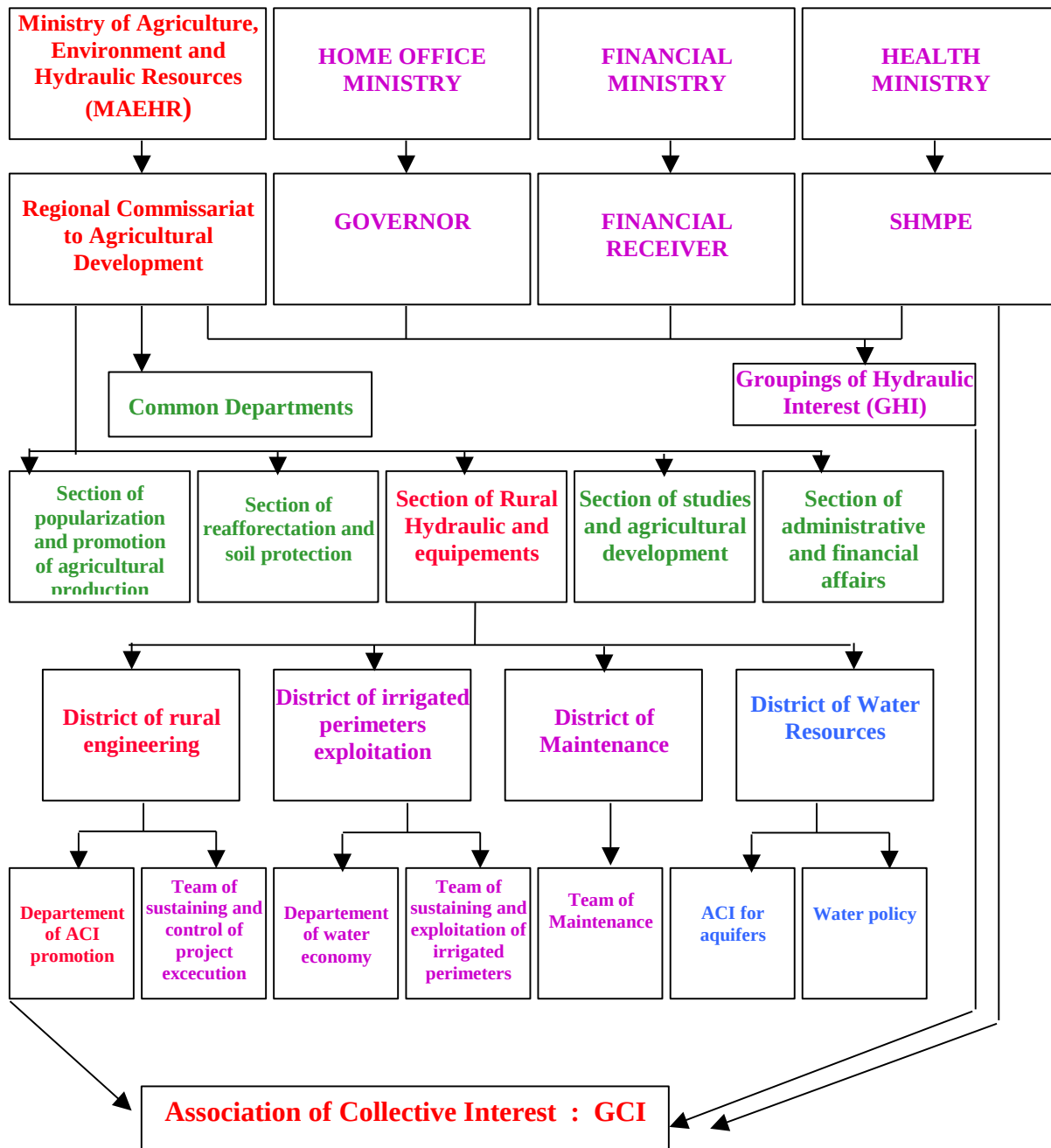
Associations of collective interest (AIC) (or grouping of development, new denomination) : They are situated at the third level of institutional framework of water management (users levels). They operate at the irrigated perimeters and at rural points of drinking water (public fountains). They are associations of users of these public infrastructures.



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An organisational Chart of the Institutions concerned by the Water Sector

The problematic of the case study presented is especially concerned by the place of ACI (Association of Collective Interest) in the application of the decision. Even if this association is not directly involved in the decision making because of the total control of the State on the decision making processes for all questions, the execution of the decision is highly dependent on the degree of conviction of the different members of the ACI.



2. DSS and water policy design and implementation

2.1 Country Experiences

Water management in Tunisia benefits a particular high authority attention, with objective to assure the everlastingness of resources. Since the independence, relative substantial strong investments have been planning for water management :

- Mobilization of resources by a follow-up and sustained scheduling notably of 1990 to 2000 [21 dams (740 Mm³)] with possibility of interconnection between some.
- Transfer of the water of the North toward the Center and the South (deficit).
- Rationalization of the water utilization (domestic use either agricultural use) by formation and information of administrators and consumers.

Completed by integrated management of used water, whose actions are sponsored by the ministries concerned by agriculture and environment.

Actually, one of the aims of water management strategy is to introduce new practices to the different intervening parties (administrators) and users (agricultural users, consumers of drinking water) in order to manage water demand as well as water resources.

If we can consider that the concept of DSS can be designated by other terms such as « expert systems », « multi-agents system » or simply « integrated management », then this concept is already known in Tunisia. However, even if it is extensively used industrial and socio-economic studies, the DSS concept remains of limited utilization in water management.

Dss-tools are always considered downstream the problematic, like a way to synthesize data and strategies. « Hydrosystem responses » to imposed constraints are studied according to technical issues independently from the related “socio-system”. However, some research projects are centered on the use DSS in water management. For the most, these projects for the most are achieved at regional and even local level. Very few projects can be extrapolated to the national level because results remain tightly related to specificities of the studied hydrosystem.

In the same way, these projects remained to the stadium of « research project » without being integrated in decisional strategies. This fact is due to the fact that decision-makers are rarely included as such in these projects but as technicians and supplier of data on waters.

2.2 DSS development

We give here, some examples, without that this list is exhaustive or same qualitative, of cases of survey concerning the introduction of the notion of decision support system in water management for various fields in Tunisia.

Example n°1 : Economy of water in Bizerte region (North Tunisia)

Among actions recorded in Tunisia, we can give the action led under the coordination of the “**Institut Méditerranéen de l’Eau**” (IME) in 1994-95 with the survey of Bizerte city case. This action allows to introduce a new approach in the economy of drinking water that, thereafter, has been generalized to all the “**SOciété Nationale d’Exploitation et de Distribution des Eaux**” (SONEDE). Main objective of this action was to introduce new practice of water uses for different intervening parties and users take. Some conclusions of this project are presented :

- Even if a rational management of water resource must take place, the national strategy allows to ensure the continuity of drinking water supply without no restriction during 3ans;
- The setting up of a politics of water economy



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- The improvement of the water quality.
- The sensitization, direct or by media, of users.
- The preservation, the improvement of the environment.

Recommendations of this Reflection-survey of Case will constitute a background to be generalized by the IME or by the direct contacts between partners or intervening parties in the domain. Results obtained through this experience are :

- To assure the continuity of drinking water supply without no restriction during 3ans;
- To defer investments.
- To duplicate the methodology of drain research and water economy through the country to all the SONEDE especially for drinking water;
- To assure the improvement and the constancy of water quality of water;
- To associate the different operators and consumers in the domain of water by showing that the sensitization and contact through meetings, studies with quantification to points limits can have a so very conducted beneficial effect when well financed and well organized.

Example n°2 : " Water management in Mediterranean "

This survey had for objective to contribute to the knowledge of water resources and their uses, and the introduction of decision support tools as legal and institutional tools for the scheduling and financings of strategies. This study was interested to the comparison of several studies achieved for several regions (**Alexandria - Bizerte - Algiers Ramallah, High Sebou, Rabat, Fès, Tanger**). This action, achieved by the l'Institut Méditerranéen de l'Eau, is integrated to the program MEDWAN-METAP II, it was ordered and financed by the World Bank. Several domain of intervention was studied of which drinking water supply, purification, irrigation and environment as well as integrated resources management in various sectors (urban, underprivileged urban districts, secondary centers and farming zones). This survey was particularly innovating in the process of communication between all partners concerned at different levels, notably in Tunisia and to Morocco.

Example n°3 : MERGUSIE Project

Since 1996, the project MERGUSIE, interests to the basin of Merguellil (1540 km²) to understand hydrological phenomena and to identify ways of improvement of water management. It is a French and Tunisian multidisciplinary program implying the IRD, the General Direction of Resources in Tunisian Water (DGRE), the Regional Police of Agricultural Development (CRDA) of Kairouan, the General Direction of the Tunisian Farming Genius (DGGR), the National institute of agronomy of Tunis (INAT) and the National school of Engineers of Tunis (ENIT). Many research have been achieved in the basin of Merguellil to try to understand water resources variations and to optimize its utilization. However, the analysis of interactions between water resources and water uses, although it is of fundamental importance to manage water demand at the level of the basin, still remain partial and concern only some limited parceled territories through the basin.

The principal aim of the second phase of MERGUSIE project is the construction of tools to support decision making for the management of hydraulic planning in the basin of Merguellil. The understanding of interactions between water resources and water, via their formalisation is therefore one of priorities of this research work. It must lead to the conceptualisation and the implementation of models achieving simulations in order to explore the evolution of the hydrosystem when submitted to different sources of variability, climatic or socio-economic and their impact on the valorisation of water.



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2.3 Decision Making

DSS are not even taken in account in policy issues on water management. No law or decree makes allusion to these tools. Decisions and strategies remain centralized at the level of the central legislative system represented by the ministry of agriculture, that if it makes call to some results of research projects on DSS implied in integrated water management, in fact not state explicitly in laws and other available legislative tools in this sector.

The use of DSS tools remains limited to the legislative aspect. The reactions of water actors is represented by their aptitude to execute the taken decisions but they are not included in the decision making process. In most cases, there is a refusal of the decision (presented case) and a conflict between decision-makers and users of water.

However, the Ministry of agriculture has created a institutional organism (ONAGRI) which main aim is to introduce DSS tools in agriculture sector. But the objectives of this organism are limited to economic efficiency of agriculture and water management is not considered in its presentation

The National observatory of agriculture (ONAGRI) is a public establishment with administrative character, a financial autonomy under the agriculture Ministry in Tunisia. Created by the decree n°308 of February 1, 1999, it is charged to accomplish the following missions:

- To make a strategic control system to support the decision: reliable information system that allows analyzing the situation of agriculture and fishing sector at national and international levels through indicators.
- To collect information and national and international data concerning the sector, to analyze them and to put them under textual or computer support.
- To distribute information and data collected and to put them to the different user disposition

The control system would cover national and international level. ONAGRI will contribute to the elaboration of decision support system through :

- Follow up and analyze of agricultural strategy at national and international level
- Follow up and analyze of commercial contracts
- Follow up and anticipation of potential international markets for Tunisian agricultural products

The strategy of this organism is based on following axes:

The « mise à niveau » of the sector and the improvement of its competitiveness in the context of the opening of the Tunisian economy on the foreign market and its integration in the world economy.

The food export development and the diversification of products exported as well as of markets.

The development of food security through the cover of needs by national production particularly for basis products.

The intensification of agriculture through a better adequacy of research activities and vulgarization to Tunisian agricultural realities and agricultural exploitation features.

3. Decision Making Processes in water management: a concrete example

3.1 Case study profile

Our case study concerns a zone of interdiction of groundwater exploitation. The “interdiction” decision is based on several studies showing that the intensive exploitation of the inshore aquifers of Jeffara risked causing, besides considerable resources decreases, an important deterioration of water quality by salinity increase and especially a serious marine intrusion.

3.1.1 Regional context

The gouvernorat of Gabès is situated on South Eastern Tunisia; it extends on 7166 km² and is constituted of 9 delegations (figure 1). Three (3) types of natural environment can be distinguished on this region:

- Zone of Matmata Mountains,
- Plain extending between western jebels and the sea at the east;
- The coastal region.



Localisation of the gouvernorat of Gabès



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Demographic data

- Population (people, 2000)	343.200
- Population density (people/km ²)	45,7
- Rate of urban population (%)	64,6
- Population growth rate (%)	1,5
- Number of family (1994)	56.431
- Active population (people of 15/59 years old)	85.800
- Effective active population	74.637
- Agriculture et fishing (%)	23,0
- Manufacturing industries (%)	41,5
- Services (%)	35,5

Main index of life level

Schooling rate of 6 to 14 years old children (%) 1994	98,02
Schooling rate of 15 to 19 years old children (%) 1994	60,13
Number of inhab./ Health center	3973
Number of inhab./doctor	1852
Number of bed/ 1000 inhab.	0,64
Rate of assisted childbirth (%)	90
Rate of global drinking water supply (%)	91
Rate of global electricity supply (%)	95,2
Rate of connecting to ONAS network (%)	64
Rate of phone line connecting	6,57
Number of inhab./ Mailing center	6.500
Number of house/family	1,1

3.1.2 Geographic context

Situated to the Southeast of Tunisia, the plain of Djeffara spreads since the region of Skhira to the North of Gabès until the Tripolitaine in the South, on a surface of about 10000 km². The whole of the Tunisian Djeffara Tunisian is subdivided in two zones that follow each other from the North to the South:

- Djeffara of Gabès, subdivided in : North Gabès, El Hamma, Chenchou, Oglet el Merteba and South Gabès and Zeuss Koutine.
- Djeffara of Médenine including regions of Médenine, Zarzis, Djerba and Ben Garden.

The Djeffara of Gabès, our case study, covers about 3000 km². It is situated between latitudes 37° N 10' S - 37° N 30' S and longitudes 8° E 10' S and 9° E 00' S and it is limited to the North and the Northwest by Jebel Zemlet El Beida, to the west by Jebels Roumana-Fatnassa, Tebaga, Hallouga, Ragouba and Recita and to the South by Jebel Matmata. The east limit is constituted by the Mediterranean Sea (Fig. 1).

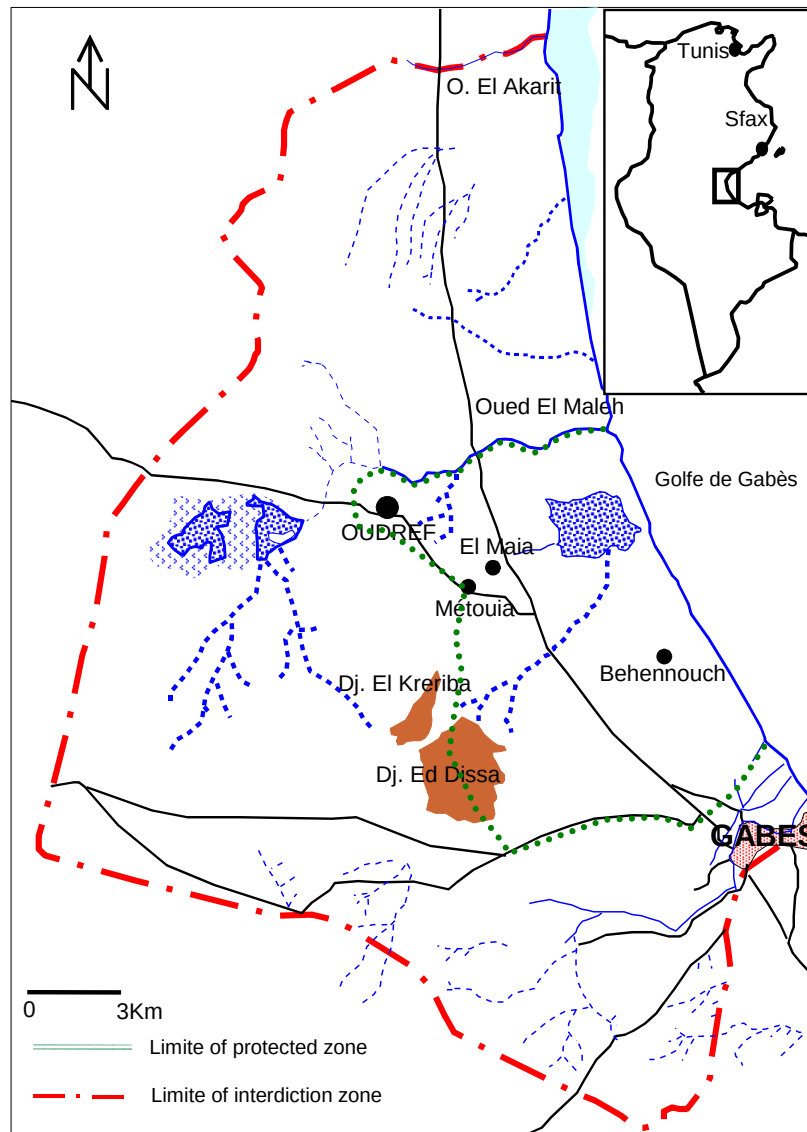


Fig. 1 : Localization map of the survey zone

3.1.3 Climatic context

a. Pluviometry

The evolution of the annual pluviometry of the meteorological station of the CRDA of Gabès during the period 1970-2001 is represented in the figure 2. This pluviometry varies between a maximum of 533 mm (1995-1996) and a minimum of 80 mm (2000-2001). The inter-annual average is about 205.1 mm. Broadly speaking, the zone of survey is characterized by two seasons, a rainy season going from September to April and a dry season that spreads of May to August.

b. Temperatures

The inter-annual temperature recorded at meteorological station of Gabès CRDA (1977-1999), vary between 8,3 and 27,9°C with an average of 18,2° C.

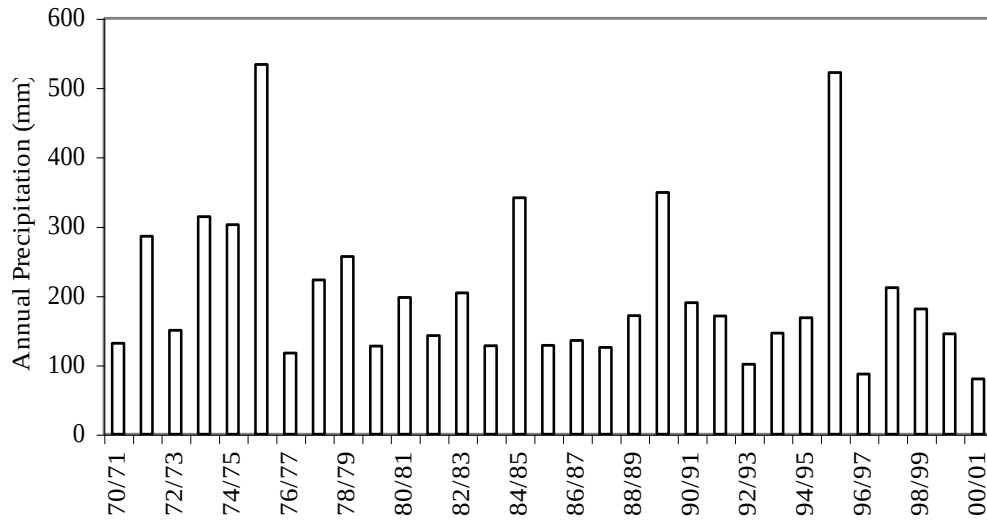


Fig. 2 : Annual Precipitations in the station of the Gabès CRDA (1970-2001)

c. Evaporation

During the period 1977-1999, the inter-annual evaporation is about 2078 mm. Monthly evaporation reached its maximum to the month of July (278mm) and its minimum to the month of December (90 mm). At seasonal level, the evaporation is more important in summer, with an average of 788.5 mm, whereas in winter the evaporation is to its minimum, with a mean of 286.6 mm.

3.1.4 Geological context

The plain of the Djeffara, is characterized by geological formation outcrop that spreads of the Jurassic until the Quaternary with a big hiatus of sedimentation of the Paléocène and the Eocène (Fig. 3).

Jurassic : represented by the Nara formation, outcrop at the level of Zeuss-Koutine region. The Nara formation is constituted on the top by the gritty limestones, to the center by alternations of clear chalky gray and charcoal gray with some rare past of clays and to the basis by the rudely crystalline gray dolomites. The thickness of this formation reaches 460 m and its depth varies 10 to 240 m.

Cretaceous :

Lower Cretaceous or Continental Intercalaire (CI) : The Continental Divider is a sedimentary episode represented by sands and sandstone between two marine sedimentary episodes. In the Sahara, it designates the continental stratigraphic interval between Upper Jurassic to the basis and Vraconien to the top. In the survey zone, the CI, represented by the Asfer formation, outcrops at the region situated between Mareth and Koutine. It is represented by gypsy sandstone with marly clay intercalations.

Albo-Aptien : This formation outcrops at Raggouba and Zemlet El Beida jebel. The Albo-Aptien serie, assigned to the Gafsa formation, is characterized by a big variation of lithologic facies and thickness. At the level of the Djeffara of Gabès, this formation is present under shape of marl alternations, marno-chalky with some intercalations of sandstone. The thickness of this formation varies 120 ms to about 400 m.

Upper Cretaceous

- *The Cénomanién* : the Cénomanién outcrops at the level of the Ragouba and Hallouga jebels. It includes three different entities and its thickness remains around 400 m. The first entity consists in an alternation of chalky dolomite with few fossils and of chalky sandstone to marly intercalations. The second entity is constituted in the lower half by a very massive layer of gypsum. The superior half is an alternation of gypsum, clay and chalky clay. The third entity is constituted of benches massive dolomite in limestones sometimes fossilized.

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- *The Turonien* : It outcrops at the Hallouga and Ragouba jebels and is everywhere dolomites to chalky dolomites. The formation thickness varies from 90 m to 115 m.

- *The Sénonien* : In the region of Gabès, the Senonian recognized by outcrop either by boreholes, is subdivided in two members. A lower member of gypsy clay corresponding to the Coniacien-Santonien (Aleg formation) and a superior member that groups the Companien and the Maastrichtien, represented by an essentially carbonated formation (Abiod formation). The lower member, known as lagunar Sénonien, outcrops at the Matmata jebel on a thickness of 250 m. In depth, this thickness can reach 500 m in the region of Arram and Kettana and between 200 and 400 m in the region of Gabès Nord and El Hamma-Chenchou. The lagunar Sénonien is met to a depth between 50 et 600 m directly under the plio-quaternary cover. The upper member represents the carbonated Sénonien, it outcrops to the Matmata jebel with a thickness varying from 15 to 250 m. In depth, this thickness reaches 400 m. The passage from the upper Cretaceous Superior to the Paléocène is marked by a big hiatus of Paléocène, Eocène and Oligocène deposits.

Mio-Pliocene : Called as Zarzis formation, covering all the plain of the Djeffara, is dissonant on lands underlying Cretaceous Superior. Its thickness varies between 20 and 270 m. The continental series of the Mio-Pliocene are divided in two entities:

At the bottom: A sandy entity of 40 meters thickness resting directly, either on the carbonated or lagunaire senonian;

At the top : A marly gypsum entity that constitutes the impervious roof of the sandy aquifer.

Quaternary : Represented by the Djeffara formation, the Quaternary is characterized by a composed detrital sedimentation of an alternation of sands, clays, stones and wind deposits of loess types, with often of chalky crusts.

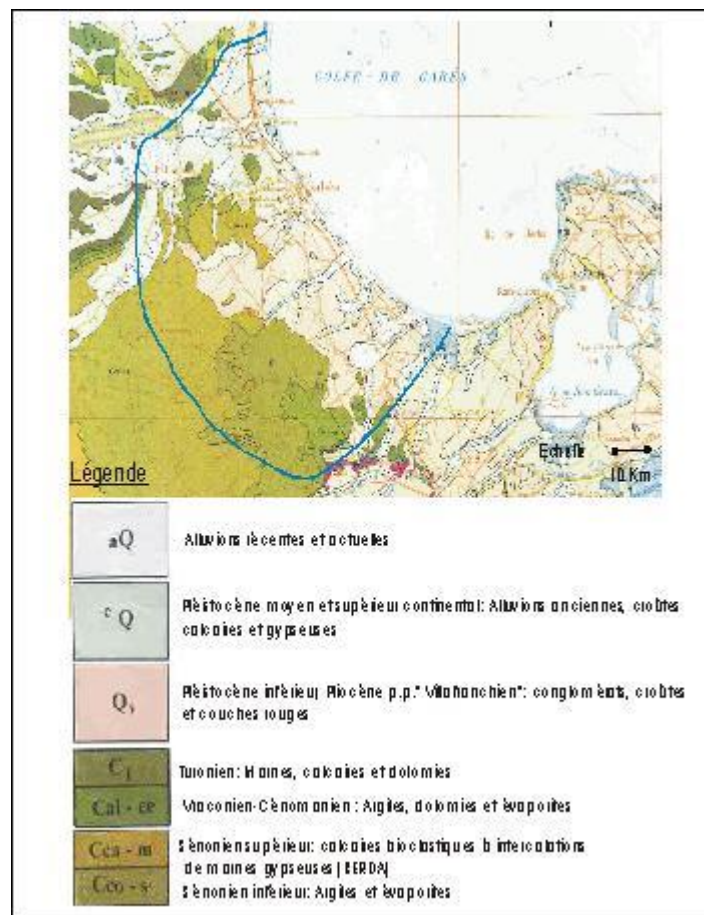


Fig. 3 : Geological map



3.1.5 Hydrogeology

a. Aquifers definition

The whole reservoir of the Djefara of Gabès is constituted of two main aquifers well distinguished :

- Continental miocène sands that constitute the main aquifer Gabès-north,
- Jurassic and cretaceous limestones that constitute the main aquifer of Gabès-south,

Miocene Sandy Aquifer : The sandy reservoir of the Djefara of Gabès is lodged in formations of Pontien age. This aquifer spreads between Gabès and Skhira (south to north). In this zone, the post-cretaceous erosion extensively encouraged the overhaul of sandstone of Drâa Oudref to give thereafter pontien sands whose thickness increases from 25 to 80 m in the sense of the sea. These sands that reach their maximum of thickness in Rhannouch and Oued Melah, are characterized by a fine granulometry and a permeability going from $2 \cdot 10^{-5}$ to $4 \cdot 10^{-4}$ m/s. As adopting a mean thickness of 50 m, the corresponding transmissivity values would be from $1 \cdot 10^{-3}$ to $2 \cdot 10^{-2}$ m²/s. The specific outflow of this aquifer varies between 0,16 and 7,9 l/s/m and its storage coefficient is $0,3 \cdot 10^{-6}$.

Carbonated Aquifer : is lodged on upper Jurassic, Turonien and Sénonien formation.

- Upper Jurassic : of least importance, it is lodged in chalky dolomites and characterize the uphill part of Mereth and Zeuss-Koutine region. The mean thickness of this aquifer is 100 m; its transmissivity is very heterogeneous and varies from $0,2 \cdot 10^{-3}$ to $300 \cdot 10^{-3}$ m²/s.
- Turonien : This aquifer of little importance is lodged in chalky and fissured dolomites whose thickness doesn't reach 50 m. It is captured by a limited number of borehole in Matmata, El Hamma, Chenchou and Oglet Mertebe regions. The transmissivity, meanly about $100 \cdot 10^{-3}$ m²/s, can reach $1200 \cdot 10^{-3}$ m²/s unusually at Chenchou where the tectonic fault is especially raised. The specific outflow of this aquifer varies 0,5 to 72 l/s/m and its storage coefficient is $2,1 \cdot 10^{-4}$ at El Hamma and $10 \cdot 10^{-6}$ at Chenchou.
- Lower Sénonien (Lagunar Sénonien) : In the region situated between Mareth and Koutine, the aquifer of the Lower Sénonien is formed by gypsy clays. This level of 50 m thickness is surmounted of a chalky unit that constitutes the main aquifer of the Djefara of Gabès. This aquifer, characterized by a variable thickness reaching 500 m, is greatly fractured. It is exploited by a big number of boreholes and support the main springs of the region. Transmissivity values vary between $0,9 \cdot 10^{-3}$ to $345 \cdot 10^{-3}$ m²/s. Its specific outflow is 0,6 to 3 l/s/ms and its storage coefficient is about $37 \cdot 10^{-6}$.
- Upper Sénonien (Carbonated Sénonien) : This chalky formation has a limited role in the hydrodynamic functions of the the Djefara of Gabès aquifer. It extend to Zarzis-Ben Garden region making part of the Djefara of Médenine. The transmissivity of this aquifer is $40 \cdot 10^{-3}$ m²/s, its specific outflow is 0,2 to 92 l/s/m and its storage coefficient is $30 \cdot 10^{-6}$.

b. Hydrogeological Relays of the aquifer of Djefara

The role of the tectonics in the structure of the Djefara of Gabès aquifer is very important due the creation of hydrogeological relays between the detrital formations and limestone (Fig. 4).

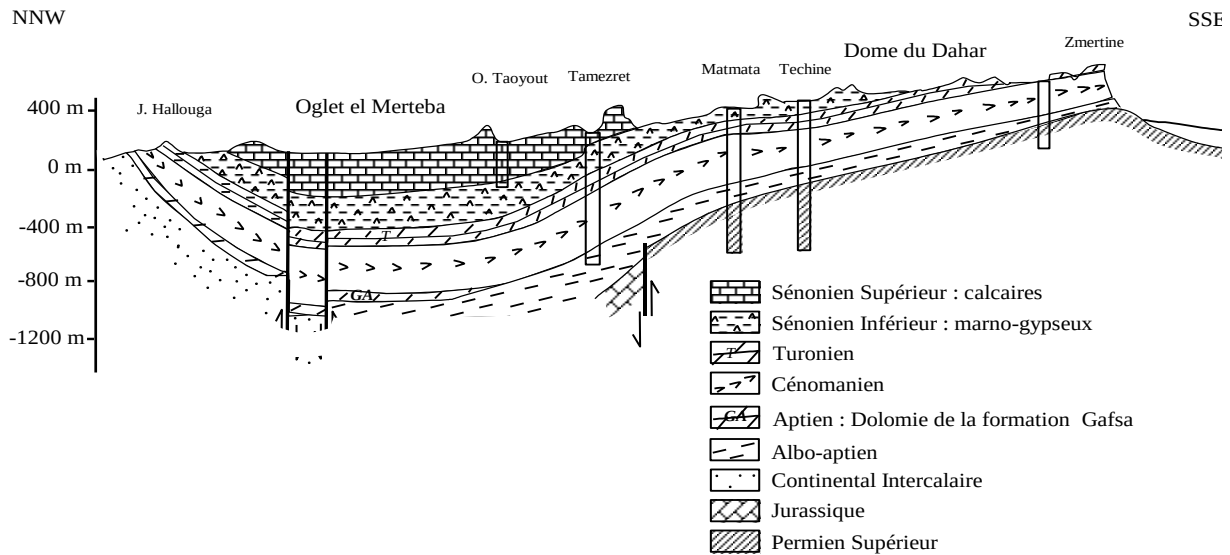


Fig. 4: Section along the aquifer system of the Djefara of Gabès

c. Piezometry of the Djefara of Gabès aquifer

Piezometric map (1988) of Djefara aquifer shows a general SO-NE outflow SO-NE in the direction of the sea, in accordance with the structures collapsed of the inshore plain (Fig. 5). In the region of Gabès-north, the recharge of the Djefara takes place from the aquifer of El Hamma-Chenchou and in the region of Gabès-south. This recharge takes place from the northern and oriental extremities of the Dahar. The region of El Hamma-Chenchou is not an actual recharge zone since it doesn't represent an actual aquifer formation outcrop. On the other hand, the northern and oriental extremities of the Dahar where outcrop Jurassic, Turonien and Senonien limestones, constitute the area of several oueds outcome and therefore the zone of present recharge of the inshore aquifer. The outflow takes place from the chain of the Matmatases toward the inshore zone following a relatively weak piezometric gradient (of about 2,5%), characteristic of a captive aquifer. The constriction of piezometric lines is bound closely to the tracing of the Médenine fault and the stake in charge of the aquifer. In the sector of Zeuss-Koutine, Jurassic limestones supplied by superficial infiltration supply Lower Cretaceous limestones. So piezometry of the aquifer of the Djefara of Gabès shows that the runoff on the oriental Dahar contributes to the recharge of this aquifer in the zone extending from Oglet Marteba until the plain of El Ouara (west to East). This recharge is important by infiltration of runoff when the aquifer is near soil surface or by linkage with another aquifer formation that receives its recharge directly from surface waters. The aquifer recharge of the Djefara of Gabès from surface waters is put in evidence by the high piezometric altitude in the region of Zeuss-Koutine. In this zone, the aquifer reservoir is formed by the chalky Apto-Cenomanien and Jurassic formations.

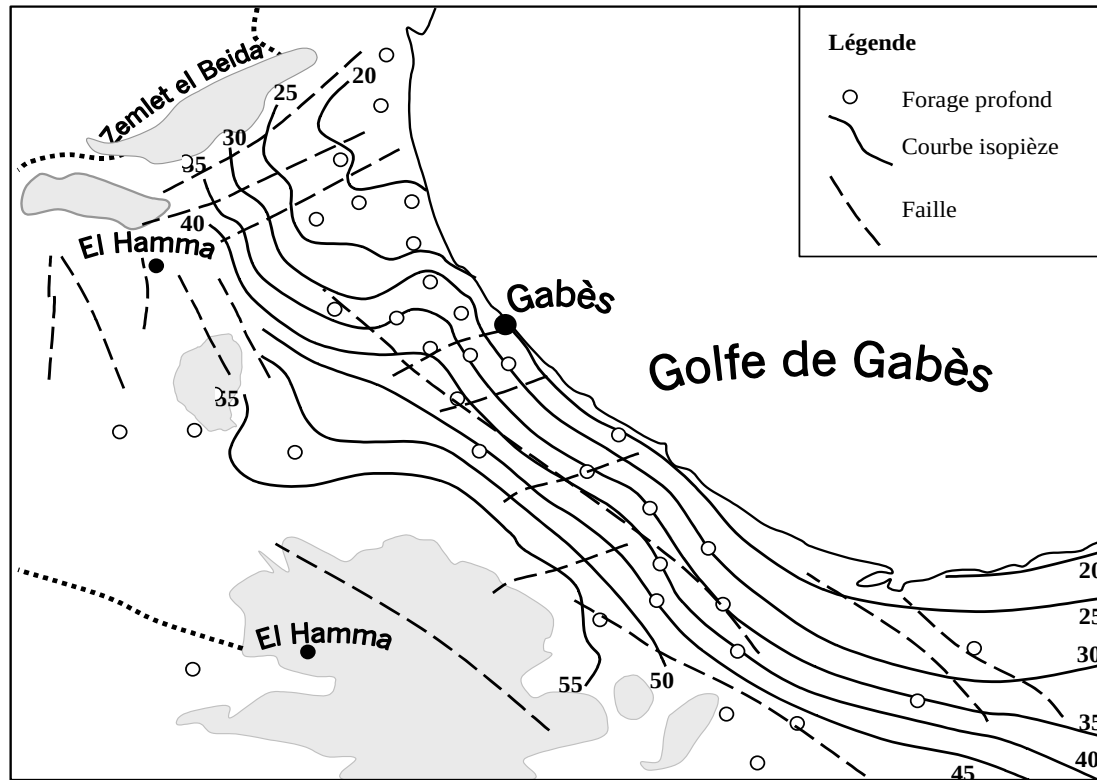


Fig. 5 : Piezometric map of Djefara aquifer

d. Exploitation of the Djefara aquifer of Gabès

Water resources of the Djefara aquifers are essentially destined for the irrigation. This need, sense quits crescent, provoked a considerable increase of the exploitation. Thus, the total number of boreholes increases from 129 in 1970 to 347 in 2001 whereas the number of exploited boreholes increases from 83 in 1970 to 124 in 2001. This difference between the total number of boreholes and exploited ones is related to the decrease of artesian boreholes and springs. Indeed, artesian outflow decreases from 1568,4 l/s in 1974 to 939,5 l/s in 2001, whereas spring outflow decreases from 810,5 l/s in 1974 to 14.8 l/s in 2001. However, the pumped outflow increases debit from 290.5 l/s in 1974 to 2328,4 l/s in 2001.

During the last century, the Djefara of Gabès aquifer was submitted by three phases of exploitation (Fig. 6) :

- Phase I (1903-1950) : The exploitation mainly made by springs, sources, was weak about 45 Mm³/an to 55 Mm³/an.
- Phase II (1950-1970) : The exploitation increased following the implantation of several boreholes, it varies between 60 Mm³/an and 80 Mm³/an.
- Phase III (1970-2003) : the exploitation is greater than the aquifer resources and reached no renewable resources, it varies between 80 and 100 Mm³/an.

Currently the total exploitation is reaching to 103 Mm³/an. Between 1903 and 1972, the exploitation of the aquifer of Djefara of Gabès was largely made in the region of Gabès-north. This exploitation that reached its maximum of about 60 Mm³, in 1972, began to regress from 1973 to reach 28 Mm³ in 1998, and then increased again until 39 Mm³ in 2002. In the region of Gabès-south, the exploitation of the Djefara, was very weak in the beginning of the century but increases continually to reach 40 Mm³ in 2002. For the aquifer of El Hamma-Chenchou, the exploitation is nearly constant since the beginning of the century; it is of about 18 Mm³ in 2002.

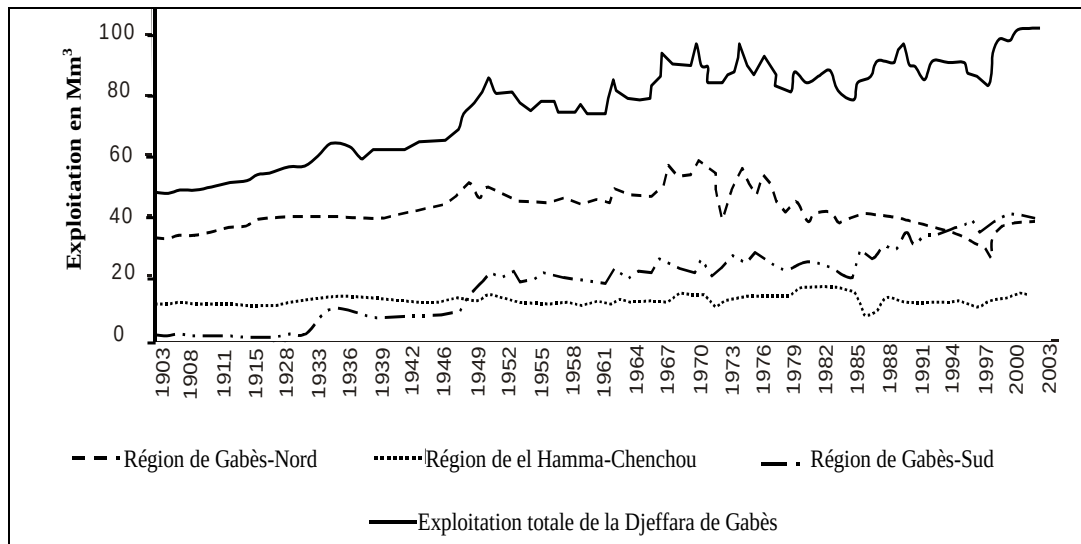


Fig. 6 : Exploitation of the Djefara of Gabès aquifer (CRDA of Gabès – 2003)

3.1.6 Hydrochemistry

The aquifer of the Djefara of Gabès is characterized by the presence of several levels lodged in different lithological and geological formations. Groundwater geochemical characterization is based on the measure of the physical and chemical parameters and major elements concentrations of the 39 samples sampled during May 2004 from boreholes distributed on the almost-totality of the survey zone. (Fig. 7). This study aims to determine the chemical type of waters and to deduct the origin of their mineralisation.

a. Physical and chemical parameters (in situ measurements)

Water Temperatures : are very variable. In the region of El Hamma-Chenchou, it is ranging between 26,7 and 41,6°C. At the level of Gabès-north, it varies between 22°C and 31,9°C. The most elevated values of water temperature are recorded in the region of Ghannouche whereas the lesser values are surrounding Oudref-Méthouia. These two distinct zones indicate the existence of two recharge zones one of hot water contribution coming from the underlying aquifer of Continental Intercalaire through tectonics structures, the other of cold water contribution coming from the meteoric water infiltration on the sandy outcrops of the Mio-Pliocene. At the level of Gabès-south, the temperature varies between a minimum of 24°C and a maximum of 35,5°C.

pH : pH values of the aquifer of the Djefara of Gabès are homogeneous. They vary between 6,8 and 8,3. In general, groundwater of Gabès-north present a more elevated pH that the waters of the aquifer of El Hamma-Chenchou and of Gabès-south.

Conductivity : Conductivity values of groundwater of the Djefara of Gabès vary between 2600 and 8300 $\mu\text{S}/\text{cm}$. Broadly speaking, the aquifer of Djefara of Gabès-north and El Hamma-Chenchou presents a more important conductivity that the aquifer of south Gabès.

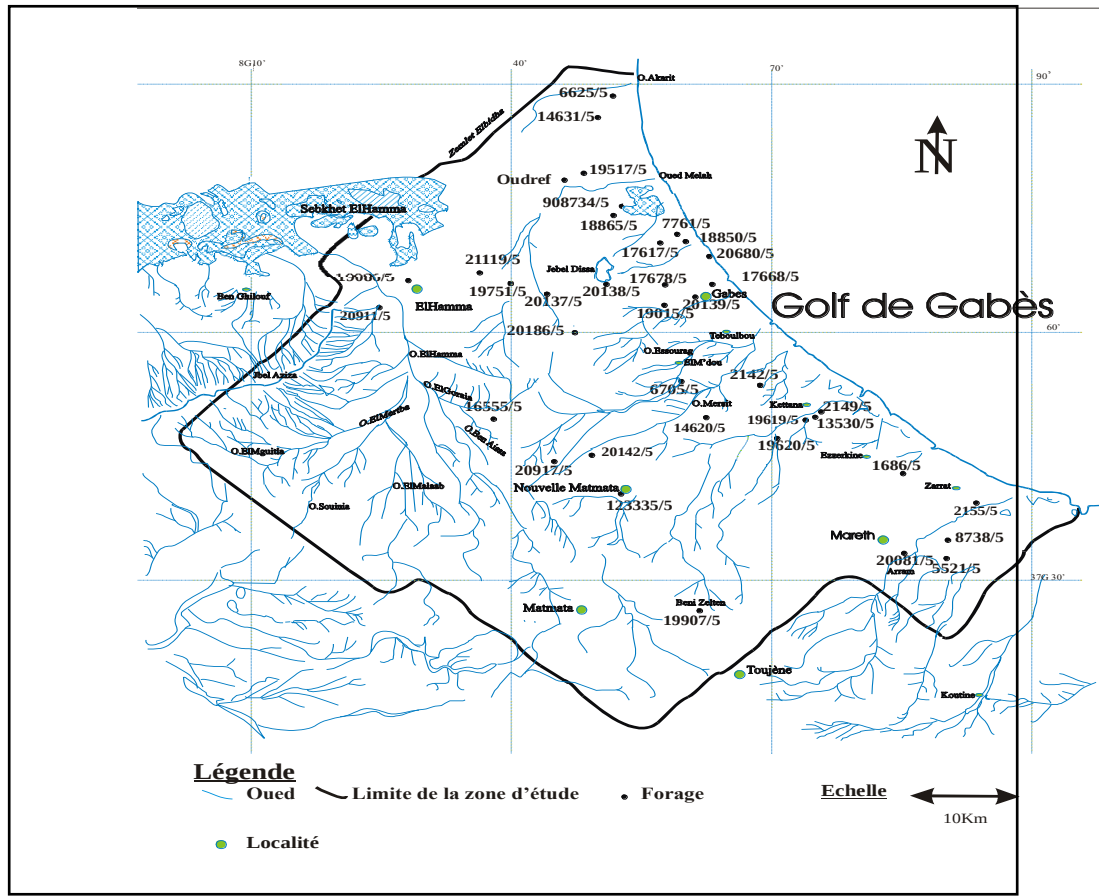


Fig. 7 : Localisation of sampled waters for the Djefara of Gabès aquifer

b. Spatial distribution of total mineralisation

Total mineralisation of Djefara of Gabès groundwater widely varies according to the captured aquifer level, the localization of boreholes and their depths of catchments. The distribution map of the salinity (2003) has been raised thanks to a data base of forty sampled points of water (Fig. 8). In 2003, we notice the apparition of the 5 and 5.5 g/l values at the level of el Hamma-Chenchou. So El Hamma-Chenchou groundwater are recharged by waters coming from Sabkhet El Hamma and Sabkhet Fedjadj whose salinities are greater than 4 g/l. The 3 g/l values are observed on the central part of the Djefara of Gabès. At the level of Matmata appear some values about 3.5 g/l. The borehole “Oued Akarit 2” shows that the transition zone between the Djefara of Gabès aquifer and the Skhira aquifer is characterized by very salted waters which salinity reaches 6,5 g/l.

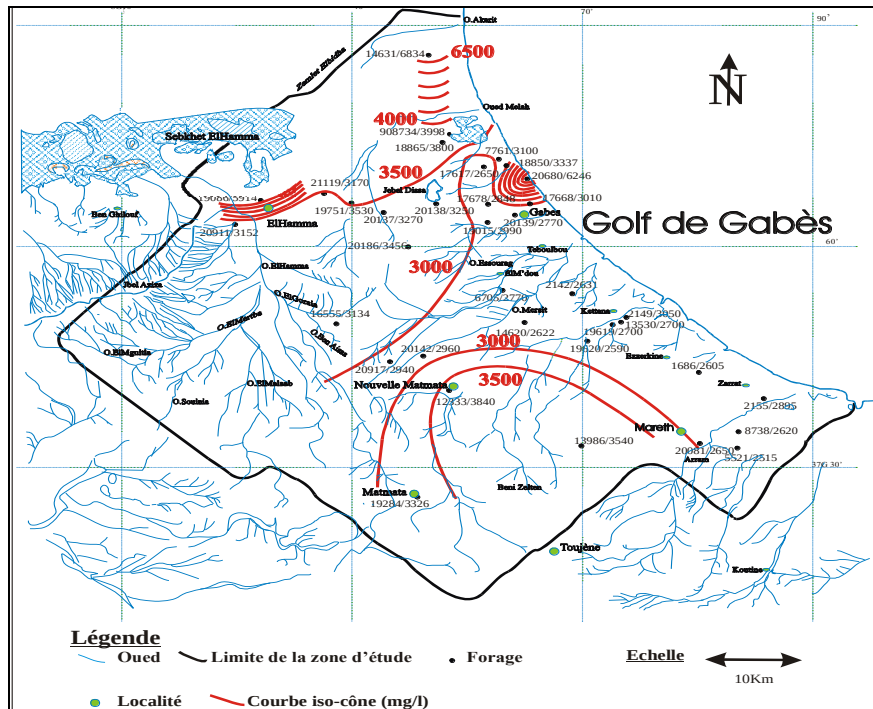


Fig. 8 : Salinity map of the Djefara of Gabès aquifer - 2003

During these last thirty years, there was an increase of the total mineralisation of the aquifer of the Djefara of Gabès following the intensive exploitation of reserves making call to the saltier waters

3.1.7 Geochemical Characteristics of groundwater

a. Groundwater Chemical facies : Piper diagram

Aquifer of Gabès-north : The Piper diagram shows the distribution of majors elements concentrations of groundwater of the Djefara of Gabès-north (Fig. 9). In the triangle of anions, waters show a dominance of sulfates and chlorides on bicarbonates. Sulfates contents present a variable percentage between a minimum of 38% and a maximum of 65%. Chlorides contents present a variable percentage between 35% and 62%. In the diagram of cations, we can notice a dominance of the sodium and the calcium. Boreholes that capture sands of the Miocène present two groups of waters:

- a first group localized to the North and characterized by chloride to sulfated sodic to calcic facies,
- a second group localized in South and characterized by sulfated to chlorided calcic to sodic facies.

El Hamma-Chenchou Aquifer : Two types of waters can be distinguished (Fig. 10) :

- Chlorided to sulfated sodic and calcic waters characterizing boreholes that capture miocène sands, at the level of El Hamma region
- Sulfated to chlorided calcic and sodic waters characterizing the region of Chenchou.

Gabès-south Aquifer : The almost-totality of boreholes of Gabès-south region capturing Turonien and Lower Sénonien (lagunar), show a dominance of sulfates on chlorides. Two groups of water are distinguished (Fig. 11) :

- the first group : sulfated to chlorided sodic and calcic waters
- the second group : sulfated calcic to chlorided sodic waters

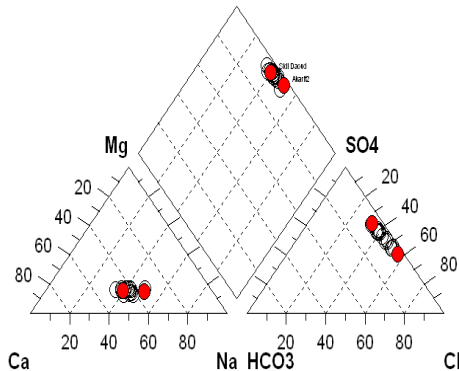


Fig. 9: Piper diagram of Gabès-north aquifer - 2003

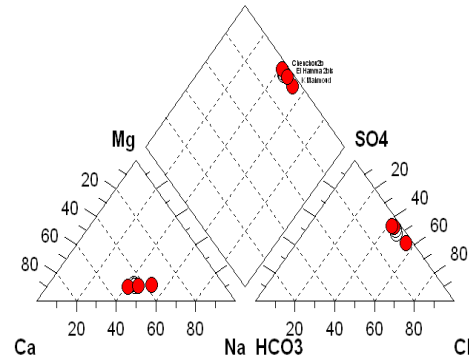


Fig. 10: Piper diagram of El Hamma-Chenchou aquifer

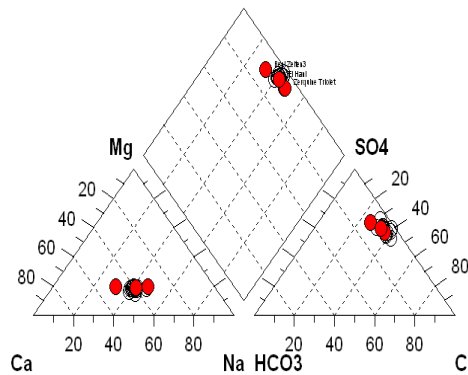


Fig. 11 : Piper diagram of the Gabès-Sud aquifer

b. Spatial repartition of water chemical facies

The map of spatial distribution of chemical facies of groundwater from the aquifer of the Djeffara of Gabès shows that three main types distribute as follows (Fig. 12) :

- chlorided to sulfated sodic or calcic type is localized essentially in Northeast and Southeasterly coasts,
- sulfated to chlorided calcic or sodic type on the Northeast coasts,
- sulfated to chlorided sodic or calcic type at central part of coasts and to the west of the survey zone.

c. Water mineralisation mechanisms

Saturation to carbonates: The almost-totality of the waters of the Djeffara of Gabès presents a saturation according to carbonated minerals (calcite, dolomite, aragonite and magnesite), exception for some boreholes of the aquifer of Gabès-north and of El Hamma-Chenchou that is slightly under-saturated on magnesite.

Saturation to evaporitic minerals: For the whole of the Djeffara of Gabès, boreholes show under saturation according to the anhydrite of gypsum and the halite. Broadly speaking, the waters of the region of Gabès-south present a more important under-saturation according to evaporitic minerals than that of Gabès-north and of El Hamma-Chenchou.

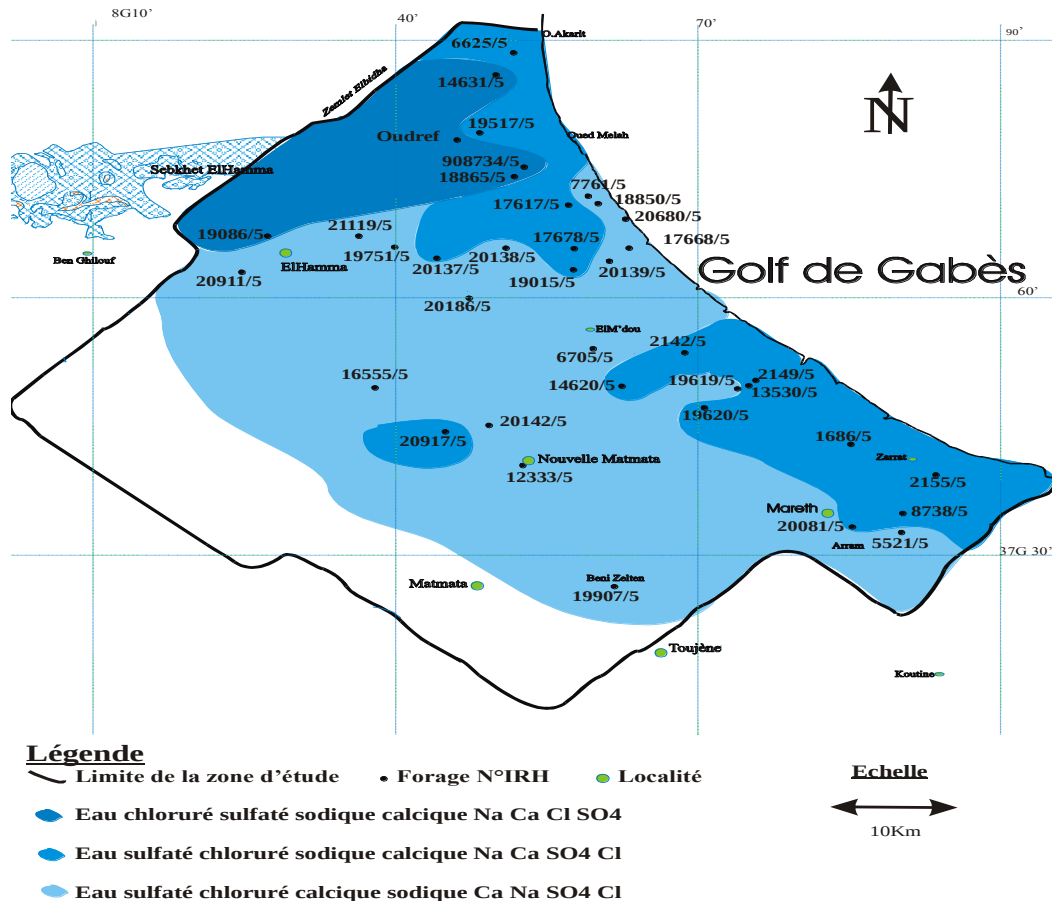


Fig. 12: Spatial distribution of chemical types of groundwater - Djefara of Gabès (2003)

3.1.8 Socio-economic issues

The region of Gabès knew a growth of the inhabitants from 240 160 in 1984 to 317 130 in 1994, what corresponds to a rate of growth of 2,6% during the decade (1980-1990). This increase dragged the growth of the number of families from 41 911 in 1984 to 56 431 in 1994, and of the number of lodgings, that passed of 43 521 in 1984 to 63 020 in 1994. The growth of the population is largely due to the creation of new irrigated perimeters following the setting up of the several deep boreholes, what allowed development of agricultural, tourist and industrial sectors.

Our case study concerns a zone of interdiction of groundwater exploitation. The “interdiction” decision is based on several studies showing that the intensive exploitation of the inshore aquifers of Jeffara risked causing, besides considerable resources decreases, an important deterioration of water quality by salinity increase and especially a serious marine intrusion.

We choose to present socio-economic index as used by ONU to characterize our survey zone

a. Water in the Djefara basin

Indicatory of state and constraint of resource exploitation of water : Three indicatory are chosen to reveal the natural constraints that can oppose to the exploitation of water resource:



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- **Indication of independence:** This indication measures the degree of resource autonomy. It expresses the degree of independence of the country (Mediterranean site) for its water supply upon upstream countries. It is defined as

$$(Q_g/Q_t) \times 100$$

Q_g: mean annual internal global out-flow Million of m³

- Q_g = Total Resource – Debit of the Continental Intercalaire aquifer
- Debit of Continental Intercalaire = 47,304 Mm³/y. (CHARFI, 2004)
- Total Resource (Q_t) = 115,2 Mm³/y (ABIDI, 1999)
- Q_g = 67,896 Mm³/y

Q_t: mean total annual out-flow Million of m³

Q_t = 115,2 Mm³/y (ABIDI, 1999)

$$\text{Independence Index} = 58,94 \%$$

- **Indication of action liberty :** This indicator gives a preview of resources of which a country can arrange without affecting the provision of countries situated downstream. For the aquifer of the Djefara of Gabès, there is no out-flow toward others basins. However, this aquifer presents discharge toward the sea estimated to 58,18 Mm³/y (CHARFI, 2004).

$$(Q_s/Q_t) \times 100$$

Q_s: mean annual out-flow to other countries Million of m³

Q_s = Q_t – Q_{sea} = 57,02 Mm³/an

$$\text{Index of action liberty} = 49,49 \%$$

- **Indications about global water quality :** They indicate the evolution of the water quality by the follow-up of the hydrochemistry on some sampling points from surface water and groundwater. They permit to highlight critical overtaking by essentially referring to a conventional classification grid for the biologic variables (DCO, OBO) or chemical (Salinity, NO₃) whose evolution can have consequences on the man.

- 1973 : 2,5 g/l < R_s < 4 g/l (CHARFI, 2004)

-2003 : 2,5 g/l < R_s < 6,8 g/l (CHARFI, 2004)

0 < NO₃ < 23 g/l (CHARFI, 2004)

We notice that the higher values of salinity increase and reach 7 g/l.

Indicators of exploitation and competition for the population : These indicators present analysis on water sampled for a specified period (1995-2000). Based on the demographic factor, they permit to discover the evolution of availability for the water consumption. These five indicators allow quantifying the relation water-man while taking account of the various economic and social issues of the studied site.

- **Index of groundwater and surface water abstraction:** Annual volume of groundwater however surface water abstracted for all uses (including loss during the transport), in percentage of the mean annual available volume of water.

- Available resource = 50,5 Mm³/y. (ABIDI, 1999)

- Annual exploitation = 47,67 Mm³/an (Annuaire d'exploitation 2001)

$$\text{Index of groundwater and surface water abstraction} = 94,4 \%$$

- **Index of resources per capita (Gabès):** This indicator is highly dependant on variations of population; it expresses wealth or the relative poverty of a country in water. It is very meaningful when it is linked to the concept of vital minimum of water resource per capita: poverty line or deficit. This concept corresponds to a norm of water need per capita as the conventional limit of 500 m³/capita.

$$Q / H : \text{m}^3/\text{capita}$$



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H : population of the survey zone for a given date.

H = 343200 inhabitant (*INS, 2000*)

Q : Global resource of deep aquifers of Gabès en Mm³/y.

Q = 184,4 Mm³/y (*Annuaire d'exploitation 2001*)

Index of resource per capita = 537,3 m³/y/capita.

- **Water demand per capita:** This indication is instructive to rudely measure the variety of demands in water in a regional whole. Demands in water vary per capita in a very extended range (of less 50 to more than 2000 m³ / year) whose world average is 600 m³ / year per capita with 50 m³/j or 135 l/j of drinking water.

A/H: m³/capita/y

A : Total annual demand m³/y.

- A = 127 Mm³/an (*Annual Demand for the gouvernorat of Gabès : Annuaire d'exploitation 2001*)

H : population for the same zone and the same date

- H = 343200 habitant (*INS, 2000*)

Water Demand per capita = 370 m³/y/capita.

- **Index of sectorial distribution of water demands (2001):** This indicator is composed of several sectorial indications corresponding to the four big sectors of water uses (collectivity, agriculture, industry and energy). The sectorial indication is expressed as follow:

(Ds/D) x 100 : %

Ds : Total annual sectorial water

D : Total annual water demand

- Agriculture use = 92,36 Mm³ (*Annuaire d'exploitation, 2001*) ; equal to **72,7%**

- Drinking water = 21,12 Mm³ (*Annuaire d'exploitation, 2001*) ; equal to **16,6 %**

- Industrial use = 13,51 Mm³ (*Annuaire d'exploitation, 2001*) ; equal to **10,6 %**

- **Index of drinking water production** : It's the annual drinking water production divided by the number of population, expressed in en m³ per capita. This index is expressed as follow

(P / H) : m³/capita/y

P : annual quantity of drinking water production Million of m³

P = 21,12 Mm³ (*Annuaire d'exploitation, 2001*)

H : population for a given date

H = 343200 inhabitant (*INS, 2000*)

Index of drinking water production = 61,5 m³/y/capita.

Indicatory of water resource constraints : The excessive abstraction that are not under control in quantity and in frequency can have some degrading consequences on the capacities of renewal resource and on the quality of exploited water. To determine the intensity of pressures on resources of the survey zone, two indicatory are chosen:

- **Index of renewal water exploitation** : This indicatory expresses the pressure of water uses for a given date. It describes the real evolution of this pressure. Groundwater is especially concerned because of intensive exploitation on a zone where surface water are limited due to climatic conditions. This index of exploitation is expressed as follow :

(P / Qt) x 100 %



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P : all water abstraction for all type of uses for a given date

$P = 102,3 \text{ Mm}^3/\text{y}$ (*Djeffara de Gabès : Annuaire d'exploitation, 2001*)

Qt : renewal resources

$Q_t = 115,2 \text{ Mm}^3/\text{y}$ (*ABIDI, 1999*)

Index of renewal water exploitation = 88,80 %

b. Socio-economic analysis

The calculated social indicators are related to the evolution of population and to the part of the urban population. Results permit to determine the relative tendencies of needs for domestic drinking water of the region. For the economic indicators, the indicator choice is based on their interference with drinking water supplying as parameters of description of sectors consumption.

Social Indicators

- **Growth rate of the population : $F : [(Y-X)\sqrt{P_y/P_x-1}] \times 100$**

P_y : population for the year y

P_x : population for the year x

For the governorat of Gabès : $P_{2003} = 343200$ (INS, 2000) ; $P_{1994} = 311713$ (INS, 1994)

$F = 1.07 \%$

- **Growth rate of urban population :**

For the gouvernorat of Gabès : $P_{2003} = 226200$ (SONEDE, 2004) $P_{1994} = 201404$ (INS, 1994)

$F = 1.29\%$

Economic Indicators

Agriculture Sector

- **Fraction of irrigated agricultural area : $F = (I/A) \times 100$**

I : irrigated area = 9500 ha

A : Total agricultural area = 597000 ha

$F = 1,6 \%$

- **Agricultural Water demand for irrigation : $F = Q_T/S \text{ m}^3/\text{y}/\text{ha}$**

Q_T : agricultural abstraction for irrigation (92,36 Mm^3 (*Annuaire d'exploitation, 2001*))

S : irrigated area (9500 ha)

$F = 9722 \text{ m}^3/\text{y}/\text{ha}$

Touristic sector : For the region of Gabès, the volume of water used by the tourist sector during 2003 is $52 \cdot 10^3 \text{ m}^3$.

Drinking water sector

- **Rate of supplying dinking water :**

Year	1994	1995	1996	2003
Rate of supplying (%)	87,1	87,2	88,7	99,1



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For 2003 :

- Rate of supplying in urban zone (SONEDE) = 100 %
- Rate of supplying in rural zone (SONEDE) = 68.8 %
- Rate of supplying in rural zone (SONEDE & GR) = 97,3 %

- **Efficiency of the distribution network:**

Year	1997	1998	1999	2000	2001	2002	2003
Distribution Efficiency (%)	82,3	84,4	86,1	87,4	88,5	87,3	83,5
Loss index	9,2	7,5	6,1	5,2	4,8	5,2	6,4

- **People consumption:** It is the water volume consumed per capita.

For the region of Gabès (SONEDE, 2004) :

Total consumed volume = $16460 \cdot 10^3 \text{ m}^3$ Population = 341800 **Unit need = 131,94 l/j/capita.**

In rural zone

Consumed volume = 1300340 m^3 Population = 115600 **Unit need = 30,82 l/j/capita.**

3.2 Decision context

The decision was made progressively by first the creation of a protected perimeter (decree n°85-1105) in 1985 that was then spread and transformed in a perimeter of interdiction (decree n°87-480) in 1987. In this last decree, all procedure having for objective an increase of the exploitation should be stopped by the CRDA of the region that can, in case of need, have resort to the national police help. However, if the observation of infringements is made after 72 hours, the CRDA must carried complaint and wait the decision of the courthouse to be able to apply the interdiction of exploitation. In fact, it is noticeable that it is very difficult to the agents of the CRDA to apply this decision as it is formulated. Indeed, their limited number doesn't allow to control all potential water users. The governor of the region, gave out in 1999, a circular in order to help these agents by creating a team whose role is to note and to pursue the decree contravening.

In answer to this regional decision, the state required that all procedures are made according to the national model, to know, have recourse to the legal central authorities to carry complaint and then some for the application of penalties, what reduced extensively the margin of regional and local agent manoeuvre. Besides, the increase of well number in the region makes very proof that the application of this decision remains very limited : the protection of water resources is not assured therefore for the long term.

Decision making processes are traditionnaly retracted to the first level of stakeholders (ministry and state secretariat). Actually, national strategies involve so called "participative actions" but only for the application of the decision. That's why, in the presented case study, the farmers have limited conviction of the importance of the interdiction perimeters. For them, it is difficult to pay, even weak costs, to obtain water from State when they can capture good quality water by their own wells.

According to our personnal investigations, we notice that the ACI of the region doesn't consider its role as a bridge between institutionnal level and the farmers, the different members of the association consider that they have to hold farmer's rights as a trade-union movement. This is due to the fact that the decision is taken as an interdiction of use of local resources and not as a protection of this resource to ensure its sustainability. We think that the first step is to bring up the association members to review their opinion in order to convict them that the decision will not constraint socio-economic development of the region.

3.3 Stakeholders' analysis

In order to understand how the stakeholders are included in the decision making process, we have consulted different water users and managers. We must specify that the different interviews of national and regional level were realized with a group of concerned persons. The answers to our questionnaire were obtained through a restricted meeting



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discussion. However, for local waters users, the interviews were done with the concerned person. The following table presents the different organism we have consulted.

National Level			
Type	Name	Activity	Contact details
Public	DGRE	Water management	Tunis
Public	SONEDE	Drinking water	Gabès
Regional Level			
Type	Name	Activity	Contact details
Public	Gouvernorat	Legislative issues	Gabès
Public	CRDA	Agriculture production	Gabès
Public	Desalination Station	Water desalination	Gabès
Local Level			
Type	Name	Activity	Contact details
Farmers Association	ADA Mizrâa	Agriculture production	Ghannouch
Private company	CIF	Agriculture production	Ghannouch
Farmer	Belhassen Ghannouchi	agriculture	Ghannouch

According to our investigation, we notice that the population of this region don't accept to be deprived of "their" water : Some of them don't understand why they have to pay to obtain limited volume of water for their agricultural activities when they can directly abstract all water needed by a simple well located on their parcel.

We have notice a clear cut between national (governorat), regional (CRDA) authorities and end users of water (Association of Collective Interest : ACI). The relationship connecting national and end users is limited to the control of water abstraction authorisation and infraction to the protected area decree. Eve if some meeting are organized, main discussions concern this two major problems.

The relationship connecting regional (CRDA) and end user are denser but mainly axed on technical support. However, relationships within end users are well developed thanks to the ACI (association of Collectivist Interest). Frequent meeting are organised and different problems related to water management are discussed. The presence of a regional responsible allows progressively making the decision more accepted by the farmers.

3.4 Participation methodology

The official number of wells and boreholes is constant since the decision of interdiction zone creation. However, non-authorized abstraction is still existent even if it is not well located.

According to our investigation, we suggest to built-up a bridge between end users of water and managers of water based on the institutional settings of management and on the consistency of the interfacing between the different levels of decision (legislative, ministerial national, ministerial regional, associative and old groupings). The participation of farmers is probably difficult to involve in the decisional process but we think that it is possible to include them in the application of the decision by explaining constraints on which the water system is submitted and probable destruction of this system. But also, we think that a financial support can make easier to accept the decision.

The participation methodology must begin with a detailed socio economic study of water use and water protection on the survey zone. This study will concern all end users and their dependency to the water system in order to evaluate the financial support needed to make the interdiction perimeter recognized by the population.

3.5 Conflict over water uses

In our case study, there is no traditional conflict between water users. The only user concerned by the interdiction perimeters is agricultural sector. In fact, the main conflict appears between the user (Association of Collective Interest) and



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the manager (State). The problem of water management in the interdiction zone of Gabès North requires frequently intervention of national and even regional authorities to ensure the application of the decree of interdiction of abstraction.

Associations of Collective Interest (ACI) transformed in Groupings (GCI) are structures on which the State rely to reduce its expenses and to manage consumptions in agricultural water and to improve the economic valorization of water. Public perimeters farmers show a wide infatuation to these structures. The situation of the ACI of irrigation or ACI/IP made the object of national analyses through visits in the different governorates and complementary investigations. Results are not in agreement and reflect a real difficulty to obtain data. Achieved Analyses (EUREKA/BTE, 1999) give a general idea of the difficulties of functioning of these ACI. The main causes of difficulties are of two type :

- social : a lack of information and formation of the Administration council enhanced by some conflict between this council and farmers, even if the council is elected by these farmers.
- Financial : ACI hasn't any governmental financial support, its accounting is only based on subscribers cost and farmers subvention that remain quite limited. One the other hand, even if the State encourage agricultural sector, banking credit are attributed to farmers with difficulties.

The major part of the difficulties is due to problems of organization, of expertise, of respective roles of State/ACI/Beneficiaries, in brief on a social management that has difficulty to be organized. The ACI are compared to a return to the historic diagram of small amenities (lakes and hillside dams, boreholes) and of agricultural uses of proximity, with a collective management that one would want strong and autonomous, but conditions are not anymore the same. On the one hand, there is a bigger reliability in the construction and an accessible technical diversity to share, to transport and to apply water to the parcel; this present technicality pleads for better performances. On the other hand, the construction of infrastructures (site and feature) and the social organization is imposed by the public state to populations that lost a big part of their hydraulic ability. There are not more of general consistency, what explains difficulties to install this decentralization phase.

4 Emerging issues and lessons learned

The water resources management must integrated three interconnected systems : the natural water system, the human activities system and the technical infrastructure that joins environment and society. Amenities (dams, pumping, ...) transform surface and groundwater available resource and transfer this resource to its use. The characteristics of these amenities (type, number, site) are conditioned so much by the spatial distribution and the variability of water resources that by human activity demands. In counterpart, they modify the resource dynamics downstream (influenced regimes). They are sometimes complex when they associate surface and groundwater reservoirs but can evolve independently (sedimentation of restraints). The water system supply amenities according to its own dynamics (water cycle) conditioned by climate, structured by hydrographic network and its connections with groundwater system. The distribution of available water resource is directly modified in quantity and quality by catchments and wastewater after use or partial consumption and indirectly by the infrastructure and the space planning. The environment provides to the human activities the physical support of exploitation including a certain number of other resources (soil, climate, vegetation).

Demands in water formulated by the different human activities are related to the easiness of access that is proposed to them but also depend of an outside environment (social, economic, technological) that modifies aims and strategies of resource exploitation of the resource. The socioeconomic spaces are therefore more suitable to define and to plan water demands (Margat, 1996). However, resources spaces and demand spaces are not often in agreement (Le Goulven, 1996).

The system of management was to the departure controled by structures generally very centralized, deciding themselves the necessary infrastructure type, assuring their construction and their maintenance and defining rules of water sharing according to strategic objectives. This vision " big administrator " evolved a lot because States disengage themselves little by little of the subsystem management (irrigation, drinking water and industrial notably) while confiding it to the regional structures or to the local organizations of collective management. The human societies are more and more implied (social management of water). Management tools are also various: technical, legal, economic and participative. The system of management is therefore a complex whole of institutions and specific organizations whose general logic is assured by their position on the diagram of water circulation that defines their level of intervention and the constraints



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uphill-downstream that they must take in account. To satisfy quantitatively and qualitatively the different demands, or even to anticipate them, it acts on the three components of the hydrosystem; planning of the space to restore natural functions of a too unsettled system, convenient of uses " to rationalize " the demand, amenities to organize rules of sharing. The whole of interventions is underlain by a lasting development strategy, criteria of equity between generations officialized by the international community (international Conference on water and the environment, Dublin 1992). Needs of information are multiple: spatial data to characterize every subsystem and its connections, chronological data of long length to analyze evolutions and related data to anticipate them, immediate data for the management of crisis. To understand and to act, researchers and administrators have need at a time of a global vision of the system of water and a more detailed vision of its different components (problems of analysis levels).

The own dynamics of every subsystem articulate on different time steps: daily time for the water resource and seasonal for agricultural systems for example. The clarification of information systems to spatial credentials is in one a present investigating theme.

Dss can integrated all these aspects and therefore allow to predict interactions between the diffrenet levels. The example that we give in this survey doesn't make call to the DSS. However, seen the relative failure of application of this decision for the creation of a protected or interdiction zone, we think that a procedure more involving and implying the different concerned stakeholders would allow a better acceptance of the decision. Indeed, this decision has been based exclusively on a scientific detailed knowledge of the hydro-system without that socio-system issues are taken in account. However, this hydro-system requires a protection because it is submitted to the socio-system constraints. The utilization of DSS tools is centred mainly on the interaction between these two systems. The dynamic of "Hydro-Socio-System (HSS)" would allow to follow the response of water users in this region, sufficiently penalized by restrictions of natural order to not accept easily restrictions of decisional order, especially when the importance of this decision is not well transmitted and when it is not accompanied by compensations (financial or other).



Annex I – Definitions and common references

Definitions

Integrated Water Resources Management (IWRM) (GWP-TAC, 2000)

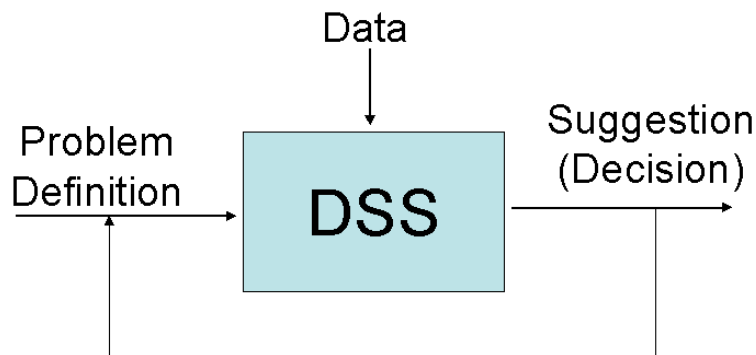
IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems

Decision problem

A decision problem is considered to exist, when a planner or decision maker (DM) perceives a discrepancy between the current and desired states of the planning system, and when (i) the DM has alternative courses of action available; (ii) the choice of action can have a significant effect on this perceived difference; and (iii) DM is motivated to make a decision, but he is uncertain a-priori as to which alternative should be selected.

Decision Support System (DSS) (D. Fortune, HarmonIT, 2004)

Dss combines aspects of information and modelling systems, suits users who are not necessarily experts in modelling or data analysis, converts policy and management decisions automatically to suitable model runs and data analyses, allows the outcomes of such decisions to be compared, and perhaps even gives advices on the optimal decision to be made



Requirements for DSS implementation

- Test case (real decisional scenario)
- Responsible party (Decision-maker) and involved stakeholders (e.g. water users)
- Databases (existence of data)
- Assessment methodology (e.g. models)
- Decision methods and rules (e.g. MCA)
- Communication platform (dossier, DSS itself, etc.)



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