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Harnessing Salty Water to Enhance Sustainable Livelihoods of the Rural Poor in Tunisia

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Foreword

In order to provide a basis for discussing the issue of harnessing salty water and the role of irrigation with brackish and saline water, the National Research Institute for Rural Engineering, Water and Forestry (I.N.R.G.R.E.F - Tunis, Dr Gaaloul N.) and the National school of Engineering (E.N.I.S - Sfax, Dr. Zouari K.) compiles existing quantitative and qualitative information on saline water resources, availability of brackish and saline water use in irrigation, evolution of rural poverty related to the water resources and the prospects for biosaline agriculture in Tunisia.

This report focuses on the work done through the I.N.R.G.R.E.F and E.N.I.S to collect and analyses available information on saline water resources for irrigation in Tunisia and their potential impact on the livelihoods of the rural poor.

The report presents the quantity and quality of saline water resources data and the integration of poverty indicator information with saline water resources. It presents and analyses the key findings of using the saline water in agriculture
A summary table provides the information on groundwater resources, prospects for biosaline agriculture and rural poverty.

The report also discusses the limitations of the approach and the information gaps that remain at country level. The aim of the work presented here is to help assess the quality and quality of saline water resources for irrigation in Tunisia and their potential impact on the livelihoods of the rural poor.

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BACKGROUND

In the arid areas of South Tunisia, where annual rainfall rarely exceeds 200 mm, no sustainable agricultural production is possible without irrigation. In these areas, groundwater is the major source of water supply. Over the past two decades, an increasing water demand for agriculture, industry and domestic uses has led to the overexploitation of groundwater resources. Currently, the rate of water extraction far exceeds the rate of water recharge, resulting in the gradual depletion of the aquifers and to seawater intrusion in coastal zones. In these areas, resource-poor farmers who have built their livelihoods on a reliable supply of freshwater are now faced with a critical shortage of this vital resource, and this impinges on all aspects of their relationship with the environment. As freshwater becomes more scarce, the pressures grow on farmers to use brackish and even saline water.

Saline groundwater exists in relatively large quantities in South Tunisia. In the coastal zones of Tunisia, such as the Jefara Plain strip, reliance on saline water and slightly saline water is the only viable alternative for irrigated agriculture. Given the dependence of agriculture on irrigation in these arid areas, the question is not whether to use brackish/saline water to irrigate, but how best to use this “technology” in a sustainable manner and with as little detrimental effect as possible on the natural resource base.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIC	Association d'intérêt collectif / Collective Interest Association
CGDR	Commissariat Général de Développement Régional / General Commissariat for Regional Development
CRDA	Commissariat Régional de Développement Agricole / Regional Commissariat for Agricultural Development
DGRE	Direction Générale des Ressources en eau / General Directorate for Water Resources
FNA	Federation of Women of Farm / Fédération Nationale des agricultrices
GNP	PNB produit National Brut
GDB	PIB
INRGREF	Institut National de Recherches du Génie Rural, des Eaux et des Forêts / National Research Institute for Rural Engineering, Water and Forests
NGO	Non-governmental organisation
PDRI	Programmes de Développement Rural Intégré / Integrated Rural Development Programmes

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1. TUNISIA

1.1 Geographic situation

Tunisia is situated to the south of the Mediterranean; it is bordered by Libya in the southeast, Algeria in the west (Figure 1). Tunisia's surface area is of 164 000 km^2, its coastline totals 1300 km, its average altitude is 700 m and its highest point is the Jebel Châambi (1540 m). Tunisia country share many common features in terms of climate, water and land resources and development issues. These include arid and semi-arid climate, limited water resources, agricultural development limited by water availability and high economic and social value of water.
Like most countries affected by aridity and particularly within the Maghreb region, water resources represent in Tunisia the most precious environmental good. The climate varies from Mediterranean to semi-arid and arid; it is characterized by hot and dry summers and mild winters receiving the major part of the annual precipitation.
The hottest month is August with a mean monthly temperature of 26ºC, and a highest monthly temperature of 28.7ºC. January is the coolest month having a mean monthly temperature of 10.7ºC and a lowest value of 8.4ºC. The mean annual temperature in Tunisia varies between 15ºC in the North to 21ºC in the South.

The climatic and geomorphologic characteristics define three major agro-ecological zones:

- The **North** constitutes a sylvo-agricultural region (mainly forests and annual crops); its average rainfall is between 400-600 mm and its main topographic features are mountain pasturelands in the northwest and fertile plains in the northeast.
- The **Center** constitutes an agro-pastoral region (pasturelands and crops); its rainfall is between 200-400 mm, and its morphology is composed of a low steppe to the east with fertile plains interrupted by depressions and a high steppe with mountain pasturelands and plains.
- The **South,** with irregular rainfall of 100 to 200 mm, is characterized by its aridity and vulnerability of its soils to desertification. This area is pastoral with oases around water points.

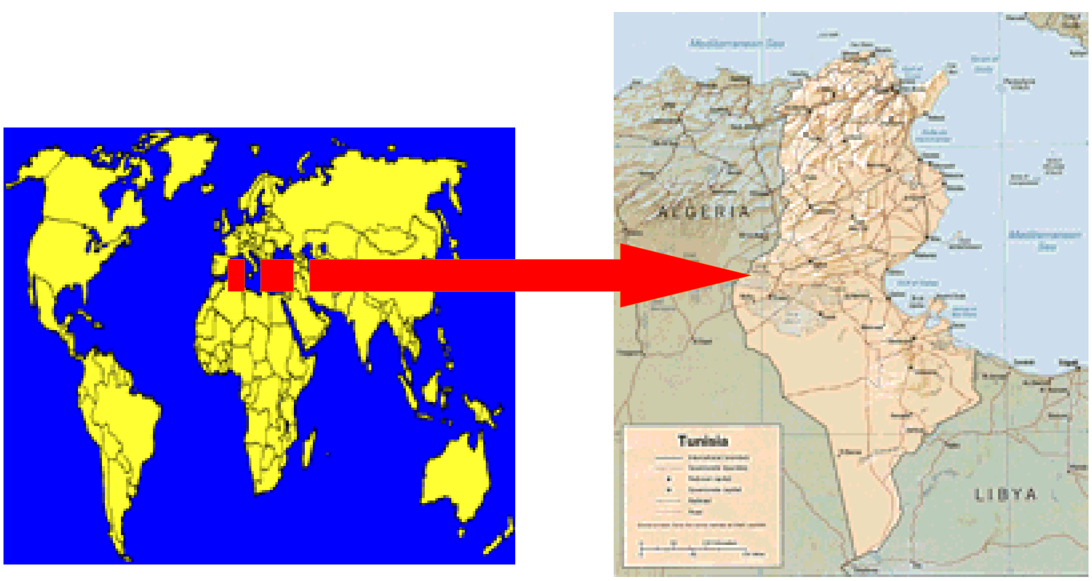


Figure 1. Tunisia situation geographic

Rainfall in Tunisia is irregular: there are long dry periods and precipitation varies from year to year and from North to South. Average annual rainfall is between 500 mm to 1 500 mm in the North, 300 mm in the Center and 100 mm in the South (Figure 2). Dry periods lasting several weeks often occur during one season or can last over several consecutive seasons. The annual average rainfall is estimated to 36 000 Millions cubic (Mm^3) / year and is ranging from 11 to 90 000 Millions cubic. Average annual evapotranspiration is also high and water deficit is particularly significant from May to October. The annual evaporation varies between 1300 mm in the north to about 2500 mm and even more in the south (Zebidi, 1990).

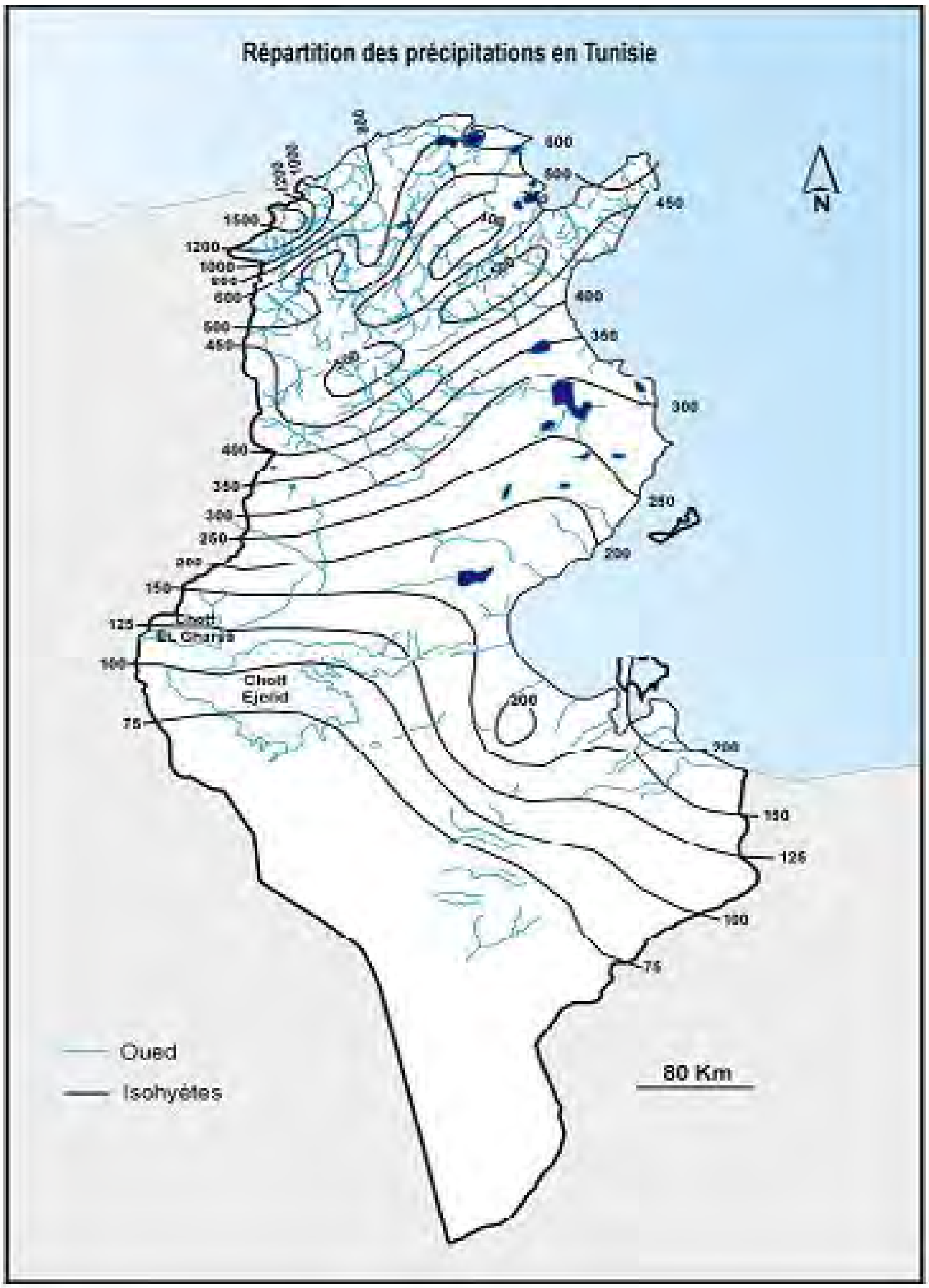


Figure 2. Precipitation of Tunisia

1.2 Population

The Tunisian population is about 9.6 million inhabitants (2004) of which 62% are concentrated to the coast in urban and industrial areas, 38% in rural areas (Table 1).

Table1.
Demographic condition in Tunisia (Annuaire Statistique de la Tunisie, 1994)

Region	No, of Delega,	No, of Imada	Total Area *(Km2)*	Population (1994)			Pop. 2003	Growth Rate(%) (1984-94)	Pop, Density *(per Km2)*	No, of Family	Family Size
				Male	Female	Total					
North	119	930	28673	2162394	2097086	4259480	3851600	1.5	360	862068	3.9
Center	89	735	35816	1599634	1564167	3163801	3592300	2.5	130	600335	5.3
South	46	379	91077	685313	676770	1362083	1509700	2.8	25	241782	5.7
Total	**254**	**2044**	**155566**	**4447341**	**4338023**	**8785364**	**8953600**	**2.3**	**56.5**	**1704185**	**5.16**

Demographic growth has fell below 2% in 1990 to reach about 1.7% at present (Table 2). Projections show that this trend of decreasing growth rate should be maintained (to about 1.3 % in 2005, 1.1% in 2015 and 0.9 % in 2030).

Table 2.
Development of population according to latest censuses

Years	1956		1966		1975		1984		1994
Population (x1000)	3,783.2		4,533.3		5,588.2		6,966.2		8,785.4
Annual growth rate (%)		1.8		2.3		2.5		2.3	
Overall fertility rate							4.64		2.87

Life expectancy rose from 51 years in 1966 to 71.4 years in 1996. Moreover, the social policy undertaken by the State which aimed at improving housing, infrastructure development, and more specifically providing drinking water and electricity, have greatly contributed to social development and the overall improvement of living conditions (Figure 3).

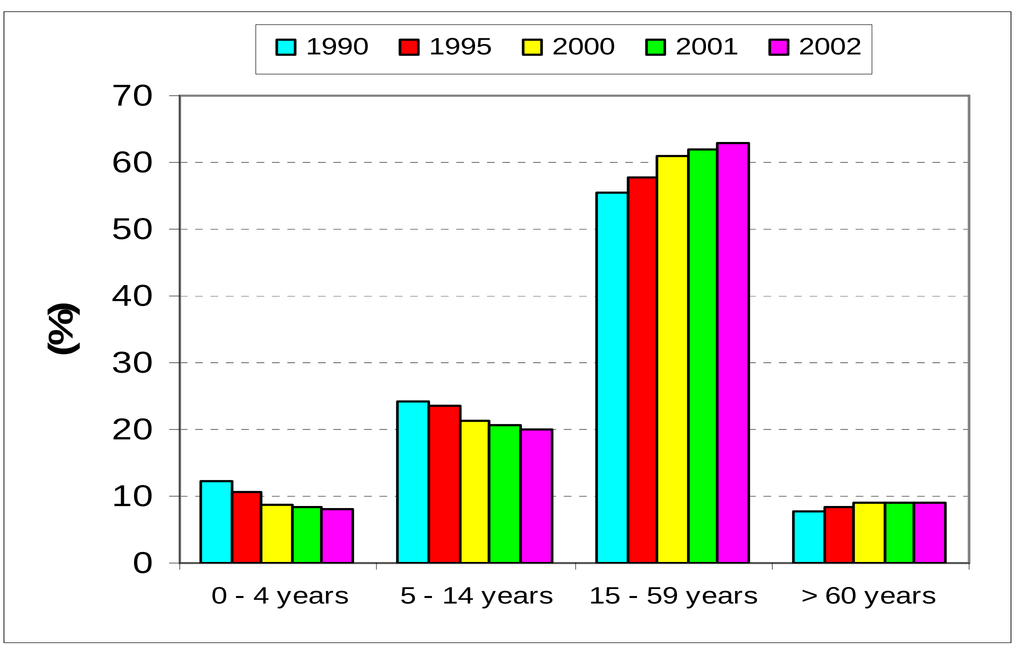


Figure 3. Structure population by ages

1.3 Water resources

Like most countries affected by aridity and particularly within the Maghreb region, water resource constitute in Tunisia the most precious environmental good.
The global potential of water resources in the country are about 4.6 billion m^3 of which 2.7 billion m^3 are from surface water and 2 billion m^3 from groundwater (Table 3).

The annual average rainfall is estimated to 36 000 Mm^3 / year, which is unevenly distributed (Hamdane, 1994):

- From 400 to 1000 mm/year, in the North
- From 200 to 400 mm/year, in the Center
- Less than 200 mm/year, in the South

Water resources are unevenly distributed across the country with around 60% located in the North, 18% in the Center, and 22% in the South.
The water resources that have a salinity of less than 1500 ppm are distributed as follows: 72% of surface water resources, 8% of shallow groundwater, and 20% of deep groundwater (Mamou and al., 2000).

Table 3.
Water resources distribution (billion m^3) in Tunisia (Eau 21 and DGRE 2001)

	1970	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Surface water	2.3	2.4	2.6	2.6	2.7	2.7	2.7
Groundwater							
Phreatic aquifers	0.2	0.3	0.5	0.56	0.69	0.74	0.74
Deep aquifers	0.6	0.9	1.0	1.1	1.1	1.2	1.2
Total	**3.1**	**3.7**	**4.1**	**4.3**	**4.5**	**4.6**	**4.6**

Unfortunately, potential water resources (total flow) represent only 4669 Mm^3/year (Bahri, 2001). This potential presents a greater regional disparity:

- 2801 Mm^3/year in the North (17 % of total area), or 60%,
- 848 Mm^3/year in the Center (22 % of total area), or 16%,
- 1020 Mm^3/year in the South (61 % of total area), or 24%,

1.4 Soil resources

Tunisia faces a number of convergent natural and anthropic factors, which account for the fairly advanced level of soil degradation. The main problems are water and wind erosion, and salinisation. The great challenge is to contain these problems whilst preserving the productive potential of the land. Preventive actions aimed at the rational management of land must be combined with curative actions to enable land improvement, rehabilitation and restoration through adequate management.
The combination of Tunisia's varied bioclimate, ranging from humid to Saharan - and its geology offering different types of rock outcrops -, generates a fairly rich variety of soils. The soils are well differentiated by their fertility and sensitivity to degradation.
Three major regions can be distinguished by the nature of their soils and the related cultivation systems (Souissi, 2001).

Northern Tunisia, a region with a sylvo-pastoral potential, has highly diversified soils:

- Acid soils on alternating clay and sandstone, non calcareous, shallow but quite rich in organic matter and relatively stable,
- Deep calcareous soils on marl slopes very sensitive to water erosion;
- Shallow soils on calcareous rock, located on tops of hills;
- Deep, stable and fertile soils of numerous more or less extended plains.

All suffer severe water erosion enhanced by slope cultivation and tillage, by overgrazing, and by inadequate rotations of rain fed and irrigated crops where the integration of animal husbandry is virtually absent. The failure to recycle organic matter (manure, straw…) accentuates the impoverishment of soils in humus and leads to their physical and chemical degradation. Soils of irrigated plains risk chemical degradation - salinisation - due to irrigation with brackish water without sufficient drainage to leach out the salts.

Central Tunisia is an agro-pastoral region dominated equally by the heavy soils of alluvial plains, which are mostly sodic, by the sealed skeletal calcareous soils of the large fans and by the deep and light soils, which were in the past occupied by rich pastures. These different units are confronted with several problems: the expansion of tree cultivation on the sandy steppes which triggers wind erosion; the cultivation of natural and esparto grass pastures which leads to the reduction of pasturelands, and as a consequence to overgrazing; the excessive development of irrigated agriculture using degraded water derived from overexploited aquifers, which leads to the secondary salinisation of soils.

Southern Tunisia has a pastoral vocation and is characterized by arid, light soils vulnerable to wind erosion, dominated by the presence of gypsum. Olive growing and cereal cultivation in the southern steppes are the cause of desertification of the natural pastures; these by deflation become stone deserts, and by accumulation, sand dunes.

In the three major regions, belonging to the sub-humid, semi-arid and arid zones, soil degradation is mainly due to human activity since land use (1995) does not correspond to soil aptitude. An estimated more than one million hectares of marginal lands are cultivated, and a large proportion of sandy soils, which are vulnerable to wind erosion in arid areas, are tilled. As a matter of fact, the usable agricultural area covers almost a third of the national territory, but fertile land does not account for even 20%. More than 60% of the usable agricultural land is in arid areas where soil is in a precarious balance, threatened by water and wind erosion.

Gypsum soils do occur in several desert regions of the world, and Tunisia is well known as one of the countries extensively covered by them. In the South and a part of the Central Tunisia, especially in the low-lying zone from Chott El Djerid to Gulf of Gabes, the gypsum soil is rather commonly observed (Job, 1992). In a total view, oases underlain by gypsum soil are 90, nearly 60% of all target oases. However, the oases at where a gypsum soil underlies thickly or widely are 34, about 22% of the total, concentrated in Kebili Province. And oases severely affected by gypsum, by hard gypsum crust or thick clayey gypsum soil, are only 15 oases, around 9.8% of all.
Figure 4 indicates the relationship of mean annual precipitation (in mm) and distribution of gypsum soil.

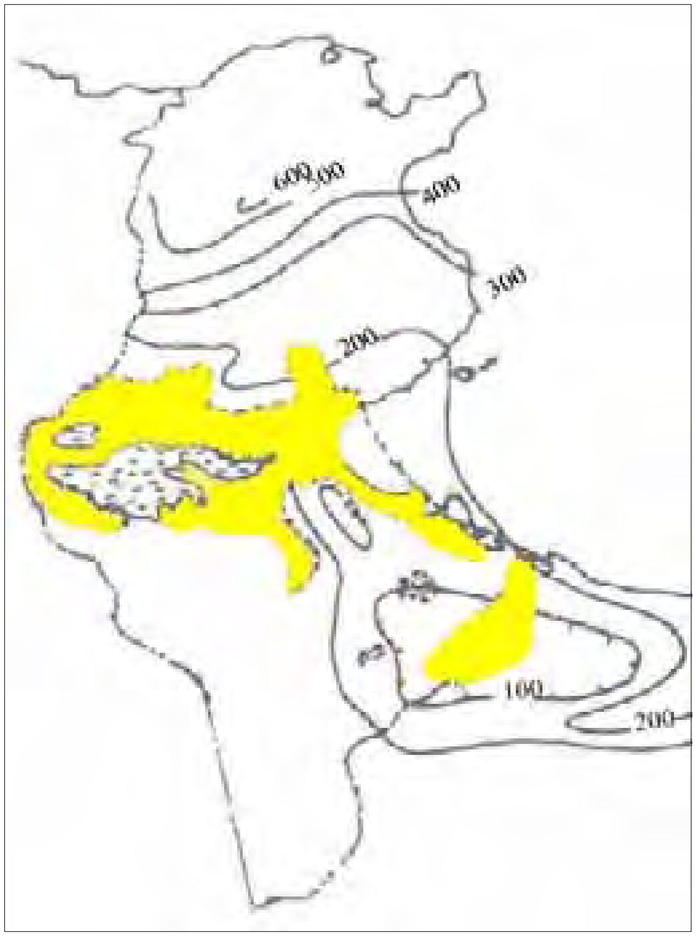


Figure 4. Distribution of gypsum soil in Tunisia (Dubief, 1963)

1.5 Erosion and desertification

Mean annual rainfall values can be exceeded by factors of two to twelve during short and intensive rainfall events producing runoff and causing soil erosion (695 to 6050 tons per km^2 and year). Annual soil losses are estimated at 23 000 hectares, of which 13 000 hectares cannot be recovered (Souissi, 2001).
Land suitable for cultivation in the north and center of Tunisia, located north of the 200mm isohyets, are most threatened by strong and moderate erosion while the Center-East and Cap Bon are somewhat less threatened. In total 1.2 million hectares are affected by water erosion, representing 25% of the nation's land suitable for cultivation. In the South, an estimated 50% of the land, not included in natural deserts, faces desertification.
Tunisia's physical and climatic diversity has had great influence on the way in which its natural resources are used, and this, in turn, has had an influence on the risk of desertification. In the south of Tunisia the steppes are reportedly being destroyed by human pressure at a rate of 1% per year. Alfa grass or plant communities associated with it dominate most of the steppes in the south of Tunisia.

The effect of such inappropriate use of natural resources tend to be amplified by physical factors, varying according to region in terms of vulnerability and sensitivity: water and wind erosion, increasing soil salinity.

2. AVAILABILITY OF BRACKISH AND SALINE WATER

2.1 Generality

The distribution water resources (Table 4 and Figure 5) in the three geographical regions is quite different:

- Most surface water resources are localized in the Northern region (81,2%) which represents only 17% of the total Tunisian area,
- The biggest part of the ground water resources are in the south, particularly in deep-lying aquifers with fossil water form,
- The Center is the poorest region on water resources.

Table 4.
Potential water resources contribution (Total Flow) (Eau 21)

Region	Surface water		Ground water resources			
	Surface water		*Phreatic aquifers*		*Deep aquifers*	
	Millions m³	*(%)*	*Millions m³*	*(%)*	*Millions m³*	*(%)*
North of Tunisia	**2190**	*(81.2)*	**395.2**	*(55)*	**216.3**	*(17.8)*
Center of Tunisia	**273**	*(10.1)*	**221.4**	*(14.2)*	**272.4**	*(22.5)*
South of Tunisia	**237**	*(8.7)*	**102.1**	*(102.1)*	**722.2**	*(59.7)*
All Tunisia	**2700**	*(100)*	**718.7**	*(100)*	**1210.9**	*(100)*

The renewable potential of aquifers (depth of < 50 m) is estimated at 670 million m^3 and that of deep reserves (depth > 50 m) at 1188 million m^3. The management of aquifers and deep reserves is carried out within the limits of 700 million m^3 and 930 million m^3 (DGRE, 1997a). Underground water reserves are very important in the south, especially deep water tables that represent 44.7% of the underground water total. Potential fossil reserves represent 605 million m^3 that is 33 % (DGRE, 1997b).

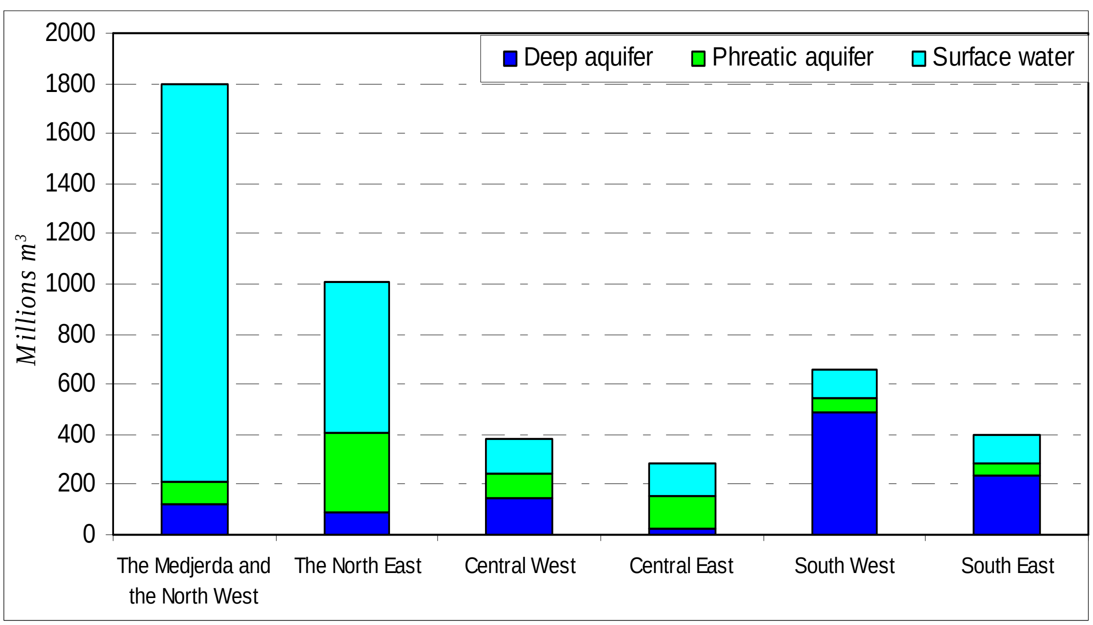


Figure 5. Potential water resources allocation by hydrological basin (Year 2000)

The salinity problem, which limits the use of water, is less acute for surface water. Figure 6 shows a detailed classification of water resources in Tunisia according to their salinity (Mamou, 1993).

Groundwater resources are exposed to various types of pollution and deterioration, increasing their vulnerability and scarcity. Water quality of ground water is based on its salinity level and can be detailed in figure 6.

Phreatic aquifers are already over-tapped. Groundwater resources in coastal aquifers (Cap Bon, Sahel, and Gulf of Gabes) and in the chotts (Nefzaoua and Jerid) suffer from salinization problems due to seawater or saline water intrusion.

As a result, the quality of these aquifers has deteriorated considerably. Pollution of some phreatic aquifers by nitrates constitutes also a major risk for domestic requirements.

Generally, deep aquifers composition is rather stable over the year while the shallow aquifers one depends on location and season and is often salt-affected. Groundwater of the shallow aquifer is generally over exploited leading to lowering of water tables and the deterioration of water quality. The majority of the shallow aquifer is located in the north and the center of the country, while deep aquifers are mostly concentrated in the south.

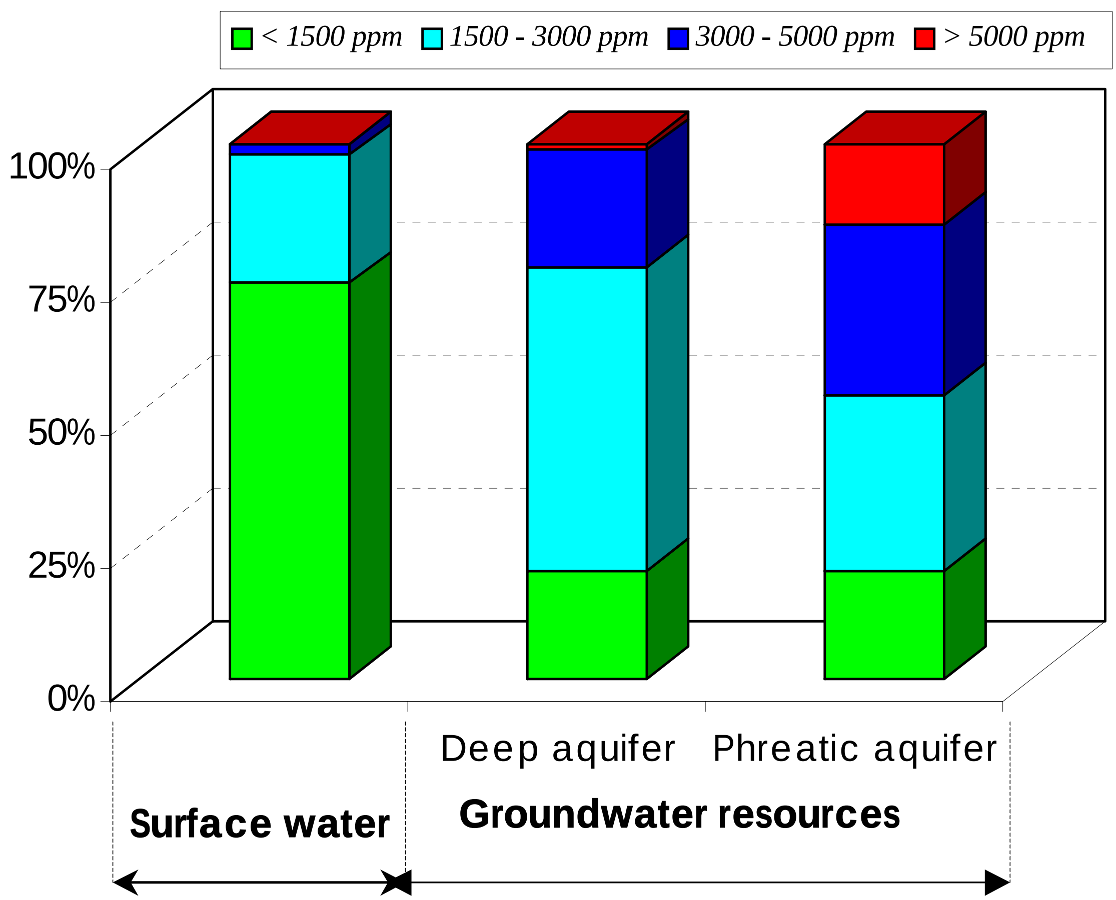


Figure 6. Water resources classification according to salinity levels.

2.2 Surface water resources

2.2.1 Surface water resources availability and use

Rainfall throughout the country is equivalent to an average of about 36 billion m^3 per year, or an average of 230 mm. From this quantity, an average of only 2.7 billion m^3 (Table 5) are annually mobilizable through a well developed hydrographic network, a topography favoring runoff and an impermeable geological stratum limiting infiltration; there are few aquifers in the North. The major basins in the North are the Medjerda Basin (Figure 7), of the extreme North, and the Oued Miliane (Kallel, 1995). The mobilizable water is collected at 81 % in the northern basins, 12 % in the center and only 7 % in the South.

Table 5.
Water balance and salinity class of the surface water by region in Tunisia (DGRE, 1993)

Natural Region	**Hydrology Basin**	**Discharge** *Mm^3/yr*	**Class of surface water (ppm)**			
			< 1500	***1500 to3000***	**3000 to 5000**	**> 5000**
North	Extrême Nord	585	*<400 to 1500*	1500 to 3000	*> 3000*	
	Ichkeul	375	400 to 750	100 to 2400		
	Medjerda	1000	460 to 1210	1800		
	Miliane	50			*3000 to 4000*	*5000 to 10000*
	Cap-Bon	180	700 to 1430			
Total North		**2190**				
Center	Sahel Nord	20			*2700 to 6400*	
	Nebhana	45		*950 to 2000*		
	Merguellil	35		*2000 to 3000*		
	Zéroud	105		*1500 to 5500*	*2100 to 4580*	*430 to 6500*
	Centre Sud	110			*1200 to 3800*	*1300 to 66300*
Total Center		**320**				
South	Chott Gharsa	70	300		*2000 to 5000*	
	Sud	120			*3000 to 4700*	*5000 to 7900*
Total South		**190**				
Total of surface water in Tunisia		**2700**				

2.2.2 Saline surface water resources

In Tunisia, surface water salinity has been classified into four classes based on the use of water (Table 5). The salinity problem, which limits the use of water, is less acute for surface water since 74% of this water has a saline content below 1500 ppm and only 2 % has a salinity content above 3000 ppm. The third and forth classes are considered as saline water because it cannot be used for human water supply. Theses classes are partly used for some crops and mainly for industry. Annual inputs fluctuate considerably, which inevitably has some effect on the production of irrigated perimeters since there are shortfalls reaching 50% compared to the average. Globally, 74 % of surface water resources have a salinity degree lower than 1500 ppm.
However, we have greater difference between regions and salinity issue is even more problematic in the southern part of the country. The distribution of the fourth classes of water in the three main regions of the country (North region: Extreme North, Ichkeul, Merdjerda, Miliane and Cap Bon) (the Center region: Sahel North, Nebhana, Marguellil, Zeroud and Center South), (the South region: Chott Gharsa and South), is shown in table 5.

Figure 7. Tunisia hydrographic network

2.3 Ground water resources

Groundwater is divided into two main components: phreatic and deep. Phreatic aquifers correspond to shallow aquifers just under the ground surface (Figure 8). In Tunisia, phreatic aquifers are located at less than 50 m depth, while deep aquifers have depths between 400 and 500 m. There are also some exceptions of very deep aquifers in the South Region (between 1000 and 2000 m in the CI).

Figure 8. Ground water resources in Tunisia

2.3.1 Phreatic aquifers

According to the 2000 inventory, the renewable potential of phreatic aquifers (Table 6) is estimated at 736.7 million m^3/year. Their net rate of development is 106% from 123 000 phreatic wells. This number of wells was 60 000 in 1980. Phreatic water reserves are overexploited at the rate of 104 %. However, this average value hides some extreme overexploitation rates (120 to 130 %) in aquifers of the eastern coast of Cap Bon, and the Sahel of Sousse and of Sfax.

Table 6.
Evolution of exploitation of phreatic aquifers from 1980 to 2000 (DGRE, 2000a)

Region	Resources *(Million m^3/year)*					Exploitation resources *(Million m^3/year)*				
	1980	1985	1990	1995	2000	1980	1985	1990	1995	2000
North	287	324.4	371.6	395.2	386.1	227	300	382.1	406.2	405.1
Center	162	194.1	199.6	220.8	235.4	137	202.5	225.2	226.5	260.8
South	27	67.2	97.4	102.2	115.2	31	60.3	91.2	112.4	111.8
Total	486	585.7	668.6	718.1	736.7	395	562.8	698.5	744.9	777.8

The majority of the phreatic aquifer is located in the North (52%) and the center (32%) of the country. Water quality of ground water of phreatic aquifers is based on its salinity level and can be divided in four class (Figures 6 and 9).

2.3.1.1. North region (Zebidi, 2003)

In northwest Tunisia (Jendouba Governorate), the Middle Valley corresponds to an alluvial plain where the Medjerda River receives its main tributaries from the north and the south. The groundwater salinity gradient, from less than 3 000 ppm on the margins of the plain, increasing towards the centre of the plain, in particular near the cities of Jendouba and Bou Salem, where it can reach over 10 000 ppm. The salinity of renewable groundwater (9.2 million m^3/yr) is categorized as follows:

North region	< 5 000 ppm	5 000 ppm to 10000ppm	> 10000ppm
Exploitation *(Millions m^3/year)*	2.4	3.4	3.4

2.3.1.2. Center region

The phreatic aquifers in the Center of Tunisia is exploited, the rate of exploitation is of 111%. The average salinity of the phreatic aquifers in the Center of Tunisia varies from 500 ppm to 10 000 ppm (Table 7).

Table 7.
Phreatic aquifers with saline water and resources of exploitation in Center and South of Tunisia

Region	Number of Aquifers	Salinity *(ppm)*		Resources *(Millions m^3/y)*		Exploitation *(Millions m^3/y)*		Rate exp. *(%)*	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Center	92	500	10000	0.2	26	0.08	28.8	9	320
South	57	1000	15000	0.15	27	0.01	26	2	219

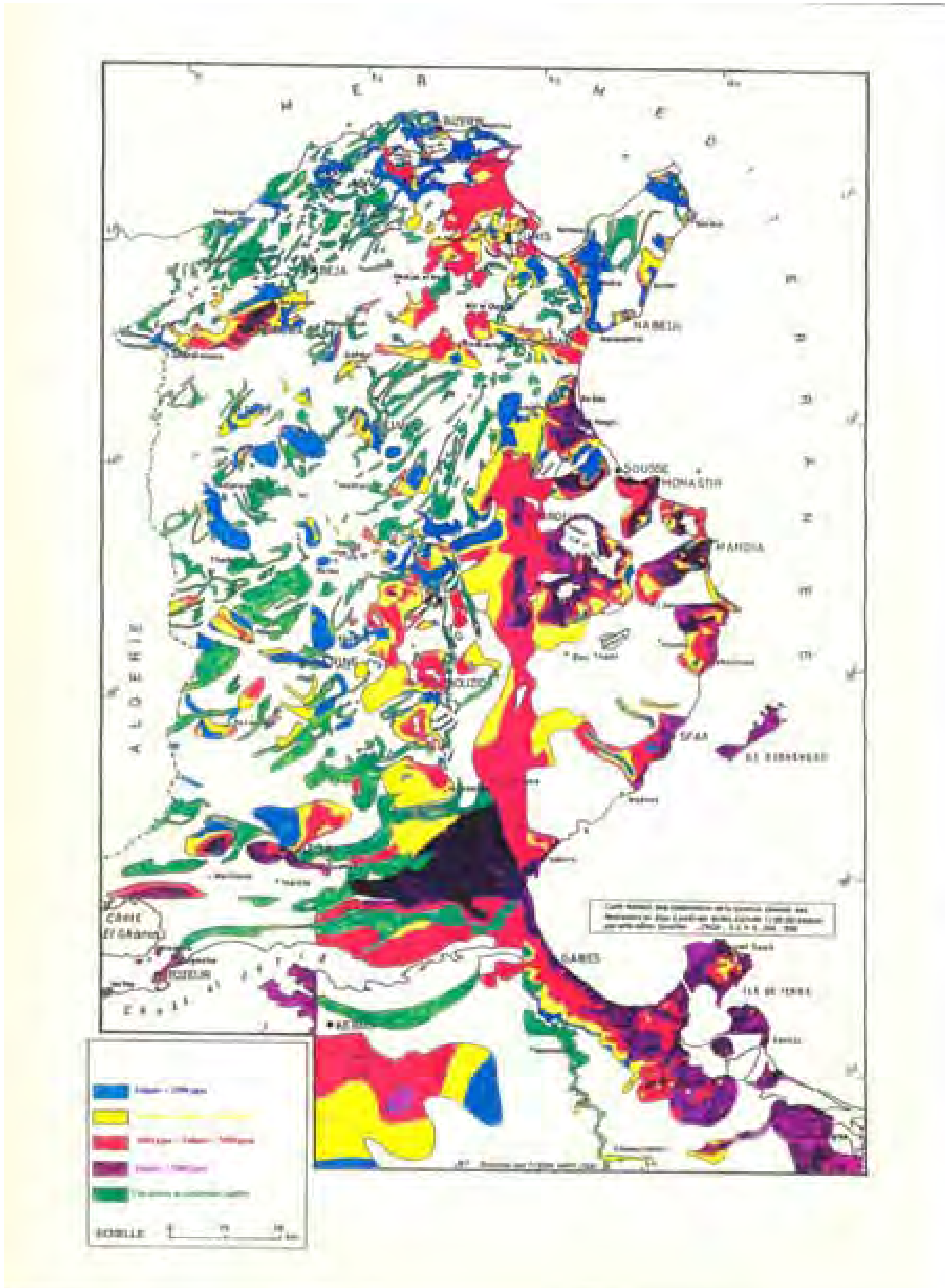


Figure 9. Salinity of phreatic aquifers in Tunisia

2.3.1.3 South region

Most of the phreatic aquifers with saline water higher than 3 000 ppm are located in the South region of Tunisia. The phreatic aquifers relates to the aquifers known through the various wells of surface, which exploit them. They correspond to the first aquiferous levels met starting from surface. Fifty-five phreatic aquifers are located in the South region of Tunisia (Table 7). The average salinity of the phreatic aquifers in the South of Tunisia varies from 1 000 ppm (Gafsa, Tozeur, Gabes and Medenine gouvernorates) to 15 000 ppm (Mednine governorate) (Figure 10).
The main part of the ground water resources of Djerid is represented by the Jerid oasis (Djerid-Dhafria). The Jerid oases are located in the southwest of the country in the Governorate of Tozeur. The Jerid oases correspond to a narrow anticline developed between the Chott Jerid in the south and the Chott Gharsa in the north. The heart of the anticline is composed of limestone from the Eocene, covered by a Miocene coarse sandy layer constituting the main aquifer of the region, the Complexe Terminal (CT).
The salinity of the Jerid oasis phreatic aquifers varies from 4 000 ppm to 6 000 ppm and exceeds 8 000 ppm near Chotts.

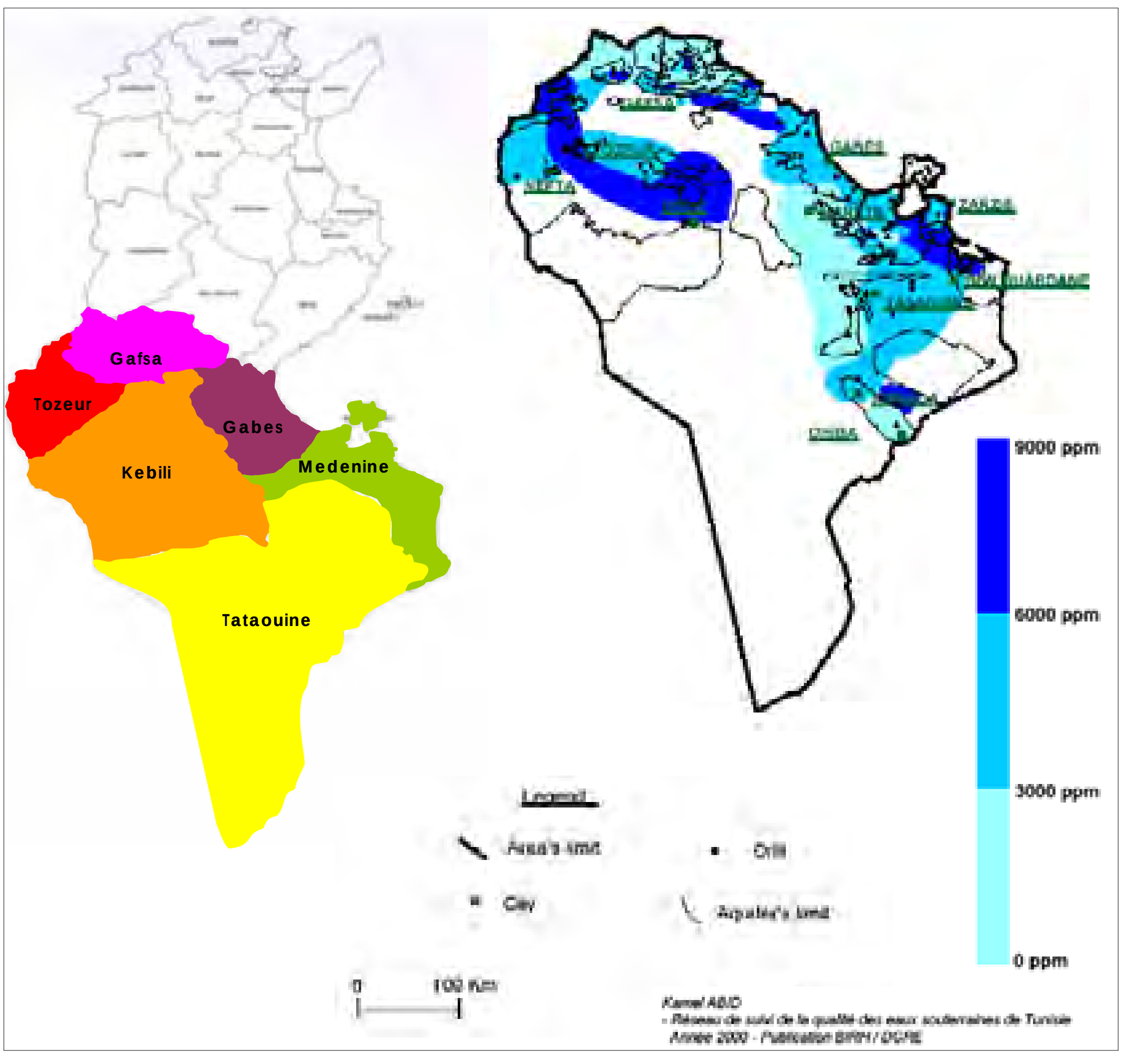


Figure 10. Distribution of salinity of the phreatic aquifers in the south of Tunisia

2.3.2. Deep aquifers

The global exploitation of the deep aquifers in Tunisia during the year 2001 is 1118.5 million m^3. She records thus an increase of 40.1 million m^3 in comparison with the one of 2000. This exploitation represents 79.7% of the total resources of the deep aquifers. (DGRE, 2000b). Table 8 shows the evolution of exploitation of the deep aquifers in Tunisia from 1991 to 2001.

Table 8.
Evolution of exploitation of deep aquifers from 1991 to 2001 (Millions m^3/year)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
North	65	74.8	87.4	96.6	101.9	101.9	106.9	110.6	115.1	124.8	133.2
Center	169.5	169.8	169.1	189.9	200.9	177.6	175.4	187.9	191.8	215.8	230.8
South	599	616.7	625.6	632.2	624.8	717.8	722.8	715.2	723.7	737.8	754.6
Total	**833.5**	**861.3**	**882.4**	**918.7**	**927.6**	**997.3**	**1005.1**	**1013.7**	**1030.6**	**1078.4**	**1118.5**

A recent study (DGRE, 2001) distributed the exploited deep aquifers between several classes of salinity in connection with water use (Table 9).
The salinity varies from 220 ppm in Kairouan gouvernorat to 24 000 ppm in Medenine gouvernorat. Deep aquifers water has a better quality 20% have a salinity degree lower than 1 500 ppm, 57% of resources with salinity between 1 500 and 3 000 ppm. The remaining part, or 23% have salinity greater than 3 000 ppm (Table 9).

Table 9.
Annual exploitation by class of salinity (DGRE 2001)

Salinity *(ppm)*	**< 1500**	**1500 to 3000**	**3000 to 5000**	**5000 to 7500**	**> 7500**	**Total**
Drinking water	97.5	61.6	15.1	9.7	0.0	183.9
Irrigation	147.8	555.2	142.8	14.9	0.1	860.7
Industry	8.7	16.3	17.2	12.0	14.9	69.1
Tourism	0.2	0.7	0.5	2.6	0.8	4.8
Total exploitation *(million m^3/yr)*	254.2 **(22%)**	633.8 **(57%)**	175.6 **(16%)**	39.2 **(4%)**	15.8 **(1%)**	1118.5 **(100%)**

Based on the above table, brackish and saline deep groundwater (more than 5 000 ppm) exploitation represents 55 million m^3/yr, which corresponds to 5% of the total annual groundwater withdrawal and is mainly allocated to industry and agriculture.

Brackish and saline deep groundwater resources are exploited mainly in the south of the country and in particular in:

- The Algerian border to improve the production of El Borma petroleum wells.
- The coastal zone between Oued Akkarit and Skhira Village at the convergence of groundwater flows coming from the northern Sfax Plain Aquifer and the southern Northern Gabes Aquifer, for industrial purposes.
- The south part of the Jeffara Plain Aquifer in particular at the level of Jerba Island and Zarzis region, for desalination.

2.3.2.1 Center region

The salinity of groundwater in the Center of Tunisia varies between 220 to 10570 ppm. The exploitation in Sfax governorate is distributed at 4.57 million m^3/yr (23.9 %) for the agricultural use, 1.34 million m^3/yr (7.01 %) for drinking water and 13.25 million m^3/yr (69.13 %) for industry. The resources of this deep aquifer are estimated at 30.5 million m^3/yr including 84 % for Sfax and 16 % for Mahdia. The total exploitation of this aquifer is 19.64 million m^3/yr including 19.16 million m^3/yr for Sfax, that is to say 75.14% of the exploitable resources estimated at 25.5 million m^3/yr. The salinity of this aquifer is between 2500 and 10570 ppm (Table 10).

Table 10.
Deep aquifers with saline water and resources of exploitation in the Center and South of Tunisia

Region	Number of Aquifers	**Salinity** *(ppm)*		**Resources** *(Millions m^3/y)*		**Exploitation** *(Millions m^3/y)*		**Rate exp.** *(%)*	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Center	58	220	10570	1.3	27.8	0	31.02	5	92
South	52	700	24000	2.8	53.6	0	296.41	0.45	97

2.3.2.2 South region

The South region of the country and characterized by two aquifers, the largest in Tunisia (the medium aquifer or CT: Complexe Terminal, and the deep aquifer or CI: Continental Intercalaire). These aquifers are the most important resources for the development of agriculture in the region, but they are rarely considered as renewable resources.

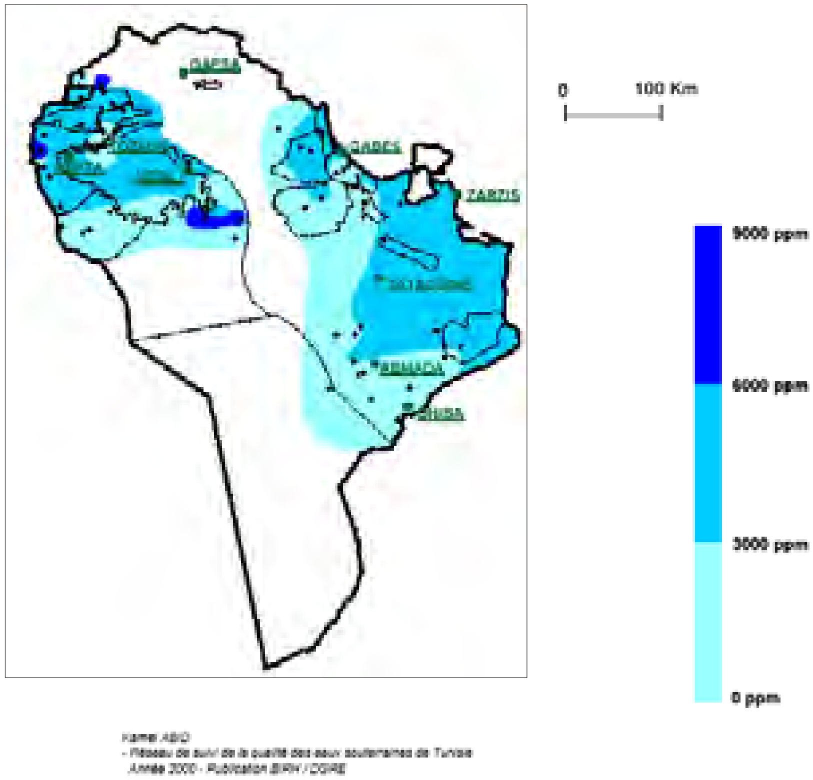
The Complex Terminal (CT) aquifer is constituted by a geological series of which the age goes Senonien to the Mio-Pliocene. His extension is of 350.000 km^2 of which a weak party only is located in Tunisia. The Gafsa and Tozeur regions are represented by the Djerid aquifer sandblasts Inferior Pontien. The study of the Final Complex aquifer showed that northern limit of this aquifer is marked by the chain of the mountains going Tamerza to Metlaoui. The direction of the general flow of the aquifer is done South towards the North, while to the North of Chott El Gharsa one attends an inversion of the due flow to the fact that this chain locally contributes to the nutrition of the said tablecloth.

This phenomenon implies an inversion of the chemical gradient:

- The Chott El Gharsa North aquifer, obtained by Shili, krichet-naâm and Thelja drillings. The salinity varies from 4 180 ppm to 4 750 ppm;
- The Djerid aquifer, obtained by El Gouifla and Segui drillings. The salinity of groundwater of this aquifer varies from 6 350 ppm to 7 700 ppm.

The Continental Intercalaire (CI) of the Chott Djerid is situated in the sands and gres albiensof Sidi Aich. The salinity of ground water of this aquifer is ranging between 2 000 ppm to 3 900 ppm (Table 10 and Figure 11).

1-Salinity of the Complexe Terminal aquifers in the south of Tunisia



2-Salinity of the Continental Intercalaire aquifers in the south of Tunisia

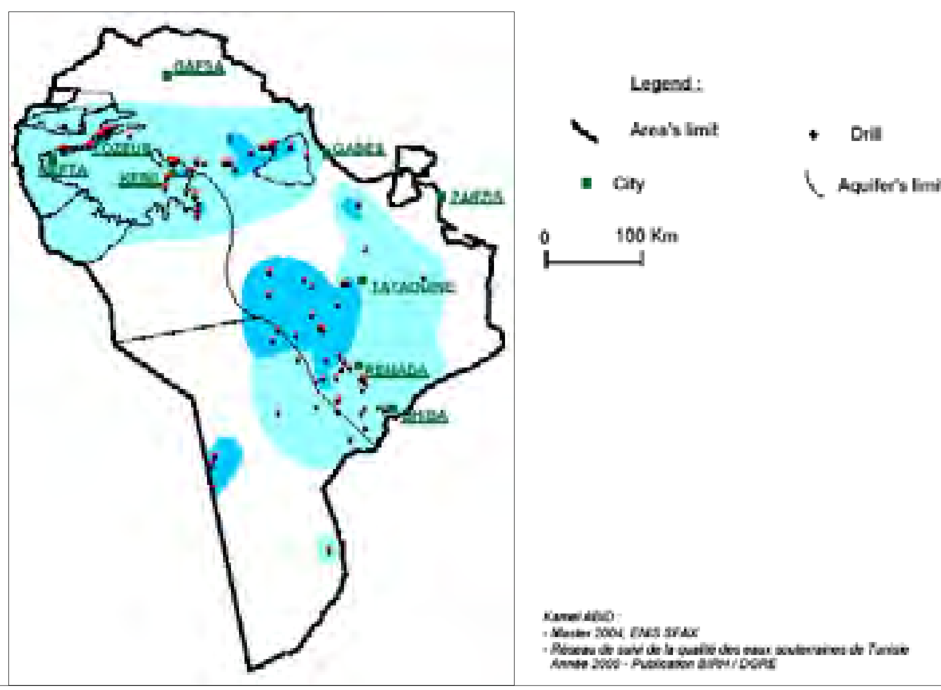


Figure 11. Distribution of salinity of the Complexe Terminal and the Continental Intercalaire in the South of Tunisia

3. RURAL POVERTY

3.1 Rural development

At 3.425 million people in 1994, although the rural population is tending to stagnate, and is expected to drop to 3.4 million in 2000, Tunisia remains a country marked by its rural character. Rural population accounts for 40% of the national total and contributes to less than 20% of GDP.

Agriculture represents the leading activity in rural and semi-rural areas and employs about 417,000 persons (43% of rural and semi-rural employment). Construction, public works and indirect activities employ about 303,000 persons, representing 31.5%. The remaining 241,000 are distributed between services and other occupations, i.e. 25.1% (INS, 2000).

The numerous rural populations exert high pressure on limited and fragile natural resources. The objective sought by Tunisian rural development policy is both the improvement of population's life conditions and the preservation of natural resources. The challenge is to reverse the process of natural resource degradation, whilst ensuring suitable incomes to an impoverished population. The way is to diversify non-agricultural income sources and intensify agricultural activities within the limits of resource constraints.

The National Solidarity Fund (Fonds de Solidarité Nationale "26-26") constitutes an original example in the field of poverty reduction. It was set up during the 8th Plan to meet the needs of impoverished areas and promote employment as well as building of infrastructure to improve the quality of life.

3.2 Evolution of rural development approaches

Since the 1970s, rural development has been addressed within five-year plans. For over a decade (1970-1980) partial solutions based on sectorial approaches were put forward for promoting employment and improving of incomes of an impoverished population. Results obtained did not reach objectives and natural resources continued to degrade.

Therefore, starting in 1984, the State was led to draw up Integrated Rural Development Programmes (Programmes de Développement Rural Intégré - PDRI) to reconcile natural resources protection and production. Some indicators show the positive impact of these programmes on improving the rural population's living conditions (between 1984-1994):

- The proportion of rudimentary dwellings dropped from 8.8% (1984) to 2.7% (1994);
- The rate of electrification increased from 29.3% to 63.7%;
- The percentage of the population with access to drinking water increased from 49.4% en 1984 to 68.3% in 1994.

Actions for agricultural development concern the creation of small-irrigated perimeters by means of dugwells and borewells, the development of fruit tree cultivation, the acquisition of livestock to integrate into farms, the improvement of pasturelands, the development of forage plantations to promote animal husbandry and above all logistical support to farmers. Basic infrastructure has been designed to develop services (marketing, packaging), create artisan skills, develop trading activities and facilitate income diversification.

3.3 Land and rural population

Rural population should decline from 3.425 million in 1994 to 3.6 million in 2000, 3.3 million in 2010 and 3.1 million in 2025. This contraction of the rural population will probably take place in the less favored mountain areas, with a reduction of resources overexploitation (tillage followed by erosion, deforestation etc.) In fact, the living population underneath the poverty threshold absolute is passed from 559 000 persons in 1995 to 399 0000 in 2000. The rate of poverty has records a decrease continues and significant from 12.95 in 1980 to 6.7% in 1990 and 4.2% in 2000 (INS, 2000).

The population and household number in the south of Tunisia of the fourth governorates (Gafsa, Tozeur, Kebili and Gabes) are estimated at around 840,200 (which accounts for 9.6% of the national population) and 148,700 respectively, with an average family size of 5.6. Population density was 6 persons per Km^2 in Kebili Governorate, which is very low compared to 57 persons per Km^2 of Tunisia average. Population in the fourth governorate summarized as follows in table 11. Number of the farmer’s household in the fourth governorate (Gafsa, Tozeur, Kebili and Gabes) in the south of Tunisia is estimated about 39600 or 32% of total household.

Table 11.

Population and household in the South of Tunisia (Annuaire Statistique de la Tunisie, 94)

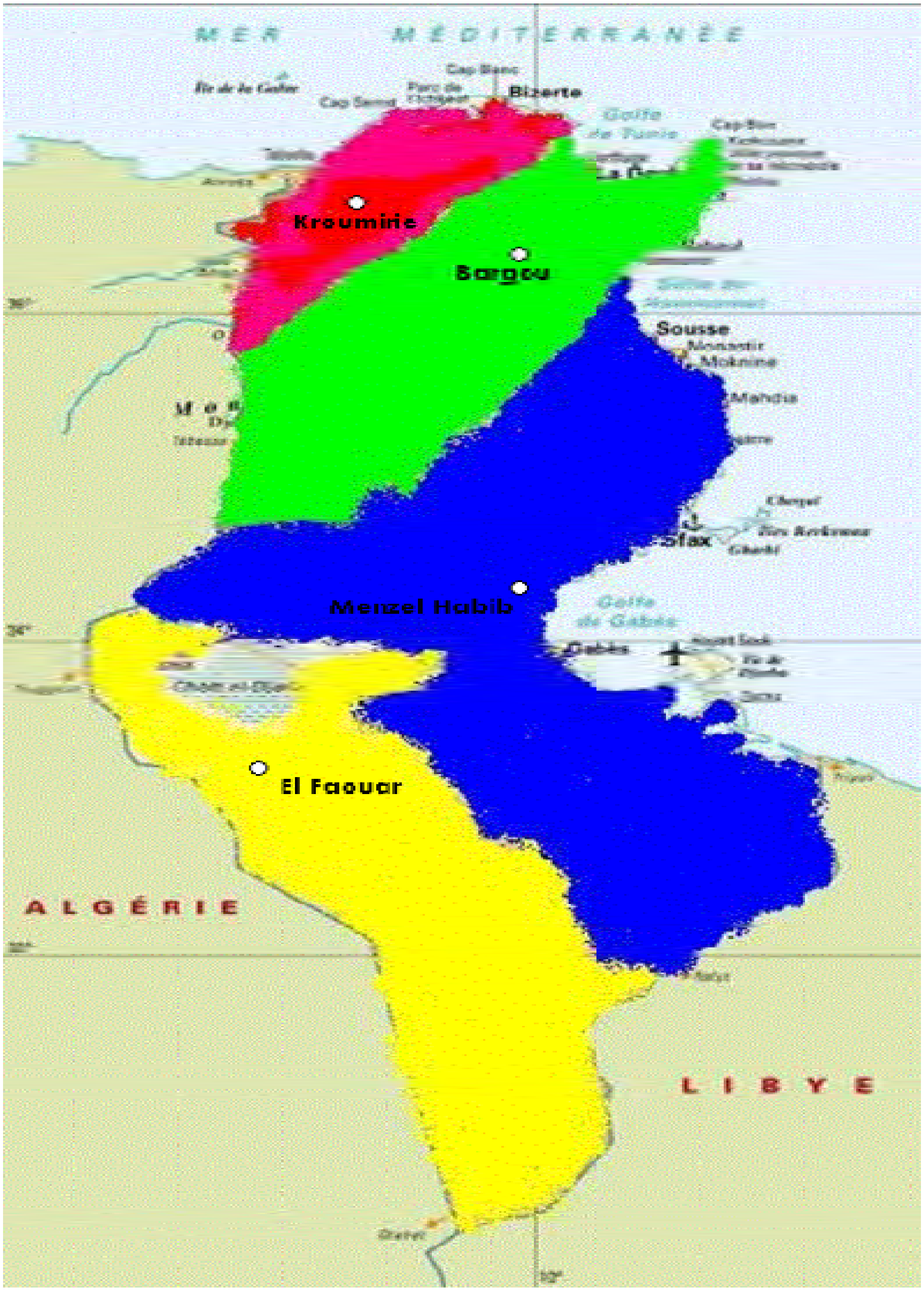
Item	Gafsa	Tozeur	Kebili	Gabes	Total
Population, 1994 *(Person)*	307513	89055	131914	311713	840195
Urban population *(Person)*	176193	63293	72198	195714	507398
Rural population *(Person)*	18504	25762	59716	87182	191164
Household Number	54330	16590	21316	56431	148667
Family Size *(per household)*	5.66	5.37	6.19	5.52	5.65
Total Area *(Km^2)*	7360	6159	22454	7505	43478
Population Density *(per Km^2)*	41.8	14.5	5.9	41.5	19.3
Population Growth *(%)*	2.7	2.7	3.3	2.6	2.8
Farmer’s number	5620	7060	9020	17900	39600
Person number	31000	37900	55800	98600	223300

The average farmland size in the South of Tunisia is estimated 0.38 hectares and ranged between 0.11 hectares and 5.13 hectares. The farmland size of new oasis is equalized distribution from 0.5 to 4.0 hectares.

The regional study MFAFMR98 of poverty shows a disparity inter-regional of the poverty rates. In fact, the poor population concentrates in the Center West and South of Tunisia and notably in the community zones of these regions. The rate poverty is 8.7% in the South West and 7.1% in the Center West and attains in the community zones of these regions 10.5% and 12.6% respectively. However, the rate poverty in the Center East and the North West of the district of Tunis is situated between 2 and 3%.

According to the inquiry realized by MFAFMR98, the rural zones of poverty are located in four zones (Figure 12).

Of peer with absence of salary, one notes a work feminine agricultural on the exterior exploitations. On the other hand, the women are numerous to affect a part of their time to the agricultural activities on exploitation of the family. This are altogether the half of them that participate in the agricultural works in the Kroumirie zones (49.5%) and El Faour (47.6%), and a little more quarter on the Bargou zones (28.9%) and in Menzel Habib (28.3%).



Kroumirie: mountainous and forest zone where threatens of the deforestation.
Bargou: in the High tell, is subjected to erosion of soils and to the deforestation.
Menzel El Habib: in the region of Gabes, knows the desertification problems.
El Faouar: oasis in edge of the Sahara, where the resources of water are starting to show signs of wearing out.

Figure 12. Location of the fourth rural zones according to the inquiry of MFAFMR98.

The sectors to which ones the women participate are diversified and hierarchies in a different way according to the sites:

- In Kroumirie, they participate very actively to the plantations and in a least way to plough and to the harvests.
- In Bargou, they are not implied in the plough but essentially in the harvests, with a small activity regarding weeding and of semis.
- In Menzel Habib, the feminine work covers all the agricultural activities in the important proportions.
- In El Faouar, this are especially the weeding activities and of harvest that are spring of the women.

The central role of the women in chore water (Table 12), particularly in the enclosed zones or the transportation does has itself foot or to backs of mule, as in the case in Kroumirie. The chores of water are an activity which take many times since they spend between 12.5 and 21 hours. For the households not disposing water in the lodging, chores are carried out with an average frequency of 12 to 20 times a week and in average time of 38 to 80 minutes according to the regions with equivalent of 2 to 3 days a week. Chore water is assured usually by the women and by schoolgirl.

Table 12.

Indicators of utilization of water resources by poverty zones in Tunisia (CREDIF, 2000)

	Kroumirie	Bargou	Menzel Habib	El Faour
Distribution of the investigated women	619	708	933	810
Percentage of the women single (%)	58.6	52.8	45.8	48.3
Percentage of the women participating in the agricultural works according to the age (%)				
10 to 19 old year	24.8	18.4	18.3	33.2
20 to 29 old year	64.0	30.9	40.0	52.8
30 to 39 old year	65.7	33.8	43.4	64.4
40 to 49 old year	73.3	35.4	35.6	70.0
50 to 59 old year	66.1	42.3	35.2	64.9
≥ 60 old year	40.0	33.9	8.3	34.4
Percentage of household's disposing a water resource in the lodging, connecting to the network, by a tank or a well (%)	8.0	27.8	66.6	82.1
Number of households dot have water in the lodging	287	216	106	57
Percentage of women assuring chore water (%)	95	72	81	98
Total average time to assure the chore water (minutes)	59	82	52	38
Average number of chore water per week for the household.	12.4	10.7	24.1	20.9
Average number of persons by household assuring chore water	1.2	1.4	1.6	1.4
Average time weekly by household devote to chore water (hours).	12.3	14.6	21.0	13.3
Proportion of households where, chore water is assured by an alone person (%).	81.6	64.7	55.7	64.3

3.3.1 Present conditions of women in Tunisia

Illiteracy rate of women in rural area is 66.1% and 37.6% for men according to the statistics of 1989 in Tunisia (CREDIF, 1994). However the illiteracy of girls between the ages of 10 and 14 in rural area is low, standing at 26% as shown in the figure 13.

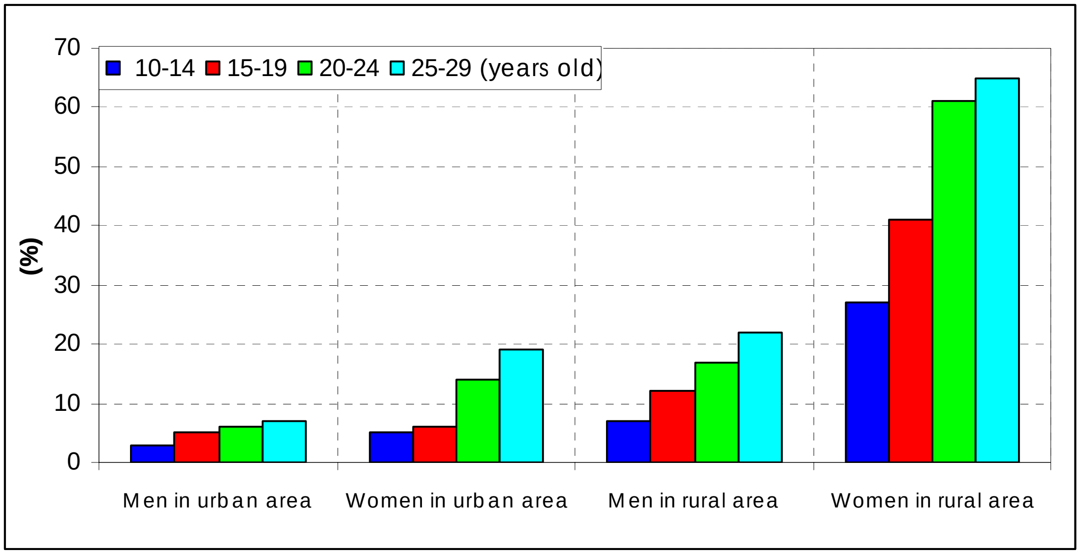


Figure 13. Illiteracy rate classified by age in 1998

3.3.2 Activities of women in the South of Tunisia:

In Tozeur: the date palm is a main crop and tenants called "accionnaire" manage the farm in irrigation and other farm work. Accionnaires have a right for one-fifth of date palm harvest and all of companion fruits tress and vegetables. Women customarily do not go out and make textile goods like rug, etc. at home.

In Gafsa: the main product is fruit trees and mainly olives trees. Women also work in the farm to weed and harvest and often work together. The Federation of Women of Farm is active and it participates in the exhibition of rural specialties for immediate sale held in Tunis several times a year Women seem to have more opportunities of going out for shopping, etc. than in other three gouvernorats.

In Gabes, main crops are fruits like pomegranates, apples, etc., though various cash crops including tobacco are cultivated. It is known for high quality of Henna and pomegranates. However few women participate in agriculture and they make crafts such as hat by palm leaves.

In Kebili: the oasis area is estimated at 15,500 hectares (51% of the total area in the country) and the oasis system is classified into three levels: the first, which is called the upper level is composed of date palms, the second one or the middle level is composed of trees under date palms (apple, fugue, grape, apricot, grenade, etc.) and the third one or the open field is composed of grass and vegetable cultivation. These three levels constitute the oasis system and are generally managed at the same time and irrigated with the same water. The cultivation of these three levels together makes a microclimate, commonly called “oases’microclimate.” People go there in the summer time for relaxation. Management of date palms is difficult for women as the work is on the palm trees and there is not much work for women in the farm.

4. PROSPECTS FOR BIOSALINE AGRICULTURE

4.1 Generality

The total area of the South of Tunisia (four governorates: Gafsa, Tozeur, Kebili and Gabes) is around 4.3 million hectares. About 1.7 million hectares or 40% of total area is used for agricultural purpose. The area of arable land is 433 thousand hectares and it occupies 26% of agricultural land. New forms of agriculture must be developed to utilize these changing farming conditions. The concept of turning saline land into a resource must be constantly encouraged instead of perceiving salinity as a problem.

Worldwide 131 species of halophytic plants are presently being studied. Potentially 250 commercial halophytes could be developed from the 10 000 salt tolerant plants that are known to exist. Opportunities are present and we must as individuals and as an industry explore them further. Tunisia has a huge biodiversity that is under developed and under researched. Many other countries are exploiting these resources in their quest to support their farm sector. We must continually ask how we support these ”potential” crops or industries in Tunisia.

4.2 Present Water management in the South of Tunisia

Water management of irrigation water is carried out by AICs and the water distribution is made based on the irrigation schedule decided by AIC with the assistance of PI of CRDA. AIC was established under the national decree, Law No.87-35 of 6 July 1987. The institutional development promoted mainly by CRDAs. The purpose of activities is to execute efficient operation and maintenance works for hydraulic facilities, which are turn over from CRDAs, and the AICs carry out the following activities to accomplish this purpose (Table 13):

- Operational works and maintenance works for hydraulic facilities;
- Administrative works for operation and maintenance works.

Table 13.
Management organization of AIC by gouvernorates in the South of Tunisia (Sanyu, 1996)

Governorates	Irrigation are *(ha)*	Irrigated are *(ha)*	Number of AIC	Number of member *(person)*	Number of executive *(person)*	Number of Worker *(person)*
Gafsa	3 467	3 294	8	6 105	64	36
Tozeur	5 622	5 622	44	7 356	253	50
Kebili	7 213	7 019	69	30 464	369	220
Gabes	7 133	6 752	48	17 777	204	176
Total	**23 435**	**22 687**	**169**	**61 702**	**890**	**482**

In general, one oasis is managed by one AIC, but some oases have plural AICs. As of October 1995, there are 153 oases in the fourth gouvernorates (Gafsa, Tozeur, Kebili and Gabes), in which 146 oases have AICs of 169 in total as shown in table 13. Only seven oases in Tozeur, three (3) traditional oases using natural springs and four (4) new oases where the terminal facilities are under consolidation, have not established AICs. The reason of non-establishment of AIC is that in case of the former oases, close coordination

on water utilization among the water users is not always necessary due to the easiness of operation and maintenance works for natural springs. However, in case of the later oases, the farmers aim to establish AIC organization after the completion of consolidation works. Thus most of farmers who have farmland in the oases recognize the role of AIC and join to AICs activities. Therefore, it seems that the AICs have borne the role as a management organization for operation and maintenance works of hydraulic facilities.
The actual allocation of irrigation water is executed by pump operators and valve keepers who are previously instructed by AIC office. Operation time for the water delivery is about 20 hours, which starts 23 and ends 19 in the next day. The actual water management at water sources facilities, water conveyance and delivery facilities, and terminal facilities are described in below (Sanyu, 1996):

1. **Water management water sources facilities**: Although three (3) kinds water sources, deep tube-well, shallow well and artesian well are used. Most of oases relied on deep tube-wells and have pumping stations The operation of pumping stations are made by pump operators, and the pumping water amount, pump operation time and operation condition are recorded in daily report. Though those pumping stations are properly operated, flow measurement meters at some stations shall be facilitated.
   Water cooling facilities are set up at water source sites in case of high groundwater temperature. They are operated and maintained by CRDAs and the temperature is controlled so as to be cool in less than 45°C

2. **Water management at water conveyance and delivery facilities:** Pipeline system with closed type is predominate as a water conveyance and delivery facilities, and ones of semi-closed type with a lifted tank also can be seen in the South of the Tunisia area. Reservoir with storage capacity for discharge control are facilitated only for irrigation net works with big dimension operated by CRDA, and ones of AIC have not such reservoirs. The monitoring and control of diverting water in the systems are executed by using flow-meters and presented valves

3. **Water management at terminal facilities:** The control of diversion water at terminal faci1ities is made by the adjustment of operation duration of valves of hydrants at terminal facilities, which is previously decided in accordance with the acreage of service area of the hydrants. The valve operation is executed by valve keepers. The farmer to be received the derivation service of irrigation water are previously informed about the date of irrigation from AICs and are waiting for the arrival of irrigation water at their field. However, the timely arrival of scheduled water at the field located at lowest part of field ditches is rarely achieved. And delay of irrigation schedule can be seen in many oases. One of the reasons is that most of field ditches (quaternary canal) in terminal facilities constructed by sandy soil with high permeability. Therefore, the water flow is very low than planned ones, another reason is that size of basin for water receiving is too big to irrigate on time.

The terminal system consists of quaternary canals and farm ditches for water distribution, and secondary, collector and field drains. Length of quaternary canals and above drains per hectare are 200 to 30 m and 50m respectively. The quaternary canals are mostly of excavated earth ditches, and hence percolation loss of distributed water through hydrant is fairly large. The improvement programs for water saving with public financial incentives to farmers in accordance with the national policy has been promoted under the instruction of CRDA.

Irrigation plan is determined by Associations d'Interet Collectif (AIC) with the assistance of the Commissariats Regionaux au Développement Agricole (CRDA). The irrigation interval is seven days in Gafsa and Tozeur, while twenty days and sixteen days in Kebili and Gabes, respectively. The maximum water requirement is estimated between 6.4mm and 7.9mm per day regardless water-loss through field ditch. Whereas the designed maximum net water requirements at parcel calculated from system capacities range from 2.0mm to 3.1mm per day which correspond to 29% to 37% of the estimated ones. This fact indicates that most of the irrigation areas are chronically insufficient in hot summer.

Utilization ratio of present irrigation facilities is defined as the ratio between actually consumed water volume at pump station and maximum capacity at hydrant calculated by using the data of irrigation plan such as number of sector, system capacity and system operation time. The obtained values are 54%, 60%, 87% and 67% in Gafsa, Tozeur, Kebili and Gabes, respectively.

4.3 Operation and maintenance cost and Water Charge in the South of Tunisia (Sanyu, 1996)

Operation and maintenance cost: The operation maintenance cost of system facilities is borne mainly by AIC and CRDA. The unit operation and maintenance costs depend on each local condition and range from 168 DT per hector per year. The present share of AIC is about 70% of the whole cost. AICs bears 125 to 232 DT per hector per year. Operation and maintenance cost of AIC mainly consist of personal expenses, electric charge and repairing cost of small spare-part. Among the items of costs, electric charge and personal expenses take high share of 62% and 20% respectively.

Water charge: The AICs collect association fee including above operation and maintenance cost and administrative fee. However total association fees, AICs annual budget, are not always the operation maintenance cost required. The budgetary deficits are observed in 42 AICs among 169 AICs. It is ruled that AICs return the negative balances in six months, and if they cannot return, the Governorates which have right of approve of their budgets compensate the balances instead of them. However, since some part of operation and maintenance cost must be borne by beneficiary, it will be necessary to raise water charge for the future. The average operation and maintenance cost is about 160 DT per hector, while net extra benefit can be expected at 900 DT in minimum per hector excluding annual repayment for construction cost. Therefore, the raise of water charge will be feasible.

There is four (4) kinds collection unit for water charge, per unit area per annual, per unit hour per annual, per unit hour and per unit quantity of water. In order to promote of water utilization in saving manner to farmers, CRDAs have recommended to AICs to change collection unit to per unit quantity of water by giving concept which irrigation water is also one economic materials.
The time of collection of water charge is different by governorate. The collections in Gafsa and Kebili governorates are ruled to carry out before water receiving, and in Tozeur and Gabes in year end after receiving water. Although the achievement rate of collection is 100% naturally in former case, the rate in latter case is more than 80%. Thus, the members of AICs recognize the necessity to pay water charge. It seems that the progress of consolidation projects for terminal farm promotes the higher achievement of the collection rate.

4.4 Prospects for Biosaline agriculture in the South of Tunisia

A considerable area of cultivated land in Tunisia, however, was undoubtedly also affected by salinity after the development of the canal irrigation system. This kind of salinity, identified as secondary salinity, is relatively temporary and can be easily eliminated by adopting appropriate rehabilitation measures. The important phenomena/activities, which have contributed to the development of secondary salinity are, lateral seepage from canals leading to waterlogging and subsequently salinity problems, and irrigation by poor quality.

Overall, climate has been the chief determinant of the kind and extent of salinity in different parts of Tunisia. In general, salinity is least extensive in the northern, sub humid parts, and most extensive in the southern, arid parts of the country. Salt composition, similarly, varies with climate, being dominated by carbonates in the sub humid regions, by carbonates and sulphates in the semiarid parts and by sulphates and chlorides in the arid areas. Thirty percent of salt-affected land in Tunisia also has sodicity problems (saline-sodic), having a pH value of more than 8.5, and sometimes around 10.

A wide range of management options is available for preventing or managing salinity problems in the South of Tunisia. In general, technical, economic, social and political considerations are major influences on the implementation of management options.

Biosaline agriculture is perhaps the best option for economic utilization of salt-affected soils for the time being, because it is a low-input (cheap) technology, is easily understood and adapted by farmers, and involves no foreign material or technical input. This technology has been tested at the laboratory level, at out-field stations, and on the farms of some progressive farmers.

Biosaline agriculture has great potential for application on saline and hyper-saline soils in the south of Tunisia, and might contribute to large-scale changes in regional coastal land use in the future, especially within the coastal sebkha in the south – East of Tunisia. Salinity-tolerant plant farms are already established in El Hicha in the south of Tunisia.

Irrigating with saline water would make many people quiver at the thought of it. It has seen many irrigation areas put at risk of environmental damage but where fresh water is limited in supply, saline irrigation is a real choice.

The major component of this technology is the development of agriculture systems using crops tolerant to salt and/or drought or water logging, such as grasses, shrubs and trees, for food, feed or fuel production. Livestock production is an integral part of this programme for maximizing the income from salt-affected soils. People like to eat meat and dairy products. As incomes rise, people tend to eat more meat and consume more dairy products. Meeting the increasing demand for livestock products without harming the environment is one of the many challenges facing agricultural development workers around the world.

Such salt-tolerant plants with high forage potential could dramatically increase the productivity of underutilized saline environments and increase forage production for domestic animals and wildlife. This may reduce grazing pressure on natural desert vegetation and conserve freshwater resources that are currently used in intensive forage production systems.

4.4.1 Implementation of the Demonstration Sites (Nasr, 2002)

There were 5 demonstration sites representative of the regional area with wasteland and saline groundwater that have been implemented at different saline environments.

- The Demonstration Site of El Hicha in Gabes that established at 1997 is the main demonstration site where the soil, water and plants have been monitored. It has 20 ha area and is covered with 30 plant species. These species are trees, shrubs, perennial and annual herbaceous. They have been chosen for food, forage, soil fertility improvement, wind breaks and wood production.
- The Demonstration Site of El Khessim, Medenine (1997), has 4 ha area and is covered with 12 plant species.
- The Demonstration Site of Menzel Habib, Gabes (2001), has 10 ha area and it is being extent to 15 ha. It is covered with 5 plant species.
- The Demonstration Site of Aïn Soltan, Kairouan (2001), has 5 ha area and it is being extent to a large area. It is covered with Kallar grass.
- The Demonstration Site of Saâdia, Kairouan (2001), has 3 ha area and it is covered with kallar grass.

4.4.2 Field screening and multiplication of useful salt tolerant plants

4.4.2.1. Selection of the suitable plants

Several plant species (trees, shrubs, bushes and herbaceous) preliminary showed to have a satisfactory success. This could be due to their adaptation to the prevailing selected site environments. The used plants at the demonstration site of El Hicha (Gabes) are *Kochia indica, Casuarina glauca*, Acacia cyanophylla, Acacia salicina, Acacia ampliceps, Acacia farnesiana, Periploca laevigata, Jojoba (Simmendsia chinensis), Atriplex nummularia, Atriplex halimus, Atriplex lentiformis, Atriplex mollis, Medicago arborea, Medicago sativa (alfa alfa), Prosopis juliflora, Prosopis stepheniana, Eucalyptus camaldulensis, Sesbania aculeata, Kaller grass (Leptochloa fusca), Pinus halepensis, Panicum turgidum, Ceratonia siliqua, Rhus tripartitum, Prosopis stepheniana, Artemisia herba-alba, Ziziphus lotus, Barley, Weat, Olive tree, Leucaena leucocephala and *Opuntia ficus indica* (cactus).

The selected plants at the Demonstration Site of El Khessim (Medenine) are *Acacia ampliceps*, Kallar grass and *Eucalyptus microtheca*. As this site is at the cost sea, the selected plants could be rather resistant to the atmospheric salinity than the other tested species.
The selected plants, at the Demonstration Site of Menzel Habib, which has desertified soil and very high saline water table (18 $g.l^{-1}$ salts), are *Kochia indica* and *Atriplex lentiformis*.
Kallar grass seemed to the suitable species for demonstration sites located at the saline low zones of Kairouan.

Folder plant species to be used in the demonstration sites are (as proposed by H.Nasr):
- Salt tolerant varieties of barley
- Synchrus eiliaris
- Panicum turgidum
- Medicago sativa var.
- Medicago arborea
- Herysaerum carnosum.

4.4.2.2. Germplasm production

Research at the National Research Institute for Rural Engineering, Water and Forestry (I.N.R.G.R.E.F), will shows that a salt-tolerant grass could help boost livestock production in the south of Tunisia using abundant saline water resources. The International Center for Biosaline Agriculture (ICBA), based in Dubai play undoubtedly an important and a leading international role in the development of halophytes and salt-water utilization.

The INRGREF is now coordinating the seed production of the selected salt-tolerant plants that have been implemented in several nurseries.

Seeds of kallar grass are yearly harvested at the different sites and supplied to the INRGREF where they are sown in pots and placed in a glasshouse. In the growing season (later spring), shoots of kallar grass are planted in the nursery. In summer, shoots are sent to being planted in the different field sites.

Seeds of Kochia indica and Sesbania aculeata are sown directly in benches located at the nurseries of the INRGREF, in Gabes, in Medenine and in Kairouan for seed multiplication.

Barley is cultivated at farms and each year there is a part of the grains is supplied to other new farms

Soft wheat is cultivated for seed production at the nursery of the Farming Centre in Medenine.

The seeds provided by the planted shrubs and trees are directly collected in the field.

The project will led to a positive socio-economic impact on the management of wastelands and irrigation saline groundwater in arid zones in Tunisia. Tunisia supplied important funds to ensure well implementation of the Project and to guarantee the sustainability of the activities that have initiated with the support of the IAEA. The obtained results provided some salt-adapted useful plants. Consequently, several farmers, in the demonstration site region, started to use some of the selected plant species mainly salt-tolerant barley.

5. CONCLUSIONS

Tunisia has developed expertise in the fields of water resources mobilization and integrated management in a context of aridity, water scarcity and social and economic constraints. This expertise has been supported from the outset by a national strategy, strong political commitment and increasing user awareness. The water sector has developed as a result of water-saving programmes, training, promulgation of laws governing regulation and development of information and decision support tools and extension techniques.

Prominent features of this expertise were:

- Mobilization of surface and groundwater, implementation of a network of water sources to allow water transfer and provide permanent water security and development of integrated management of surface and groundwater;
- Creation of and assistance to Water User's Association running water-management and hydraulic infrastructure in irrigation schemes, with a corresponding increase in awareness of water scarcity and need for rational use;
- Protection of the environment through allocation of water to protected sites;
- Increase of potential resources for irrigation of fodder crops by promoting using brackish or saline water.

Recent droughts have decreased the quality and quantity of surface water resources in this country and ground water is also suffering from salinity increase due to over pumping.
So, the quantity of good quality water supplies available to agriculture is diminishing. Therefore, the needs for new water resources are becoming more acute and pressing. It is very important that the irrigated agriculture makes use of marginal quality water such as saline water in a way that is technically sound, economically viable and environmentally non-degrading.

In the Mediterranean area Tunisia is an example, where the water resources for agricultural use are rather limited, and the extension of irrigated agriculture is only possible by using saline water. For this reason, extensive field research was already carried out in the 1960's, within the framework of UNESCO project (UNESCO, 1970).
The development of the agriculture production system necessity in general at the same time an amelioration of irrigation efficiency, and augmentation of leaching capacity by installation drainage systems. The issue of the strategic between the amelioration of irrigation and or drainage is difficult to be resolved because it depends on many factors, which are more technical than economic.

In Tunisia, irrigation differs from most regions because water resources are almost entirely tapped, brackish water is used at salt concentrations of up to 3 000 – 6 000 ppm higher than standard irrigation practices. Tunisia has therefore acquired considerable experience in using higher quality water.

The following points should be taken into consideration when Tunisia promotes a policy of water savings in irrigation:

- Tunisia is characterized by a climatic pattern in which average annual rainfall decreases from north to south. On average, farmers do not need much irrigation water in the northern part of the country, which is why existing schemes are underutilized except in drought periods.
- Water salinity is increasing from north to south. Water transfers from the north to central areas of Tunisia increase water availability and decrease water salinity in irrigation transfer schemes.
- With regard to equipment, the Tunisian water saving programme has not focused sufficiently on software such as farmer training in optimum use of the equipment. Use of brackish or salty water, for example, of which there is not much experience in the world, leads to the clogging of equipment.
- in the field. Such results would be valuable in the development of Tunisian water policies.

Drainage may have a role to play in some circumstances in South of Tunisia particularly tiled closed systems, if the economics of high value crops can justify the investment in salinity control measures. Cheaper surface water control measures and agricultural methods can be used to overcome freshwater waterlogging than drainage.

Four laws must be quote when we talk to use of saline or brackish water for agriculture.

1. First law: protect fresh-water crops from salt.
2. Second law: develop salt-tolerant varieties.
3. Third law: develop local halophyte species.
4. Fourth law: introduce domesticated halophytes.

These do have some credence considering south Tunisia’s record with introduced species. This methodology will merit in the problem solving process considering plant based solutions to salinity.

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