Chapter 8
Water Policy in Tunisia

Mohamed Salah Bachta and Jamel Ben Nasr

Abstract In Tunisia, climate varies from Mediterranean to arid and semi-arid. Water resources are characterized by scarcity and a pronounced irregularity. The water supply policy, with nearly 40% of agricultural investment in the 1980s, allowed to develop an irrigated agriculture and to create an undeniable productive potential. Despite the performances in irrigated agriculture, the water sector still suffers from economic, social, ecological, and institutional problems. The scarcity of water induced by the increasing demands of various economic sectors and climate change effects leads to the questioning of current allocations of the water resources. Given the economic model adopted and the current governance, water scarcity would be a major threat for sustainability.

Keywords Water demand · Scarcity · Climate change · Sustainability · Governance

8.1 Introduction

Tunisia has a predominantly semi-arid climate. Two-thirds of the country is semi-arid to arid. Both the climate and especially precipitation levels fluctuate greatly throughout the year and from year to year. These extreme variations observed can be seen in the form of droughts or floods, which can have serious consequences both ecologically and economically, including soil impoverishment, overexploitation of aquifers in the case of prolonged droughts, as well as variations in agricultural production and therefore, farmers' income.

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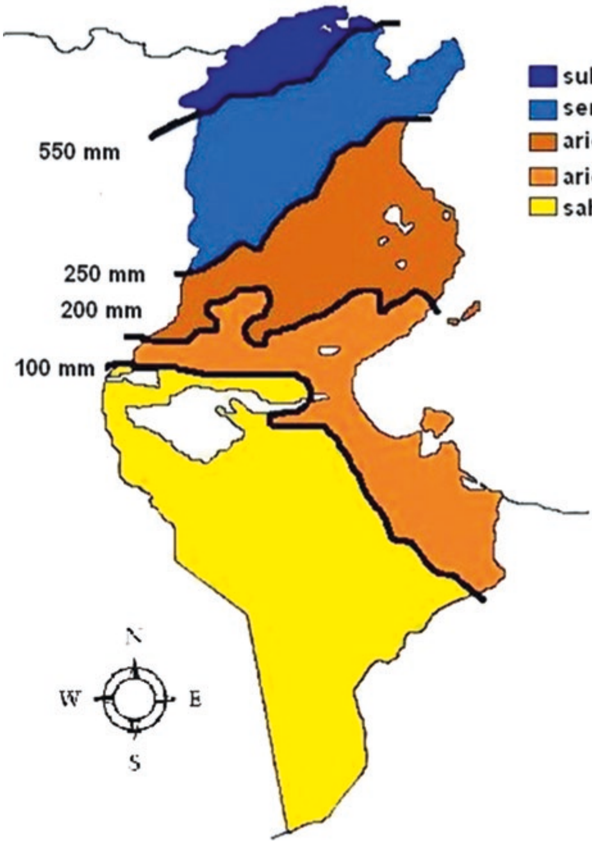


Fig. 8.1 Climatic and rainfall map of Tunisia. (Source: Hentati 2010)

To mitigate these fluctuations, the Tunisian government developed a policy aiming to increase supply of water resources and create irrigated areas. The water resources are estimated at 4.874 billion m^3/year from which 2.7 billion m^3/year are surface water. The rate per capita, 385 m^3/capita/year, shows that Tunisia has been in a situation of absolute water scarcity since the 1990s. Moreover, the availability of water, particularly surface water, has many regional disparities. Whereas in the north, which makes up around 25% of the total area of the country, rain varies from 400 to 1500 mm, approximately 60% of the country receives less than 200 mm a year (Fig. 8.1).

These variations necessitated the creation of a large infrastructure of surface water reservoirs in order to transfer water to areas with water scarcity, in particular, the coastline.

By the end of 2014, infrastructure included 33 dams with a total cumulative storage capacity of 2.237 Km^3, 253 hill dams with a total capacity of 266 million m^3, and 902 hilly lakes with a total capacity of 93 million m^3. This hydraulic infrastructure was developed during the pre-revolution (before 2011) sociopolitical context, with a strong State and a submissive society. Three Master Plans were developed and led to an inventory of water resources and the identification of uses. The legislation in the form of the water code of 1975 authorized the State to manage the water resources (assignment, transfer, and pricing). An omnipresent Administration was in charge of managing the infrastructure in place. This Administration exercised a discretionary power; consequently, all decisions were imposed via a top-down mechanism. In this natural and sociopolitical context, irrigated agriculture was designed and implemented. This technical and sociopolitical arrangement, however, suffers from many failings and seems to have reached its limit.

8.2 Legal and Institutional Aspects of the Water Sector

The analysis of the Tunisian water policies shows that the institutional framework of water management has undergone significant transformations. These transformations can be summed up in three decisive periods: The period of colonization (1881–1956) during which we note the deconstruction of the ancestral system of collective management and the establishment of a new system reflecting the despotism of the colonial authorities. The second period extends from the year of independence (1956) till the late 1980s (1989), and the nationalization of water resources through the creation of the development boards and the promulgation of the water code are the main features of this period. The third period runs from 1989 until the 2011 revolution, starting the water management transfer to the stakeholders in 1989 and the genesis of a series of emergence of new organizations and dismantling of the public ones. This development illustrates the progressive disengagement of the State in favor of a "collective" management of water resources.

The establishment by the colonial authority was marked by a process of centralization of natural resources, particularly water resources. An operation of destruction and destabilization of the traditional system of governance has begun to gradually install traditional management methods marked by the expropriation of local populations in favor of a despotic colonial administration. A despotic colonial system gradually replaced local institutions. New instruments have been created and imposed. The first decree sealing the centralization of water resources was promulgated in 1885. Legal forms of irrigation water management institutions have increased ranging from trade union associations of owners of oases created between 1912 and 1920 in southern Tunisia to special associations of hydraulic interest instituted in 1933 whose powers are similar to those of AIC which appeared in 1936. We also note the unification of regulatory texts. Nevertheless, these imposed institutional transformations clashed with disengagement and almost total rejection of the local population.

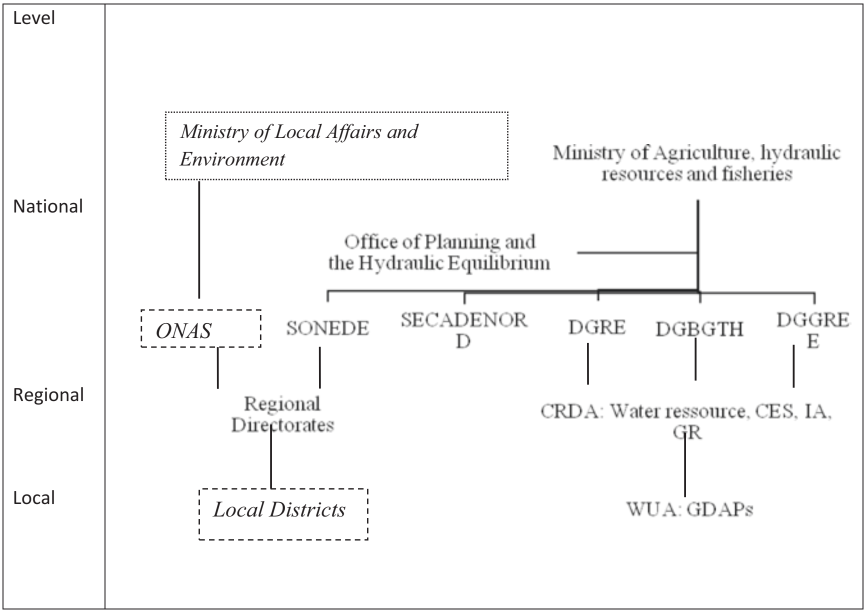
In the aftermath of independence, the Tunisian State relied on the establishment of development offices as an instrument for the management of the irrigated areas and supervision of farmers. The first office, the office development of the Medjerda Valley, (OMV) was established in 1958. It is in the mid-1970s that the water policy was most clearly defined with strong objectives for resource mobilization and allocation. This period was marked by the promulgation of the Water Code in 1975 (Law No. 75-16 of March 31, 1975) by the development and implementation of master plans and by the establishment of irrigation development boards in the main regions of the country. The promulgated Water Code clearly and definitively established the ownership of all water resources, transforming old property rights into use rights. Resource allocation priorities are set by the State through the Master Plans aimed at the precise identification of available resources and to plan their mobilization and allocation among the different uses in the three main regions of the country: the north, central, and south.

Since 1975, the management of the public hydraulic domain (DPH) was put under the auspices of the Ministry of Agriculture. Several technical departments were established, the most important of which are (i) the Directorate General of Water Resources (DGRE), which ensures the day-to-day management; (ii) the General Directorate of Dams and Large Hydraulic Operations (DGBGTH) for the feasibility and construction of dams, the exploitation of dams, and the development of large irrigated areas; (iii) the General Direction of the Rural Engineering and the management of water resources (DGGREE) for the implementation of the policy of development of irrigated areas, drinking water supply in rural areas, and the promotion of the water saving and associative management of water systems. This system is complemented by the Office of Hydraulic Planning attached to the Minister's cabinet, in charge of inventories of water resources and uses, as well as the planning and scheduling of water allocations (Fig. 8.2).

The Development Offices are regional establishments whose mission is the management of hydraulic equipment and the supervision of irrigators. External demands by international donors have forced the Political System (SP) to change the approach to undertake water management through market mechanisms or collective actions at the level of irrigator communities. The development offices in charge of irrigated areas were dissolved and user associations (AIC) were created from scratch. Thus, since 1990, management has been entrusted to "AIC", which were later transformed into "GIC" collective interest groups and then into "GDAP" Agricultural Development and Fishing Groups (Law 99-43 of May 14, 1999 as well as Law N ° 2004-24 of 15.03.2004) (Al Atiri 2006).

Wanting to keep control of water resources, the state has triply dominated the associations created (financially, technically, and politically). In these circumstances, the sustainability of these associations in terms of financial, political, and social issues seems problematic. The consequences of this institutional mechanism on resources are obvious: overexploitation and poor maintenance of equipment (Bachta et al. 2001).

The analysis of these institutional transformations and their impact on the performance of the management and exploitation of water resources has been the subject of several research projects conducted in Tunisia. The first approach considers the institutional mechanisms as major determinants of the action of the actors and giv-



Acronyms

CES: Water and soil conservation

CRDA: Regional Commissariat for Agricultural Development

DGRE: Directorate General of Water Resources

DGBGTH: General Directorate of Dams and Large Hydraulic Operations

DGGREE: General Direction of the Rural Engineering and the management of water resources

GDAPs: Agricultural Development and Fishing Groups

IA: Irrigated areas

ONAS: National Sanitation Office

SECADENORD: the Northern Water Canal and

Adductions Exploitation Company

SONEDE: National Society for Water Exploitation and Distribution

WUA : Water User Association

Fig. 8.2 Main actors of water management in Tunisia. (Source: Self-elaboration)

ing the absolute power to the organizational structure. The performance of the managers is considered as an endogenous variable. According to this methodological approach, Mokrani (2012) explains that the water allocation rule and the number of irrigators have proved to have an important explanatory power of the recovery rates recorded by the groups (GDAP) investigated. The second approach admits that the actors have the latitude to influence the structures in place and therefore enjoy a certain freedom in their choices (Ben Nasr 2015; Rekik and Bachta 2016). Ben Nasr and Bachta (2016) have shown that a greater involvement of farmers in the selection of the members of the management committees of these GDAPs and their participation on the definition of rules to adopt are likely to improve the performance of the GDAPs.

8.3 Agricultural Water

In Tunisia, two major types of farms are observed, the rain-fed and the irrigated ones. Under various incentives (economic, financial, and institutional) developed within the framework of agricultural policy, these two types of farming have achieved great advances. The irrigated area went from 62,000 ha in the 1960s to 450,000 ha in 2014. Rain-fed farms, in particular those in the central and southern regions, also expanded considerably, particularly the plantation of olive and almond trees. It should be noted that this type of farming is totally dependent on climatic conditions, drought in particular.

The undertaken investments resulted in an undeniable economic growth. The average annual growth rate of the agricultural gross domestic product was estimated at 3.5%. The irrigated farming system contributed 40% to the agricultural GDP on average and the value of agricultural production has seen significant interannual fluctuations (Hamdane and Bachta 2015). Despite the development of the other sectors of the economy, agriculture still represents a relatively significant part of the GDP with 11% on average. It is important to note that this performance required heavy investments in water reservoirs which are predominantly used for agricultural purposes.

8.3.1 Mobilization of Water Resources

A strategy of water supply was implemented and great efforts of surface waters storage marked the decades of 1970s and 1980s with the construction of large dams. During the following decade (1990s), small and medium-sized reservoirs represented the main public water investments. The objective was to reach control of 95% of surface water and groundwater resources. Table 8.1 shows that such a rate has been achieved for the surface water resources. Currently, Tunisia has 33 dams with a total capacity of 2.242 billion m^3, 253 small dams, and 837 hill lakes. Nearly half of the water resources are stored in large dams, 5% comes from small dams and mountain lakes, and the rest is from aquifers (ITES 2014).

In Tunisia, surface water is distributed among the three main regions of the country, as follows: Ninety percent is available in the north with 2190 million m^3 per year of which 1796 million m^3 is of high quality with salinity lower than 1.5 g/l. The center is with 320 million m^3 including 153 million m^3 with a salinity less than 1.5 g/l. The southern part of the country is with 120 million m^3 per year including 5 million m^3 with a salinity of less than 1.5 g/l.

Groundwater resources represent nearly 44% of all of the total water resources. The deep aquifers have the largest storage capacity. Their exploitation is reserved to the public authorities. Private entities can reach it only after obtaining proper authorization. However, illicit drillings abstracting these resources can be seen. On the other hand, no authorization is required to access aquifers, and thus, they are much

Table 8.1 Changes in surface water captured in Millions m^3

	Potential available water resources	Actual reservoirs capacity				
		1990	2000	2005	2010	2015
Large dams	2170	1170	1688	1927	2080	2170
Hill dams	195	5	125	160	190	195
Hilly Lakes	135	7	38	62	88	94
Total	2500	1182	1851	2149	2358	2459
Rate of surface water captured		44	69	80	87	93

Source DGRE (2015)

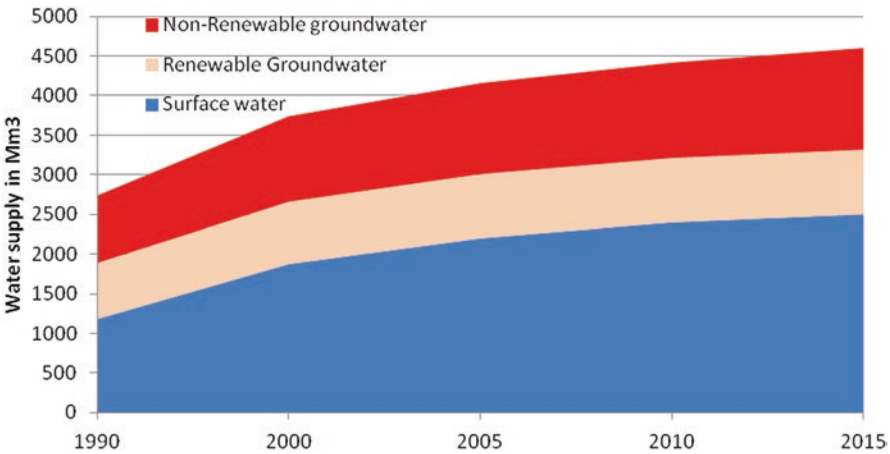


Fig. 8.3 Water resources in Mm^3. (DGRE 2015)

demanded. However, illegal drillings that capture these resources are observable. These practices are reported in the central (Kairouan) and southern (Kebili) regions – regions where water resources are the most in demand. In the region of Kairouan, the farmers manage to circumvent the prohibition texts by proceeding with deepening of their surface wells. In Kebili, local societies still have a certain capacity for organization, which gives them opportunities to collectively carry out locally determined actions such as extensions of palm plantations.

In parallel with the increase in the volumes of water withdrawn, the number of wells has steadily increased, reaching in 2010 more than 130,000 surface wells and 9300 deep wells (Hamdane 2014).

Figure 8.3 shows the evolution of the mobilization of all the exploited water resources.

Some 30 deep aquifers are overabstracted with a rate of abstraction 1.68 and a volume estimated at 315 Mm^3 (World Bank, cited by Elloumi 2016). For the shallow aquifers, the volume abstracted was estimated in 2005 to be 548 Mm^3 while the renewable volume is about 355 Mm^3. Thus, the deficit is estimate at 193 Mm^3"

(Hamdane, cited by Elloumi 2016). The overabstraction resulted in the degradation of the quality of the water, in particular an increase of salinity, as well as on the drawdown of the level of water table, pushing the farmers to deepen their well and complicating the sustainable management of the resource. As a response, the response from the government was a supply side policy by starting a strategy to recharge some of the aquifers with volumes varying between 30 and 70 Mm^3 per year.

8.3.2 *Reuse of Treated Wastewater*

The nonconventional water resources are limited mostly to treated wastewater and are estimated at approximately 232 Mm^3 in 2012 representing 5% of the total resources. It is estimated that wastewater in 2030 will reach 300 Mm^3 per year (ITES 2011). Sewage discharges are increasingly bulky and numerous, resulting in a more complex pollution to the receiving bodies, making them increasingly vulnerable. This pollution seriously threatens groundwater and surface water resources as well as beaches and other water environments.

As shown in Fig. 8.4 below, wastewater has not been the source of such a development.

From this figure, it can be seen that the agricultural use of treated wastewater remained, overall, below forecasts. The quality of the treatments and the constraints imposed by the law limiting the crop mix to be practiced are the variables put forward by the farmers to explain this underutilization. The reuse of the wastewater is more significant in the regions of the south and the center (Sfax and Mahdia) where

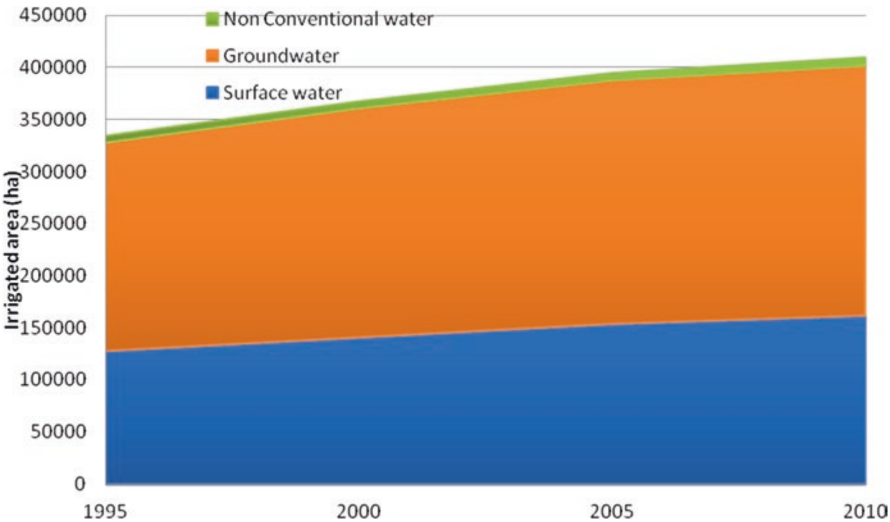


Fig. 8.4 Evolution of the irrigated areas by irrigation sources. (ITES 2011)

the cultural choices of farmers, olive trees, and forage crops correspond to the crops allowed by the legislation in place. To these variables should be added the absence of other alternative water resources which are otherwise completely absent, at least rare and coveted by other uses. Improving the quality of these waters through further processing, in accordance with established and institutionalized standards, could encourage farmers to use them. Thus, improved bacteriological quality of the treated water reduces the health risk for farmers and encourages them to use these waters (El Amami et al. 2003). The protection of the environment and public health could provide additional legitimacy for such improvements.

8.3.3 Pricing

The pricing of irrigation water has undergone successive adaptations. In fact, at the beginning of the service of the main irrigated areas, the tariffs were kept at low levels to encourage farmers to adopt irrigation. The cost of providing water services for irrigation has weighed heavily on the state budget. The agricultural structural adjustment program and the devolution of the irrigation institutions to farmers led to the search for water cost recovery rates as an important objective in the management of the irrigated areas. Successive increases to the irrigation water prices have been decided. A rigorous policy of annual increase of irrigation water prices has been implemented since 1991 and prices have been increased by 9% in real terms. Such rates are generally higher than those recorded by the prices of other factors of production and those of the producer prices of most agricultural crops (Hamdane and Bachta 2015). This policy has been observed in most governorates, but in a less sustained manner in some central and southern governorates.

As a replacement for the governmental irrigation (Offices de Development), user associations were created and then generalized. During the last decade, each association has been authorized to set its selling price level and its water pricing method, taking into account its budget balance. Currently, there are different modes of pricing in the irrigated areas. Each tariff system is influenced by the type of management of the irrigated area, the equipment in place, and the cropping systems. In the irrigated areas equipped with meters, a single pricing method has been adopted. In the absence of meters, the pricing becomes lump sum. Billing takes into account only the areas declared and the price per cubic meter. It is obvious that this alternative pricing does not encourage the farmers to value the resource and does not reduce the waste. Irrigation water pricing can also be per ha. It is practiced in southern oases where water demands are relatively uniform. This mode covers 7% of the total Tunisian irrigated areas. Sales by the hour is another mode of pricing practiced in the old irrigated areas with open networks of the lower valley of Medjerda river and the irrigated areas of the south and the center.

Finally, the two blocks pricing mode consists of a fixed term payable per ha and a variable term depending on the actual consumption of water. Dual pricing is an incentive to increase the demand for water. Indeed, the average price of m^3 will decrease when the quantity consumed increases. It is therefore recommended in irrigated areas where intensification rates remain low, especially in winter and where the supply of water is higher than the demand. In addition, this pricing method provides fixed revenues to the manager and is a cost-sharing instrument within an area among all owners. Thus, in order to guarantee regular revenue to the managing institution of the irrigated areas, the move to block pricing was introduced by public authorities from 1999 to 2000 on the large irrigated areas of the north in particular.

This diversity of pricing methods leads to significant variations in water prices paid by irrigators. Zekri et al. (1996) have shown that groundwater prices vary considerably between regions and in the same region. The authors explain these differences in water prices by the effects of economies of scale.

The policy of increasing water tariffs faced several constraints including the low rate of intensification, the abandonment of irrigation in winter, and the shortage of water. In addition, these tariffs are set without any link with the payment capacities of farmers. Such a demand management tool is totally ignored by irrigated areas managers. Kefi (1999) and Kefi et al. (2004) showed that in the irrigated areas of Kairouan, farmers' ability to pay depends mainly on the crops grown, the irrigation technology adopted, and the management method. They concluded that the increase in tariffs must be accompanied by measures that improve the economic valuation of water: more efficient irrigation practices and mainly the introduction of value-added crops.

8.3.4 Irrigation Efficiency

Studies conducted in different irrigated areas in Tunisia still show relatively low technical and economic efficiency scores (Albouchi et al. 2003; Belloumi and Matoussi 2006; Dhehibi et al. 2007; Dhebi and Telleria 2012; Ben Nasr et al. 2016). Thus, efficiency gains are still achievable through the implementation of production technologies that save water, increase land-use rates, improve crop yields, the limitation of land fragmentation, and the reduction of interfarm conflicts. The different components of the increase in efficiency should lead to a better valuation of this resource increasingly coveted by other sectors of the economy.

In this logic of improving the value of irrigation water, the State has implemented panoply of reforms and actions, including, in particular, (i) reforms of demand management through rehabilitation and the modernization of the hydraulic infrastructure; (ii) the financial and technical incentive to save water, within the framework of a National Program for Water Economy (PNEE); and (iii) the creation and institutional strengthening to empower users in the management of water distribution and the maintenance of tertiary networks.

The National Program for Water Economy in Irrigation (PNEE) was adopted in 1995 This program has been widely disseminated with the extension of the modernization of irrigation water systems, which has been favored by the political decision to increase the grant allowed to modern equipment of irrigation [40, 50, and 60% of the cost of investments, respectively, for large, medium, and small farms]. From 1995 to 2010, the total investments made under this program were estimated at 937 MD, including 468 MD in financial incentives from the State. A relative progress has been recorded, thanks to the program under consideration; the rate of equipment in water-saving technology has increased from around 37% of the total area irrigated in 1995 to 83% in 2010 and 87% in 2012. The total area equipped in 2012 by the PNEE is estimated at 365000 ha of which 90,000 ha is in improved gravity irrigation, 116,000 in sprinkling, and 160,000 in localized. Localized and sprinkler irrigation has introduced innovations such as fertigation.

It is hard to believe that this program has resulted in a reduction in the overall demand for irrigation water. Consumptions per hectare have certainly decreased. The adoption of this program led, on the one hand, to an extension of irrigated surfaces and, on the other hand, an increased energy required by new irrigation techniques.

Most of the groundwater comes from deep aquifers in the south, the largest of which is nonrenewable fossil groundwater (610 million m^3/year, which represents 42% of deep aquifer resources). The total contribution of these aquifers is estimated at 1429 million m^3 per year.

Groundwater quality is generally poor. Nearly 84% of these resources have salinity levels in excess of 1.5 g/l. The overabstraction of these aquifers, estimated on average at around 103%, is one of the determinants of the deterioration of their quality. This average hides important interregional variations. The governorates of Nabeul with 154%, Kairouan with 123%, Kasserine with 112%, and Kebili with 179% are the most affected.

The major consequences of this overabstraction are a significant lowering of the level and prospects of disappearance of shallow aquifers and the gradual deterioration of the chemical quality of water. These consequences would result in excessive increases in treatment costs of these waters and an aggravation of the deterioration of their quality. Such developments would make future uses of these waters truly problematic and could put an end to their use.

Groundwater, whose potential is estimated at 846 Mm^3, is suffering from overexploitation, which has reached 139% for some groundwater in the center of the country. All pumped volume are used for irrigation, as only 2% is less than 1.5 g/l.

For the future, the resource-use adequacy considered by the "Eau XXI" study (see Table 8.2) focuses on the rather moderate evolution of domestic, industrial, and tourist water demands. Volumes allocated to the irrigated sector are revised downward due to competition from other sectors of use. Measures to encourage farmers to use water-saving techniques and to adopt lower-water demanding crop varieties, rear-season crops, and short-cycle varieties would lead to a significant reduction in the allocation of irrigation water. Thus, the average allocation per hectare would decrease from around 6000 m^3/ha in the 1990s to 4350 m^3 by 2030. The total allocation to the sector would thus be revised from 2150 Mm^3 in the 1990s to 2035 Mm^3 at the same horizon. The only possible compensation for the irrigated sector is the use of treated wastewater; a volume of around 220 Mm^3 would be made available

Table 8.2 Evolution of water demand by use (Mm^3: Million cubic meters)

Water Uses	Horizons				
	2010	2015	2020	2025	2030
	1. Urban water				
Domestic	381	410	438	464	491
Industrial	136	150	164	183	203
Tourism sector	31	33	36	39	41
Subtotal	**548**	**593**	**638**	**686**	**735**
2. Agricultural water	**2140**	**2115**	**2082**	**2058**	**2035**
Irrigated areas (1000 ha)	410	417	433	450	467
Volume in m^3/ha	5200	5000	4800	4600	4350
Total	**2688**	**2708**	**2720**	**2744**	**2770**

Source: MARHP (2000)

Table 8.3 Evolution of the share of irrigated agriculture in exports

	Value of exports (1000 DT)				
Year	1995	2000	2005	2011	2015
Total agricultural exports	462,000	628,200	1,225,600	2,126,300	3,647,000
Irrigated agriculture					
Dates	58,300	52,700	131,500	297,500	445,300
Citrus	10,600	9800	15,200	18,700	23,000
Drift of fruits and vegetables	39,800	71,200	63,000	116,000	92,900
Vegetables	0	0	22,200	103,400	97,000
Total irrigated agriculture	*108,700*	*133,700*	*231,900*	*535,600*	*658,200*
Share of irrigated agriculture (%)	*23,53*	*21,28*	*18,92*	*25,19*	*18,05*

Source (ONAGRI, several years)DT: Tunisian dinar

for irrigation by 2030. Such use could concern land not far from wastewater treatment plants, usually located outside urban centers.

The content of Table 8.3 will be interpreted as the result of projections aimed at testing hypotheses of changes in the various components of the water resources-use balance sheet. These simulations should test the feasibility of a balance between supply and demand for water.

These projections have highlighted the necessity to reduce the need for water per irrigated ha to observe the water balance. It is important to question the technical and sociopolitical feasibility of such an assumption, the implementation of which seems to be taking into account the controlled technologies and the capacity of irrigators to manage situations of shortage, which is particularly problematic. In fact, the limited availability of surface water recorded during year 2017 led irrigation water managers to ration the supply of this resource.

8.4 Water Property Rights

The water code of 1975 converted all private property rights of water into use rights as a consequence of instituting the nationalization of the water resources which is an eminently political decision. Through this decision, the state has given itself the legitimacy to reconfigure the interests involved. The water code indeed authorized the State to control all the resources, their allocation between sectors and between regions and this, without reference to society. For example, water transects from the north to the center have been decided and implemented and the supply of domestic water is considered a priority over other uses.

8.5 Food Security vs Virtual Water/Food Imports

The flagship products exported by Tunisia are, with the exception of olive oil, particularly demanding in water. We talk about dates and citrus fruits. While palm trees are irrigated by fossil water, citrus fruits require the transfer of water from the north via the Medjerda-Cap Bon canal. The selection of current production mixes has allowed irrigated agriculture to make a significant contribution to total exports of agricultural products. Table 8.3 traces the evolution of this contribution.

This table shows an increase in the share of irrigated crops in total agricultural exports. Despite this steady growth, the contribution of the irrigated sector remains below that of olive oil estimated at around 40% on average of agricultural exports. Cereals with low irrigation requirements constitute the bulk of our imports of agricultural products. The food security interpreted by the government as the trade balance of agricultural and food products could result in a negative balance of the exchange in terms of virtual water.

8.6 Water Salinity

In Tunisia, conventional water resources are naturally affected to varying degrees of salinity. About 74% of the country's surface water has a salinity less than 1.5 g/l (82% of the waters in the north, 43% of the waters in the center, and 38% of the waters in the south). With regard to groundwater, only 8% of the resources have a salinity lower than 1.5 g/l and 21% have 4 g/l and more. About 20% of deep underground resources have a salinity less than 1.5 g/l, 57% have a salinity between 1.5 and 3 g/l, and the remaining 23% have a salinity exceeding 3 g/l. In summary, the salinity of waters exploited for irrigation purposes is as follows (Table 8.4).

Table 8.4 Salinity classes of conventional resources used in irrigation

Class of salinity	Volume in Mm^3	% of volume
S < 1.5 g/l	527	25%
1.5 < S < 3 g/l	791	37%
3 < S < 5 g/l	586	28%
S > 5 g/l	220	10%
Total	2124	100%

8.7 Urban and Drinking Water

Urban water with its drinkable and industrial components is considered a priority use compared to agricultural uses. It must also be of better quality. Under the effects of demographic growth, especially urbanized populations, but also the improvement of the standard of living of the population and diversification of the Tunisian economy, the share of this water in total uses will only increase in the future. This increase will be to the detriment of the agricultural sector (MARHP 2000).

The rate of access to drinking water is relatively satisfactory in Tunisia. In fact, the drinking water supply rate in urban areas is 100%. These national averages hide inter- and intraregional disparities. In rural areas, it rose from 30% in 1985 to 93.4% in 2012. Despite this remarkable increase and improvement, the rural service rate remains particularly low in the northern regions of the country (Bizerte, Beja, Kef, Jendouba and Siliana), although 80% of the surface water comes from these regions (BPEH 2013). Another form of regional inequity problem is confirmed here. These governorates have the lowest service rates (87%). Both the dispersal of habitats and the isolation due to the topography in rural areas of these regions do not facilitate the supply of the conquered populations.

The unconventional water resources considered are those derived from seawater desalination. Desalination of brackish water has been already taken into account in groundwater uses. Three seawater desalination plants were considered: that of Djerba with a capacity of 18.5 Mm^3/year that will be allocated to drinking water and that started operation in late 2018; a desalination plant in Sfax with a capacity of 73 Mm^3/year of which only 50% will be available in 2020 and the rest by 2030; and that of Zarrat, governorate of Gabes, with a capacity of 18.25 Mm^3 which will be totally dedicated to drinking water and available from 2020. A seawater desalination plant for the industrial needs of the Tunisian Chemical Group in Gabes is scheduled for 2020 with a capacity of 10.95 Mm^3/year.

Domestic water is metered and billed according to a scale of tiered pricing with several quarterly water consumption bands. The pricing system, which is the same for all the country, has seven consumption bands with a single tariff per bracket. Rates range from 0.2 dinar/m^3 for the first social block (0 to 20 m^3/quarter) to 1.315 dinar/m^3 for consumption greater than 500 m^3/quarter. It should be noted that a single tariff of 1315 Tunisian Dinar/m^3 is applicable to the tourism sector (SONEDE 2017).

8.8 Water and the Environment

ONAS (National Sanitation Office) is the only operator responsible for the collection and treatment of wastewater. Around 90% of the urban population is connected to sanitation networks. The number of inhabitants connected to the sewerage network is estimated at 6.3 million in 170 communes supported by ONAS. With a total of 110 wastewater treatment units, the total volume treated is 232 Mm^3/year in 2012 (BPEH 2013). Given the potential for rain-fed agriculture, treated wastewater is little used in the northern regions. In some cases, they are therefore surplus and a source of pollution. In the southern and central regions, the use of these waters is limited by the degree of treatment below the required standards; handling also remains a source of pollution.

The environmental water component accounts for about 2% of total available water. This water is essential for the maintenance of the ecosystems and hence for sustainable development. It should not suffer from reduction and should even be increased as much as possible (ITES 2011).

Regarding the allocation of soil irrigated by the saline water, there are about 60,000 ha of land sensitive to salinization and 75,000 ha subject to an enhancement of the aquifers in the irrigated areas in north and south in particular. On the other hand, it is estimated that about 60% of the public irrigated land in Tunisia is moderately to highly sensitive to secondary salinization following irrigation; this rate reaches 86% in the private irrigated areas. These salinity risk categories are shown in Fig. 8.5 below.

In addition to these uses with socioeconomic objectives, it is important to highlight the needs of eco-systems in blue and green water. Blue water is used in some cases as a source of environmental balance. Lake Ichkeul illustrates the case of an ecosystem dependent on a complex hydrological balance. This balance results from seasonal freshwater inputs from six streams flowing into the lake and water movements between the lake and the sea via the Tinja Canal.

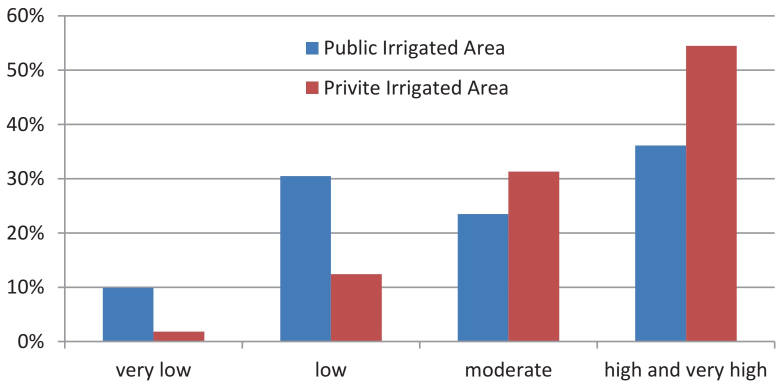


Fig. 8.5 Soil salinization risk classes. (MARHP- DG/ACTA 2005)

When the inflow of water is high, due to winter precipitation from October to March, the lake level increases, its salinity drops, and the excess water flows into the sea On the other hand, with low flows of freshwater, the level of water in the lake decreases, and the flow between this lake and the sea is reversed. The salinity of the waters of this lake will only increase. From 1992 to 2002, the hydrological balance was disrupted by two prolonged droughts and the diversion of a large volume of water from the streams that feed the lake. The lake's ecosystems were significantly affected, and there was a decline in lake productivity, a loss of key habitats, and a dramatic decrease in waterfowl populations using the lake and surrounding areas (ANPE 2004).

The intensification of agriculture can lead to the degradation of fertility and the pollution of irrigated land. A survey carried out in 2007 (Directorate of Soils, DG/ACTA) as part of a study on the evaluation of land degradation forms in irrigated areas revealed in particular the following facts relating to fertilization and pollution in these irrigated areas.

The decline in fertility of irrigated soils constitutes a dominant form of degradation in relation with the modification of certain physical, mineralogical, chemical, or biological properties of the soil (degradation of the structure due to lack of organic matter, loss of major nutrients, etc.). This change affects the overall quality of the soil and can lead to an often significant decrease in crop yields with significant economic consequences in the long term. The phenomenon in question affects about half of the public large irrigated areas surveyed.

Chemical pollution in irrigated areas is mainly due to the misuse or inadequate use of mineral fertilizers and crop protection products. It threatens in the long term 28% of the irrigated areas with localized low-to-medium pollution risks.

In some cases, particularly in the oases of south, hydromorphic signs due to lack of drainage systems are observable, such as the oases of Hezoua and Ibn Shabbat in Tozeur and the oases of Tarfaya in Kibili. Water logging damages soil structures and affects the growth and productivity of date palms. During the rainy years, in the northern region, particularly in the upper Madjerda Valley, 4000 to 5000 ha are submerged by runoff water (the case of Bou Salem in Jendouba). The water logging negatively affects crops, soil structure, as well as livestock and habitats.

It should be noted that the intensive use of nonrenewable resources threatens the sustainability of these resources. This situation essentially characterizes the oases and some of the irrigated areas which consume about a quarter of the water supply for irrigation in the country. Despite the implementation of careful planning and monitoring of these resources, signs of overuse and loss of the shallow aquifers are worrying for the future (see the case study of large illegal extensions of the oases at Kebili). This can seriously affect the salinity of the resource and increase the energy costs for abstraction. These risks are very serious for the south and constitute a challenge to the sustainability of date production, which is currently the mainstay of the economic development of certain regions of the south.

8.9 Energy–Water Nexus

The direct consumption of energy in the agricultural sector is estimated at about 7% of the country's total energy consumption, of which 2% is for irrigation. The consumption of this form of energy is generally fluctuating according to the climatic conditions. In fact, climatic factors determine the total area requirements of irrigated land and subsequently the energy requirements for irrigation. However, consumption of this form of energy has increased at a very low rate over the last decade, with an average of 1% per year. It is noted that total electricity consumption of the agricultural sector has been growing regularly in recent years, with an average of 6% per year. This is due to the replacement of diesel pumps with electric pumps. This increase in electricity consumption is due to the rapid growth of electrification for pumping due in part to the adoption of water-saving techniques. These technologies need an important quantity of energy (STEG Several years). The following graph relating to the number electrical agricultural connections to the electricity grid for Medium Voltage (MV) and Low Voltage (LV) shows such an evolution (Fig. 8.6).

Increasing use of energy, especially electricity, has not translated into real savings in water.

The desalinated water comes from brackish water or seawater. Thanks to the competitive cost of reverse osmosis desalination, it is becoming a valuable and economical source of water supply. Thus, the installed desalination capacity is currently estimated at about 138,000 m^3/d.

Energy consumption by the agricultural sector and the water sector is continuously increasing. Between 2015 and 2016, there was an 11% increase in the consumption of energy for pumping fresh water and treated wastewater and a 6.7% increase for agricultural water pumping. The total electricity consumption for the agricultural sector reached 1286 Gwh in 2016 including 602 Gwh for agricultural activities and 684 Gwh for water pumping energy (STEG 2016).

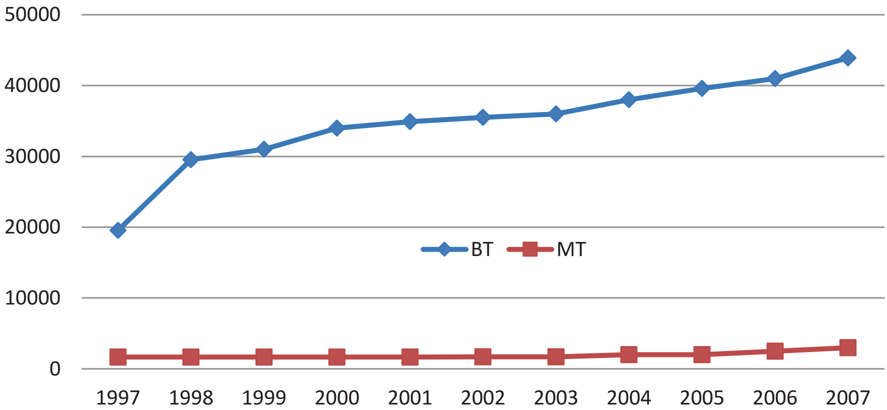


Fig. 8.6 Evolution of the number of subscribers to the electricity utility: Low voltage (LV) and medium voltage (MV). (Source Several years)

8.10 Special Issues

8.10.1 International Water: Conflicts, Negotiations, and Agreements

The two main aquifer systems in the south of Tunisia are transboundary resources with the majority of the corresponding surfaces located in Algeria (68%) and Libya (24.3%). Algeria withdraws 1.3 billion m^3 per year, or 60% of total withdrawals, followed by Tunisia with 0.540 billion (24.6%), followed finally by Libya with only 0.340 billion m^3 (15.4%).

The scenarios developed in the framework of the Northern Sahara Aquifer System project (SASS) all converge toward the more or less controlled increase in abstraction with significant effects in terms of the depletion of aquifers, up to 300 m for some aquifers. Total abstractions estimated at 600 Mm^3 per year in 1970 increased to 2.2 billion in 2000 and are expected to reach 8 billion m^3 in 2030 (OSS 2008, cited by Elloumi 2016). More broadly, the SASS program draws attention to the problem of these shared aquifers which is quite complex and which requires coordination between the authorities of the three countries.

In fact, the Tunisian authorities are caught between, on the one hand, a regulation of the abstractions by a strict control of the wells development and a race in the neighboring countries in order to make the most of such fossil and low renewable resources.

Oued Madjerda, which is a major source of surface water in Tunisia, is also shared with Algeria. Consultation mechanisms, particularly in case of flooding, are observed.

8.10.2 Climate Change Effects

Like all African countries, Tunisia will not escape the impacts of climate change phenomena despite its insignificant emissions of GHG compared to the global average. All the studies carried out over the last 10 years were based on the climate projections from the 2007 study on the adaptation strategy of the agricultural sector and ecosystems to climate change, which were also used in the second national communication published in 2014. These projections provided for an annual average increase in temperature concerning the whole country of +1.1 °C by 2030 and + 2.1 °C by 2050. The magnitude of this increase in temperature would vary from one area to another. It averages 1.6 °C in the northern region, 2.1 °C in the center, and 2.7 °C in the southern region.

Decrease in the annual volume of rainfall, which ranges from 10% in the north to 30% in the south by 2050, compared to the current situation. This decline will most likely be accompanied by an increase in the frequency and intensity of the extreme dry years.

These results are reinforced by the climatic projections published in 2015 by the National Institute of Meteorology (MNI), which, based on a dynamic downscaling of the results of the 4th IPCC report and on a mesh of 25 km^2, offer to Tunisia the first climate projections from one of the general circulation models validated for the case of Tunisia on 9 models.

The selected socioeconomic scenario describes a future world in which economic growth will be very rapid, the world population will reach a maximum in the middle of the century and then decline, and new, more efficient technologies will be introduced rapidly. It is a median scenario. The reference climatology is that of 1961–1990, which constitutes the historical period of reference of the climate. These are the climate projections that are used to assess the vulnerability of water resources to climate change.

This situation will worsen in the coming years as demand for water increases and as a result of climate change, with a decline in conventional water resources estimated at around 28% by 2030. The increase in extreme events (floods and droughts) will further weaken the country's water situation. These results are from the first initiative to assess the needs of agriculture and ecosystems for adaptation to climate change following the severe drought experienced by Tunisia between 1998 and 2002 (MARHP and GIZ 2007). In addition, following the accelerated sea-level rise, the salinization of the coastal aquifers would result in losses of about 50% of the current resources by 2030, that is, losses of nearly 152 Mm^3. All studies carried out on the coastline confirm the fragility of coastal water resources and the major risks of seawater intrusion.

A recent study in 2016 assessed Tunisia's vulnerability to climate change. Vulnerability is approximated by the product of exposure, the ratio of water demands to water availability, and the ratio of sensitivity to adaptive capacity. Estimated at the level of the governorate, the vulnerability scores are all greater than unity, which means a proven vulnerability. Some governorates such as Kairouan, Sidi Bouzid, and Kebili are hot spots.

As part of this study, a prospective exercise was conducted. A basic scenario known as regional rebalancing has been adopted. This scenario simulates a process of population adjustment and unemployment rates. According to this simulated process in situations with and without CC, the populations of the western governorates will evolve at the national average rate, and the rates currently observed are lower than this average. The various water demand components estimated for this scenario were for the 2030 and 2050 horizons. As shown in Tables 8.5 and 8.6, total water demand will increase in the case of climate change. On the other hand, the decrease in demand for water by 2050 expressed by the agricultural sector would result from the fall in agricultural activity in favor of other sectors (industry and services), but also from the technological improvements linked to irrigation efficiency. With regard to water availability, Table 8.5 below summarizes blue water resources by category, taking into account the increase in aridity due to climate change.

We note that the water consumption of the agricultural sector will decline despite the effects of climate change. The predominant effect would be the diversification of economic activity which would result in an increase in the opportunity cost of the

Table 8.5 Supply of and demand for blue water at different horizons with CC (Mm^3)

	Horizons	2014	2030 with CC	2050 with CC
Demand	Urban water	701	1121	1323
	Irrigation	2650	2296	2093
	Total demand for blue water	**3351**	**3417**	**3416**
Supply	Available surface water (Mm3)	1072	1176	843
	Shallow aquifers	746	720	705
	Deep aquifers	1429	1404	1380
	Total supply of blue water	**3247**	**3300**	**2928**

CC: Climate change; Mm^3: Million cubic meters
Source: MARHP (2000)

Table 8.6 Supply of and demand for green water at different horizons – with Climate change scenarios (in Millions m^3)

	Horizons	2014	2030	2050
Green water demand	Rain-fed agriculture	5069	4517	4150
	Forest and grass-land	9011	9034	9541
	Total green water demand	**14,080**	**13,551**	**13,691**
Green water supply	Rain-fed agriculture	11,033	10,880	10,770
	Forest and grass-land	9011	8800	8822
	Total green water supply	**20,044**	**19,680**	**19,592**

Source: MARHP (2000)
Mm: millions m^3

labor force. This evolution will be to the detriment of agricultural activity. Such an economic context could imply the abandonment of certain irrigated areas or certain crops that have become uncompetitive with regard to the use of the primary factors of production, water, and labor. Citrus fruits and dates seem to be the most endangered.

For green water, supplies for rain-fed agriculture, rangelands, and forests are presented in Table 8.6 above.

The "green waters" – water indirectly available in the form of agricultural, animal, and vegetable production (rain-fed agriculture, rangeland, and forest) – total about 23 billion m^3/year. There is therefore a huge reservoir that needs to be better exploited and mobilized to ensure and reinforce water security (ITES 2011).

While it is generally estimated that about 60% of rainwater is absorbed and evaporates and 39% flows and/or goes underground, in Tunisia, 90% evaporates and only 10% flows. The importance of green water is emphasized and there is a lack of research and interest in it (Besbes 2011).

The drought during the last years has led to overexploitation of the aquifers. The Ministry of Agriculture, Water Resources and Fisheries has programmed at the end of 2018 a measure of groundwater recharge. This recharge aims to improve the piezometric level and reduce the groundwater salinity. This recharge is possible by the releases from surface reservoirs, infiltration basins, and injections into surface wells. This recharge program targets a total of 48 million m^3 and covers eight regions (see Table 8.7).

Table 8.7 Groundwater recharge in Tunisia in 2018

Regions		Quantity (millions m³)
North	Nabeul	10
	Ben Arous	2
	Bizerte	2
	Zaghouan	2
Center	ElFekka	10
	Kasserine	2
	Kairouan	10
South	Gafsa	10
Total		48

Source MARHP (2019)

8.11 Research

According to the summary report of the Strategic Study, Water 2050, a profound review of Agricultural Research and Development may be necessary in terms of defining missions, objectives, organization, work methods, and productivity. It is proposed to include research activities, with specific objectives, within the framework of the National Priority Programs. The technical and technologies proficiency in all areas of water particularly in the artificial recharge of aquifers, the tertiary treated wastewater, the silting of dams, the desalination of water, the selection of plants and seeds adapted to the Tunisian climate constitute the essential components guaranteeing national water security. Scientific research is to be developed in all these areas and it is necessary to rethink this effect (ITES 2011). In addition to these technical components, particular attention should be given to institutional aspects, governance, and water management, particularly at the local level.

8.12 Conclusions

The public authorities have chosen to invest in irrigated agriculture since it reduces the dependency on rainfall variability. They have made important investments in the supply of water and creation of irrigated areas. The relations of dominance between the state and society have given it considerable discretion. The agricultural activities created allowed undeniable performances. However, this agriculture suffers from threats of unsustainability. In fact, irrigated agriculture is threatened in its environmental, institutional, financial, and political components.

The water and soil resources are overexploited, especially groundwater, as well as risks of salinization and hydromorphic soils. These risks are more observable in areas with a long tradition of irrigation: the Cap Bon region, oases, etc.

In addition to these threats of the physical environment supporting the activities of irrigated agriculture, a three-tiered dualism characterizes farms. The first is of a structural nature, opposing small farms with little equipment to large production units with a balanced production structure. The second reflects the observable differences in the production techniques adopted. While the smaller farms use "traditional" technical itineraries, the other farms are in direct contact with technological advances on a global scale. The third component of this dualism is institutional in nature and reflects the differences in the relations of production. Salaried employment is the most widespread social relation at the level of large farms. The small ones practice various forms of sharecropping. This dualism is reflected in differences in the value of irrigation water. Small farms with an unbalanced structure ensure valuations far below the prices of water paid. As a result, there is a risk of nonpayment of water bills and, as a result, financial difficulties are often faced by water user associations.

On the political level, the revolution interpreted as a collective refusal of public choices has aggravated the questioning of the choices decided previously. There have been almost universal refusals to pay water prices. Protests have begun to rise against some interregional water transfers.

Finally, the guidelines adopted in terms of economic development, in particular, are being confronted by the new relations that the state maintains with the postrevolution society and, on the other hand, by the tensions over the water resources exacerbated by the effects of climate change on existing agriculture.

References

Al Atiri, R. (2006). Evolution institutionnelle et réglementaire de la gestion de l'eau en Tunisie. Vers une participation accrue des usagers de l'eau. L'avenir de l'agriculture irriguée en Méditerranée. Nouveaux arrangements institutionnels pour une gestion de la demande en eau, Cahors, France.

Albouchi, L., Bachta, M. S., & Le Grusse, P. (2003). Pour une meilleure valorisation globale de l'eau d'irrigation: une alternative de réallocation de la ressource sur des bases économiques: cas du bassin du Merguellil en Tunisie centrale [en ligne]. Séminaire PCSI [Programme de Recherches Coordonnées sur les Systèmes Irrigués] sur la Gestion Intégrée de l'Eau au Sein d'un Bassin Versant; 2003/12/02; Montpellier.

ANPE (Agence nationale de protection de l'environnement). (2004). Le suivi scientifique au parc national de l'Ichkeul. Année hydrologique 2002–2003. Tunisie.

Bachta, M. S., Le Goulven, P., Le Grusse, P., & Luc, J.-P. (2001). Environnement institutionnel et relations physiques pour une gestion intégrée de l'eau dans le milieu semi-aride méditerranéen. Le cas tunisien. In: Séminaire international Montpellier 2000, « Hydrologie des régions méditerranéennes », Montpellier, 11–13 octobre 2000. Paris, Unesco, PHI-V/Documents techniques en hydrologie, n° 51, pp. 177–186.

Belloumi, M., & Matoussi, M. S. (2006). A stochastic frontier approach for measuring technical efficiencies of date farms in Southern Tunisia. *Agricultural and Resource Economics Review, 35*(2), 285–298.

Ben Nasr, J. (2015). Gouvernance et performance de la gestion de l'eau d'irrigation en Tunisie: cas des périmètres irrigués de Nadhour-Zaghouan. Agronomie. Institut National Agronomique de Tunisie. Thèse conduite à l'INAT-Tunisie sous la direction de Pr. Bachta MS.

Ben Nasr, J., & Bachta, M. S. (2016). Gouvernance et performance de l'exploitation de l'eau dans les périmètres irrigués de Nadhour: Quels effets des rapports de force? Revue des régions arides.

Ben Nasr, J., Akkari, T., Fouzai, A., & Bachta, M. S. (2016). Le mode d'accès à l'eau d'irrigation un déterminant de l'efficacité des exploitations agricoles: Cas du périmètre irrigue de Sidi Ali Ben Salem, Kairouan-Tunisie. *Journal of New Sciences, Agriculture and Biotechnology, 29*(5), 1676–1686.

Besbes, M. (2011). L'eau en Tunisie: gestion de la rareté conjecture de pénurie. Conférence du 28 Mai 2011 à l'Auditorium de l'INAT. Tunis.

BPEH (Bureau de planification et des équilibres hydrauliques). (2013). L'alimentation en eau potable et l'assainissement en Tunisie. Note a élaborée en Novembre 2013 par BPEH (Ministère de l'agriculture des ressources hydrauliques et de la pêche). Available on this website: https://www.ohchr.org/Documents/Issues/Water/Handbook/Tunisia.pdf

DGRE (2015). Direction Générale des Ressources en Eau. Ressources en Eau en Tunisie. Rapports annuels

Dhebi, B., & Telleria, R. (2012). Irrigation water use efficiency and farm size in Tunisian agriculture: A parametric frontier analysis approach. *American Eurasian Journal of Agriculture and Environmental Science, 12*(10), 1364–1376.

Dhehibi, B., et al. (2007, September). Measuring irrigation water use efficiency using stochastic production frontier: An application on citrus producing farms in Tunisia. *African Journal of Agricultural and Resource Economics* 1(2), 1–15

El Amami, H., Natsoulis, D., & Xanthoulis, D. (2003). Evaluation économique du traitement des eaux usées traitées par épuvalisation. Proceedings des actes du séminaire International Réutilisation des eaux usées traitées et des sous produits: Optimisation, Valorisation & Durabilité (Tunis 24–25 septembre 2003).

Elloumi, M. (2016). *Groundwater governance in the Arab world*. IWMI project report N0.7.

Hamdane, A . (2014). La gestion des ressources en eau souterraines (nappes et aquifères) comme biens communs : Cas de la Tunisie, SCET, Tunisie, Version provisoire citée par Elloumi 2016.

Hamdane, A., & Bachta, M. S. (2015). Intensification de l'agriculture irriguée en Tunisie. FAO-Banque Mondiale. Programme Eau, Climat et Développement pour l'Afrique "Carte de vulnérabilité des ressources en eau et de leurs usages aux impacts du changement climatique en Tunisie »- Novembvre 2016.

Hentati, A. (2010). *Geomorphological study on erosion vulnerability of small hillside catchments in the semi-arid region of Tunisia*. PhD thesis in civil and environmental engineering, with specialization in hydrology. Tokyo Metropolitan University.

ITES. (2011). Institut Tunisien des Etudes Stratégiques. Etude Stratégique: Eau 2050 en Tunisie. Rapport de synthèse.

ITES. (2014). Etude stratégique : Système hydraulique de la Tunisie à l'horizon 2030, janvier 2014. p. 222.

Kefi, M. (1999) – Estimation de la rente économique de l'eau dans les PPI de Chébika, gouvernorat de Kairouan. Mémoire de PFE en Economie Rurale et Gestion sous la direction de Pr BACHTA MS.à l'INAT.

Kefi, M., Faysse, N., Le Goulven, P., & Bachta, M. S. (2004). Comportement des irrigants face à des changements d'accès à l'eau dans les périmètres irrigués de la plaine de Kairouan. In: Le Goulven P., Bouarfa S., Kuper M., 2004. Gestion intégrée de l'eau au sein d'un bassin versant. Actes de l'atelier du PCSI, 2–3 décembre 2003, Montpellier, France.

MARHP (Ministère de l'agriculture des ressources hydrauliques et de la pêche). (2019). Gestion pluriannuelle des épisodes de crue et de sécheresse dans le nord la Tunisie par référence aux années (2016-17-18).

MARHP, & Giz. (2007). Stratégie nationale d'adaptation du secteur agricole et des écosystèmes au changement climatique.

MARHP(Ministère de l'agriculture des ressources hydrauliques et de la pêche). (2000). EAU XXI-Stratégie à long terme du secteur de l'eau en Tunisie 2030, DGGR.

Mokrani, A. (2012). *Essai d'explication de la performance des associations d'irrigants : Gouvernorat de Nabeul*. Mémoire de mastère. Institut National Agronomique de Tunisie.

Rekik Bouguecha, S. & Bachta, M. S. (2016). Une dynamique co-évolutive « institution-innovation» et gains de productivité dans la gestion des ressources communes. Revue des Régions Arides n°40 (2/2016) – Numéro spécial : Actes des travaux du colloque international LOTH 2016 « Gouvernance et communication territoriales » Mahdia (Tunisie) 7, 8, 9 avril 2016

SONEDE. Société Nationale d'Exploitation et de Distribution des Eaux. (2017). Tarification de l'eau potable. Available on http://www.sonede.com.tn/index.php?id=111.

STEG. Société tunisienne de l'électricité et du gaz. (2016). Rapport annuel. Available on http://www.steg.com.tn/fr/institutionnel/publication/rapport_act2016/Rapport_FR2016.pdf

STEG. (Several years). Société tunisienne de l'électricité et du gaz. Rapport annuel.

Zekri, S., Echi, L., & Sghaier, M. (1996). Tunisia. In: A. Dinar, & A. Subramanian (Eds.), *Water pricing experiences, an international perspective*. (pp. 125–133). World Bank technical papers N° 386.

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