Chapter 2
Tunisia

Abdelkader Hamdane

Abstract Tunisia is structurally affected by water scarcity and irrigation practices are profoundly marked by the culture and history of the Mediterranean and desert areas. Since 1956, the new Tunisian state has mobilized the financial resources necessary for the development of major public water projects. It also encouraged farmers to develop individual irrigation projects. Despite the relatively limited extension of irrigated areas, irrigation is considered as a strategic sector (food security, economic and social role).

In Tunisia, total water withdrawals are close to the potential of the resource. A "weak form of water demand management" prevails, characterized by the implementation of technical, economic, and regulatory instruments primarily aimed at reducing water losses and inadequate water use and encouraging the use of nonconventional water resources. Weaknesses in agricultural development are found in the majority of large-scale irrigated schemes, where agricultural intensification and the productivity of water remain to be enhanced.

Keywords Water demand management · Water saving · Agricultural intensification · Irrigation policy · Tunisia

2.1 A Short History of Hydro-Agricultural Development

2.1.1 History at a Glance

In Tunisia, irrigation water management practices are profoundly marked by the culture and history of the Mediterranean and, in desert areas, those of the Sahara. The extreme characteristics of the Mediterranean climate mean that this management has been a crucial element of civilization and development since ancient times (Fig. 2.1).

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F. Molle et al. (eds.), *Irrigation in the Mediterranean*, Global Issues in Water Policy 22, https://doi.org/10.1007/978-3-030-03698-0_2

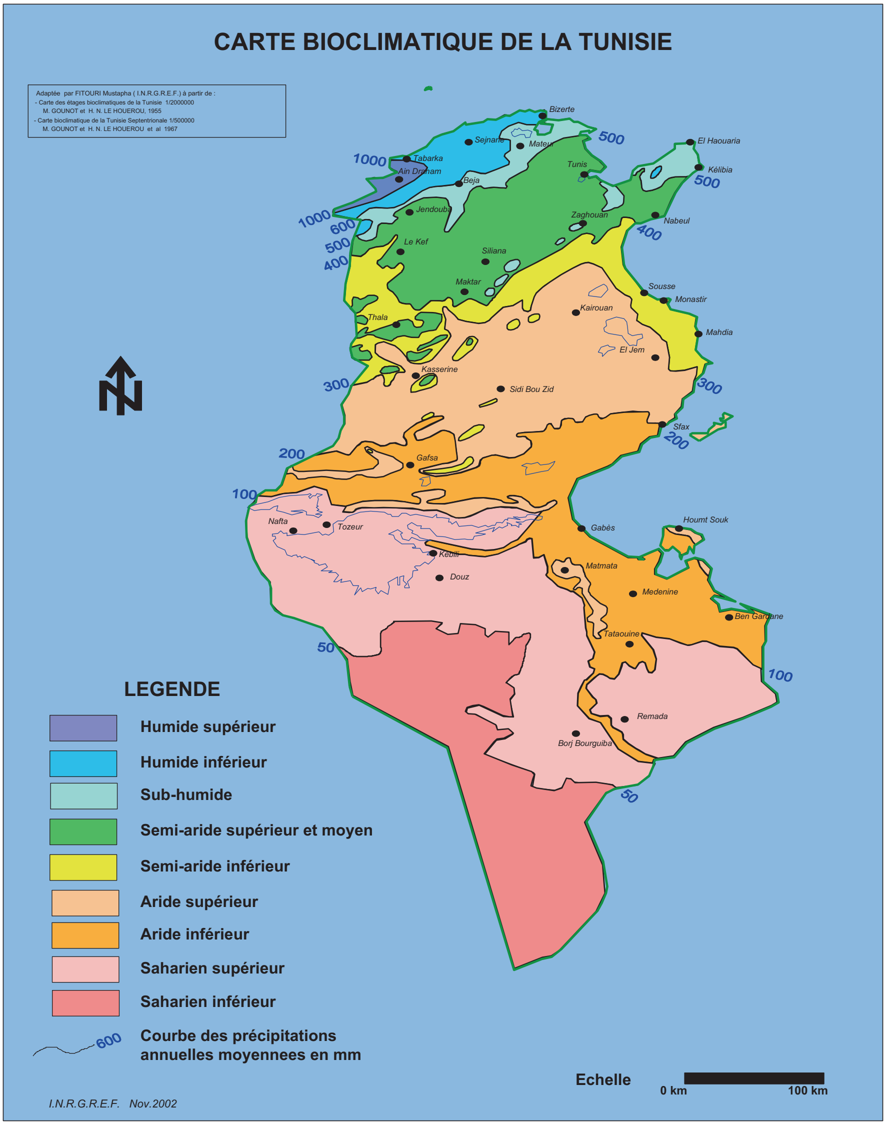

Fig. 2.1 Bioclimatological map of Tunisia (INRGREF 2002)

Hence today we find a range of infrastructures, in almost every region, which serve one or several purposes (e.g., storage, transfer, spate irrigation, distribution to urban areas, and agriculture) and which together form an impressive accumulation of works built over the centuries. Then the hydraulic infrastructure was reworked, developed, and modernized, entailing a series of innovations but also some patent failures, with continual readjustments as requirements evolved. Throughout the ages, irrigation has consequently accounted for a very significant share of the volumes of the water thus mobilized.

Hydraulic development traditions and irrigation practices were first disseminated in Tunisia by the Berber people, well before Phoenician times, but it was during the Punic Era that abstraction and rainwater harvesting techniques were imported from Oriental and Mediterranean civilizations. These techniques were subsequently consolidated and spread to every region in the country from the Roman period onward (see the treaty on agronomy by Mago in the fifth century BC). Although some significant water transfer structures were built to supply towns with water (e.g., the 132 km-long Zaghouan-Carthage aqueduct, built in the middle of the second century AD under Hadrian), Roman hydraulic works in Tunisia mainly consisted of small-scale local developments designed to make use of local resources and the rainwater collected and stored (Gaukler 1897).

From the seventh century onwards, Arab and Islamic influences gave way to a new legal and institutional approach to water management, with the rehabilitation of ancient structures and the extension of existing hydraulic techniques to other parts of the country, as well as new contributions, transfers, and exchanges with other countries in Islamic and Oriental civilizations, bringing Tunisia into contact with world hydraulic engineering heritage.

In the southern deserts, hydraulic societies developed community-based networks in the oases. From the thirteenth century, a strict water distribution system in the Tozeur oasis, promoted by the jurist Ibn Chabbat, provided a model for water supply according to a fixed schedule of rotation between users. Despite the scattered nature of agricultural activities in rural areas and the predominance of pastoralism in the country's hinterland, flood or spate irrigation led to the development of several flourishing hydraulic centers in the high steppe areas and the Kairouan plain in Central Tunisia. In the Sahel (the coastal area), runoff water was collected in reservoirs, supporting extensive olive groves over the centuries (El Amami 1984).

Likewise, innovative technology was introduced in Tunisia via successive waves of Andalusi immigration. The *noria*, an improved version of the Persian wheel, was the first attempt to mechanize water lifting, the basis for all irrigated agriculture in the north of the country and in the coastal zones, while water abstraction via underground galleries (*foggaras*) made it possible to supply some towns with drinking water and to irrigate the oases. In 1622, the Andalusis initiated the construction of a dam with a bridge and locks on the Medjerda, Tunisia's largest river, at El Bathane. This structure supplied two main pipe systems built to irrigate the Tebourba olive grove over a 2500 ha area (Kress 1977). It was in fact the first major hydro-agricultural development in Tunisia's modern history (Besbes et al. 2014).

With the Andalusi influence, Tunisia also felt the consequences of an "agricultural revolution" that swept the entire Muslim world and spurred its demographic expansion. This agricultural revolution led to the extension and improvement of irrigation systems and the introduction of a variety of plants largely requiring irrigation (rice, sorghum, durum wheat, sugarcane, cotton, aubergines, water melons, spinach, artichokes, citrus, bananas, etc.), plus others used as medicine, condiments, and dyes (henna and indigo), most of which were imported from India (Watson 1984).

2.1.2 The Modern Era and Hydro-Agricultural Developments

With the dawn of the French Protectorate in 1881 came a publicly funded policy to drill relatively deep wells to tap aquifers. This was rolled out across the south and center of the country to help farmers expand their olive groves, other tree crops, and fodder crops. At the same time, there was an extension of surface areas irrigated by shallow wells dug at the initiative of farmers to access groundwater, mainly in the regions of Tunis and Cap Bon, specialized in vegetable crops and citrus. In the 1950s, intensive groundwater abstraction led to the overexploitation of aquifers, witnessed for the first time in Tunisia and consequently raising the question of its conservation, especially in the coastal area of the Cap Bon and the Soukra region near Tunis.

The policy of developing publicly funded collective groundwater-based irrigation systems to supply several tens of hectares continued throughout the twentieth century in most of the country. As a result, Tunisia now looks like a succession of separate irrigated islets.

After the Second World War and given the then very harsh economic and social conditions, the policy to develop large storage dams was favorably received in the Medjerda basin, home to the country's largest river and where large swathes of fertile land are found. Here, only irrigation could offset erratic rainfall in the main rain-fed areas. These factors led to the emergence of the first regional hydro-agricultural development plans.

(a) *In the North*: the program to build large dams with a total usable capacity of 400 Mm^3/year and the Lower Medjerda valley irrigation scheme (40,000 ha irrigable from the Neber dam, the Laroussia reservoir and the old Taullerville canal) were the largest hydro-agricultural projects based on collective networks in the period from 1950 to 1980. This project was part of the "Tunisian modernization and equipment plan" (Chevalier 1950) but was not completed by the colonial administration (Fig. 2.2)[1] (Poncet 1956). It was continued by the Tunisian state with the coming of independence and provided a framework for the development of the Medjerda and its tributaries for irrigation purposes (Besbes et al. 2014).

(b) *In the Center*: the oueds in this region are very erratic and do not permit the dam-type solutions adopted in the North. However, groundwater was extracted for use in numerous public irrigation schemes totaling 11,000 ha. The public boreholes enabled the development of small- and medium-sized areas from 50 ha to around 200 ha. Spate irrigation has been used in the area for thousands of years and is still used on the Kairouan plain: modernization work was carried out to better control aggradation and floodwater distribution mechanisms.

[1] The funding of the project's initial phases came from the Marshall Plan to rebuild Europe after the Second World War.

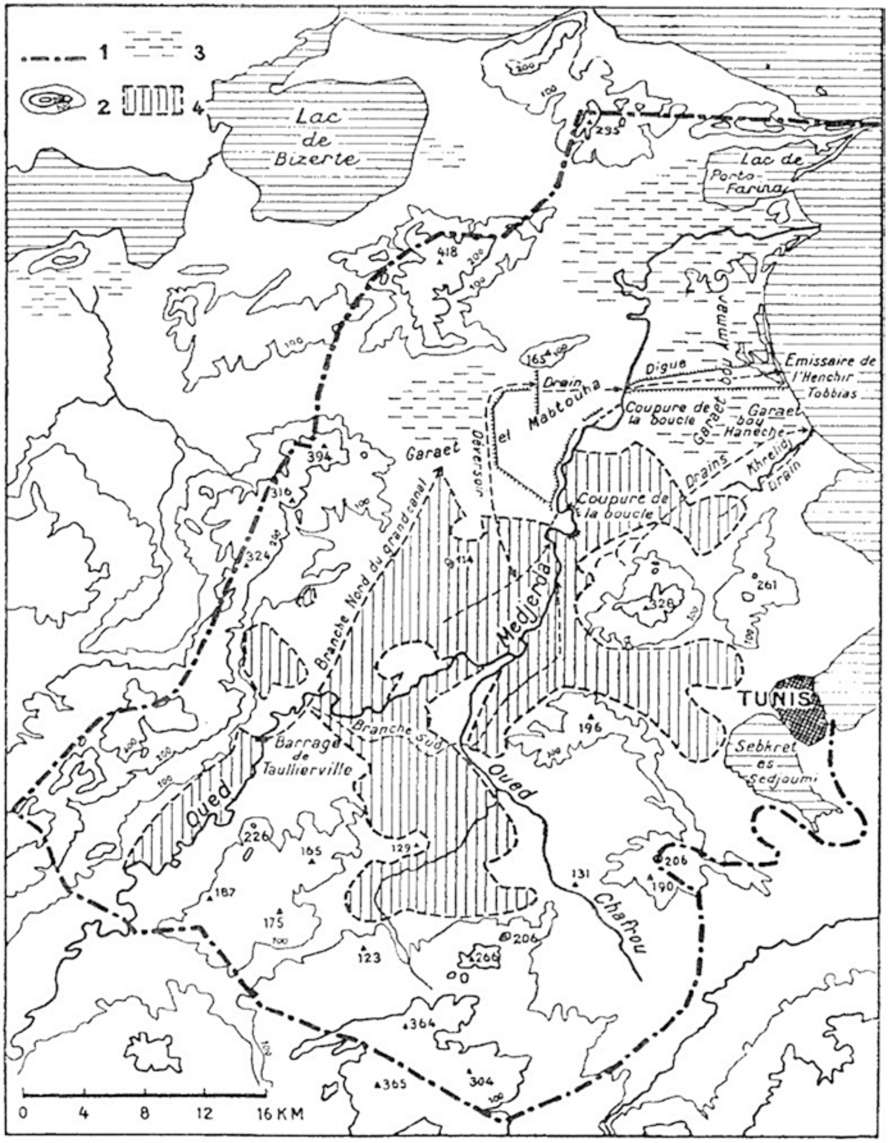

Fig. 2.2 Main works planned and irrigable areas for development of the Lower Medjerda Valley (OMVVM 1958)

(c) *In the South*: the main projects are the works to safeguard the older oases where natural resources have dried up and the creation of new structures in Djerid and Nefzaoua. New, nonrenewable water resources became available with the creation of very deep boreholes, some of which were artesian and provided hot water (70 °C in the Continental Intercalaire Aquifer). In the Jeffara-Gabes basin, there has been work to spread and retain floodwaters from the Dahar wadis.

2.2 The Postindependence Water Policy and the Dominance of Supply-Side Management

2.2.1 Water Policy and Planning

After independence (1956) the new Tunisian state mobilized the necessary national and international resources to complement the major projects initiated during the colonial period. The *Office de Mise en Valeur de la Vallée de la Medjerda* (OMVVM – Medjerda Valley Development Agency) was set up in 1958 to operate hydraulic structures, conduct technical studies for new projects, advise and assist farmers in the agricultural development of the area, and implement a land reform. The importance given to the Medjerda hydraulic development project was such that the OMVVM initially reported directly to the presidential administration. It was then transferred to the Ministry of Agriculture which went on to play a key role in the implementation of regional development policies.

The "Decennial development outlook for 1962–1971" (Secretary of State for Planning and the Treasury 1961) defined the initial precepts for social and economic development in independent Tunisia, based on the founding principles of "decolonization and development of production means, human advancement, structural reform and self-development." When it came to water, these principles contained some specific goals: "the scarcity and irregularity of rainfall forced Tunisia to use every possible means to maximize its capacities to store surface water and exploit groundwater." The measures to be undertaken included (i) studies and research to improve knowledge of water resources and soils; (ii) urban hydraulic infrastructures for water supply to the cities, to prevent flooding and ensure urban sanitation; and (iii) agricultural hydraulic works with the construction wells and boreholes, four large dams (Kasseb, Bou Hertma, Joumine and Nebhana), as well as smaller dams and structures, to irrigate 60,000 ha.

In the early 1970s, the key notion underpinning agricultural policies was planning with a view to ensuring a higher level of food self-sufficiency. In a dry climate, intensified farming through irrigation was intended to boost agricultural output and help develop rural areas across the country. Tunisia introduced large-scale hydro-agricultural planning to fulfill the political goal of food self-sufficiency. In this respect, the hydraulic schemes introduced in the colonial era had paved the way for large-scale development schemes.

While maintaining an extensive publicly managed collective water system, the State also encouraged the private sector (the operators actually exploiting the land developed by the State) through public technical services and financial incentives and support to develop modern, productive irrigated agriculture. Large-scale hydraulic development was identified as the priority for improvement of the northern region, and the preference for major structures impacted the technical choices made in this part of Tunisia. The development of groundwater resources to establish public irrigated areas and privately run schemes was an approach particularly favored in the coastal regions, the Center, and the South.

The originality of the Tunisian approach, dictated by the scarcity of water resources and a deficit in the national food balance, is no doubt reflected in this early awareness of the major challenges raised by water in terms of regional development and spatial distribution of resources and needs: the "hydraulic option" was upheld and bolstered by a policy of large-scale transfers to deficit areas, establishing an interconnection at the national scale designed to overcome inter-regional disparities in access to water (Besbes et al. 2014). Apart from drinking water supply, water transfers were meant to meet the needs of agriculture, a major consumer of water. This policy led to the design and development of vast hydraulic infrastructure program based on three water master plans elaborated in the 1970s, respectively, for the North (with the PDEN) (MA 1970), the Center (PDEC), and the South (PDES).

2.2.2 The Institutional and Legal Framework

2.2.2.1 The Water Code

In Tunisia, the primary legal instrument governing water management is the Water Code enacted by law no. 75-16 of 31 March 1975. Taking inspiration from the principles of Islamic law and common law, as well as the reform of water rights that came with the French colonization, this Code also introduced the following fundamental principles with direct impacts on the water sector as a whole and on irrigation in particular:

The public ownership of water resources: The Code restricts the protection of individual rights and freedoms in favor of the needs and imperatives of the general interest and public utility.

The central role of the public administration is in the planning, mobilization, control, and monitoring of water use from both quantitative and qualitative points of view.

The principle of obtaining maximum efficiency from every cubic meter of water was adopted nationally and for all sectors of use.

The protection of the water environment, with the prohibition of any action likely to cause direct or indirect pollution of water habitats.

2.2.2.2 Administrative, Technical, and Professional Organizations

Since 1975, management of the public hydraulic domain (PHD) has been the remit of the Ministry of Agriculture, which is in charge of water. It is assisted by two commissions: (i) the *Comité national de l'eau* (National Water Board), known as the *Conseil National de l'Eau* from 2001 onward, whose role is to guide water policy involving a broad spectrum of stakeholders and operators in the sector, and (ii) the Public Hydraulic Domain (PHD) Commission.

Although a large portion of the PHD is still supervised by this Ministry, the Ministry of Environment has been involved since the 1990s in environmental protection matters (National Environmental Protection Agency: ANPE) and in urban sanitation and wastewater treatment (National Sanitation Agency: ONAS). The Ministry of Public Works also oversees certain flood control operations in urban areas. This is a fairly long-standing arrangement and reflects the priority given to agriculture, which is subject to very unfavorable climatic variations and which therefore monopolizes a large share of the available water resources and infrastructures. Furthermore, the Ministry of Agriculture is still the only technical administration with local offices covering the entire country and able to ensure control over the resource.

Within the Ministry of Agriculture, there are several technical divisions and associated public establishments involved in water prospection, hydraulic works, rural engineering, management of the public hydraulic domain, etc. By the nature of its core tasks, the Ministry of Agriculture is responsible for the general supervision of the agricultural sector via several specialized bodies working in the irrigated agriculture sector: autonomous public bodies with an important specific role in agricultural planning in the irrigated areas; inter-branch groups tasked with the integration of various stakeholders in the value chains, market regulation, and the promotion of product quality; agronomic research and rural engineering institutes; and the technical centers in charge of experimentation and technological adaptation, information and technical support to producers, training of technicians, and so on.

The *Commissariat Régional au Développement Agricole* (CRDA, or Regional Agricultural Development Commission) is the body representing the Ministry of Agriculture in each region. Each of the 24 governorates has its own CRDA bringing together the main services provided by the Ministry of Agriculture. This is a public administrative establishment (PAE) with its own legal identity and financial autonomy but officially reporting to the Ministry of Agriculture. It also heads the implementation of national agricultural and hydraulic policies within the governorate, including the development of irrigated schemes and agricultural water management.

2.2.3 Changes in the Institutional Framework and Management Structures

2.2.3.1 Irrigation Development Boards: State Planning, Development, and Management

Implementation of the hydro-agricultural policy was supported by the institutional setup established over the first few decades after independence. The irrigated area development boards at the regional level (OMV-PPI) played a key role in applying the regional masterplans for agricultural development and irrigation management. Thirteen of these boards were established after the restructuring of the OMVVM (Medjerda valley development board) in the 1970s. These public industrial and commercial organizations spearheaded irrigation policy and were involved in various tasks similar to those of the OMVVM, some of which concerned agricultural development and were subsequently extended to private irrigated areas. The principal missions of the OMV-PPI were the integration of all activities related to irrigation development at the regional level: construction of irrigation schemes, management of collective hydraulic networks (operation and maintenance, fees collection, etc.), participation in the implementation of the agrarian reform, agricultural and irrigation extension, agricultural financing, marketing, etc. The OMV-PPIs were absorbed by the CRDAs in 1989.

The impact of these boards was relatively positive in terms of local development and food security. Despite undeniable technical success, the beneficiaries had little involvement in the collective management of water systems and the maintenance cost, and successive rehabilitation projects were mainly borne by the State, since the fees charged remained very modest. Continued implicit subsidies from the State for public irrigation became increasingly heavy as irrigated areas were extended.

2.2.3.2 Collective Water Management

In Tunisia, irrigation is based on traditional know-how and has long been practiced using common natural water resources in the oases or private shallow groundwater wells.

The Water Code, amended by law no. 87-35 of 6 July 1987, endorsed the longstanding model of Collective Interest Associations (CIA) established in 1936 and in particular defined the roles of these associations in water management, including operation, maintenance, and use of networks affecting the public domain that the CIAs have the right to access, irrigation or land reclamation through drainage, the management of domestic water systems in rural areas, etc.

According to law no. 2004-24 of 15 March 2004, amending and completing the previous law, the different water users' associations are now called *Groupement de Développement dans le Secteur de l'Agriculture et de la Pêche* (GDA or agriculture and fishing sector development group), and their role is extended to protect national resources (water, soils, forest, etc.) and to rationalize their use and conservation. They are tasked with equipping the areas under their remit with basic agricultural and rural infrastructures, participating in the supervision of their members and advising them on the most appropriate agricultural techniques, carrying out income-generating activities to provide services upstream and downstream of agricultural production, etc.

2.2.4 Land Reform in Irrigated Areas

Land reform in irrigated areas began in 1958 covering the large tracts of public land under the responsibility of the OMVVM. It was extended in 1963 to include all public areas in the country. The main goals of the reform were the distribution of plots of irrigable land taken from large state-owned estates and the limitation of irrigated property, the reorganization of private land ownership, and the obligation to exploit developed land. In 1977, a dedicated agency – the *Agence de la Réforme Agraire dans les Périmètres Publics Irrigués* (Agency for Land Reform in public irrigated areas), which became the *Agence Foncière Agricole* (Agricultural Land Agency) in 1999, was set up to implement the land reform policy in irrigated areas where collective hydraulic facilities were provided by the State.

If the land reform did succeed in reorganizing ownership in public irrigated areas, its results with regard to social objectives and the promotion of intensive agriculture were very mixed. The political project of a land reform that went back to the 1950s–1960s seemed to have become less consistent over time and less relevant in terms of its social aims, giving way to a new "liberal" policy designed to lease large irrigated areas owned by the State to private agricultural interests [agribusiness companies (SMVDA), farmers]. The land reform thus became "obsolete" but should now be adapted to the new context and updated to better reflect the social and economic changes occurring in irrigated areas.

2.3 Demand-Side Management and Recent Reforms

2.3.1 The Need for a Shift Toward Demand-Side Management

In Tunisia, total water withdrawals are on average close to the potential of the resource, and the search for a more secure water supply naturally raises the issue of the reallocation of the resource among the various users and sectors. In reality, if the available resource is considered as constant, the reallocation of water to satisfy the priority demand for domestic uses and ensure supply to productive economic sectors (industry and tourism) can only occur to the detriment of the agricultural sector. The prospects of increasingly scarce good quality water for irrigation as well as the competition between sectors already observed in several coastal regions very much underpinned the general framework of the «*Etude du Secteur de l'Eau* » (water sector study), a strategic study conducted by the Ministry of Agriculture in the 1990s.

This diagnosis of the water sector clearly indicated that the water policy implemented over the past several decades, primarily based on supply-side management, needed to be replaced with demand management, an important component of Integrated Water Resources Management (IWRM) which in particular aims to (i) reinforce measures to monitor, control, and protect resources; (ii) promote efficient use by controlling demand and getting maximum value from all usages; (ii) promote decentralization by strengthening the roles of users and of private operators; (iv) give economic, social, and environmental value to water; and (v) control risks. Within the framework of these general principles, this study put forward possible solutions for the medium and long term, all with significant impact on the irrigation sector (DGRE 1999).

Taking the above-mentioned challenges into consideration, Tunisia has been gradually shifting toward a still timid demand management policy (Cf. the law 2001- 116 reforming the Water Law on water conservation, participation of the private sector in nonconventional water resource management, self management of water resources, etc.). At the same time, it continues to develop additional resources, sometimes at a very high cost, especially in areas where there is a water deficit. A "weak form of water demand management" prevails, however, characterized by the implementation of technical, economic, and regulatory instruments primarily aimed at reducing water losses and inadequate water use in irrigation systems, stabilizing consumption in certain areas and encouraging the use of nonconventional water resources (Hamdane 2006). Against the backdrop of these early stages of demand-side management, the main political reforms and instruments applied are described in what follows.

2.3.2 Decentralization and Associative Management of Irrigation Infrastructures

2.3.2.1 Widespread Collective Management

As the institutional framework, with the Office de Mise en Valeur/CRDA, began to evolve (see Sects. 2.3.1 and 2.3.2), a vacuum appeared with relation to the management of irrigation between users. Over time, the need emerged for GDAs to serve as intermediaries to rebuild the link between water users and the public authorities. Furthermore, the support to irrigated agriculture had faded away, and new areas, with no tradition or structure for support, were pretty much neglected.

With regard to hydraulic management, the operational difficulties faced by the CRDA were the main reason for the large-scale development of users associations in all public irrigated areas after 1998. In small- and medium-sized systems, the GDAs were responsible for the operation and maintenance of all existing collective infrastructures. In larger schemes, the GDAs were entrusted with secondary and tertiary infrastructures (network subdivisions), while the main infrastructure was kept under the responsibility of the CRDA's departments concerned. The CRDA sold bulk water to the GDA.

All of this means that Tunisia has a relatively advanced legal and institutional framework. However, that framework is marked by (i) legislation, that is, to a certain degree, obsolete with regard to some aspects of water management and despite the various amendments to the Water Code (autonomy of the associations, clarification of the role of the various stakeholders, etc.), and (ii) during the second half of the twentieth century, institutional instability with successive cycles of organization/reorganization of management structures (the various Offices/CRDA, AIC/GDA), a policy that significantly reduced the likelihood of institutional progress in the irrigation sector.

2.3.2.2 The Strategy to Ensure Long-Term Sustainability of the GDAs

The number of GDAs in charge of public irrigation infrastructures stood at 200 in 1995. This number rose to 1253 GDAs by 2014 with these groups responsible to a varying extent for a total surface area of 213,000 ha of public irrigated areas. At present, 88% of these GDAs are considered to be active, while 12% are subject to temporary interruption of their activities for different technical and social reasons.

According to the GDA evaluation system (DGGREE[2] 2012), the technical and financial management of irrigation networks by GDAs is very inconsistent, and the performance of these groups in terms of service quality is still relatively disparate: 24% of the GDAs are seen as performing well, 56% of them show average performance, and 20% of them are poorly performing or have ceased operations for various technical, social, and organizational reasons.

Their main weaknesses lie in a diminished community spirit for some GDAs, in the interventionism and interference of the public authorities and local or regional authorities (especially during the pre-revolutionary period), and in the lack of GDA capacity for financial and administrative management or for the necessary maintenance and servicing of water systems. This latter shortcoming is often linked to the limited financial capacities of the GDAs and their difficulty in paying for outsourced maintenance services that are also often not available in remote rural areas, where the market is still marginal for this kind of service (CIRAD 2011). Several assistance, support, and research projects initiated by international cooperation organizations (WB, AFD, BAD, JIBIC, KfW, etc.) are currently being set up to reinforce the GDAs' capacities and ensure the sustainability and durability of the services they provide.

The strategy to ensure the sustainability of the GDAs adopted by the government has enabled the development of five cross-cutting concepts, namely, (i) the necessary institutional support for GDAs at national and regional level and an update of the GDA regulatory framework to take into account the specific nature of water management, (ii) the improvement of GDA financial control procedures, (iii) the professionalization of GDAs to gradually bring an end to the voluntary basis of current GDA management, (iv) involvement of the local private sector in water system operation and maintenance activities, and (v) responsibility for the protection, conservation, and efficient use of water resources in addition to the operation and maintenance of water systems (DGGREE/KfW 2013).

For the longer term, there are plans to study the conditions required to adapt other public irrigated area management models to the various irrigation contexts found in Tunisia: regional boards, public operating company (the SECADENORD[3] model), and public-private partnership (PPP).

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[2] DGGRE: Direction General of Rural Engineering and Water Management – Ministry of Agriculture.

[3] Public company charged of management of the Northern transfer canalisations for drinking water and irrigation.

2.3.2.3 Participatory Management of Groundwater

Participatory management of groundwater (35% of the country's irrigable area) is not a common practice in Tunisia, despite the expansion of individual irrigation based on deeper aquifers in several parts of the country and the overexploitation of groundwater resources in some coastal regions and in the Center. Various strategies are currently being discussed at national level and often consider collective approaches involving the individual groundwater users (see "institutional support to public policies of water resource management for rural and agricultural development," known as PAPS-Eau: National strategy to conserve groundwater 2010). The participatory management experience concerning the Bsissi-Oued El Akarit aquifer in the Governorate of Gabes is interesting in terms of its success in reducing the number of wells operated, thanks to local community ("tribal") spirit, to effective awareness raising among members organized by an association of groundwater users (Laghrissi 2013; Lavenus et al. 2016), and to the administrative and technical support of the CRDA.

2.3.3 Infrastructure Rehabilitation and Modernization

Public irrigated areas are equipped with various types of distribution network which were designed according to the technology that prevailed at the time of their construction:

- Networks dating from before the 1970s are usually made up of reinforced concrete or prestressed concrete open channels, with a suitable hydraulic control system and rotation as the preferred distribution method, at least during peak periods (Oasis, Central Tunisia, and Lower Medjerda Valley). Lining of the channels was widely applied.
- The networks built over the last four decades are usually either low-pressure pipe systems (one bar) with rotational distribution, used for gravity-fed irrigation (coastal areas in the east), or medium-pressure systems (three bars) suited to sprinkler irrigation via mobile sprinkler lines (large areas in the North and Kairouan plains).

The fairly rapid shift toward modern "Californian" gravity-fed type of irrigation, manual or automatic sprinkler, and micro-irrigation in individual plots made it necessary to adapt the older systems designed for conventional gravity-fed irrigation. These adaptations involved pressurization equipment and individual on-farm storage and are partly funded by farmers in addition to the irrigation equipment specific to the plot. Farmers appreciate these technological developments for their quality of service in terms of flow rate, pressure, and continual supply but also labor savings.

With these new technologies and because of the deferred maintenance and aging of the collective facilities in public irrigated schemes, substantial investment in rehabilitation, replacement, and modernization is increasingly needed in many areas, if greater efficiency is to be achieved while lowering operating and production costs.

The modernizing of irrigation systems and substantially modifying one or several components in the development began in the 2000s and was witnessed in three main systems that are representative of the regional contexts: (i) the water-saving project in the small- and medium-sized hydraulic schemes in Central Tunisia (modernization of 11,000 ha: conversion to pressurized systems, empowering GDAs, etc.); (ii) the improvement project for irrigated areas in the oases in the South (APIOS-23000 ha: lining earth canals, subsurface drainage, etc.); and (iii) the modernization project of the former large-scale scheme in the Lower Medjerda Valley (first phase of 4000 ha: conversion to pressurized systems, strengthening of GDAs, water pricing reform, etc.). The modernization projects were financed by KfW and JICA, and there is no real contestation or debate regarding the relevance of these programs.

It should be noted that in the future, rehabilitation and modernization projects will increase in number and cover larger surface areas, affecting most regions in the country, since irrigation infrastructure is aging and has been amortized (Hamdane and Bachta 2015).

2.3.4 The National Water-Saving and Efficiency Improvement Program

The national irrigation water-saving program (PNEE) was adopted in 1995 with "the overall goals to rationalize irrigation water use on plots, maximize the economic value of water, and maintain irrigation water demand at a level compatible with available water resources."

The program gathered significant momentum with the modernization of irrigation water systems at plot level, further to the political decision to increase the level of subsidies for irrigation equipment (60%, 50%, and 40%, respectively, for small, medium, and large agricultural holdings). Between 1995 and 2014, total investments made through this program were estimated at $715 million, of which $240 million were financial incentives from the State. The high level of public aid is, in fact, one of the basic critiques against the PNEE expressed by some international financial agencies which are not involved in the program.

However, over a 20-year period and thanks to the PNEE, the conditions for irrigated agriculture have considerably changed from both a technical and economic viewpoint. New stakeholders have emerged on the institutional scene. The private sector, most especially the agri-food business and other downstream sectors, has taken on an unquantified but substantial role in irrigation development, especially for large farms. After evaluation of the program, we can note the following impacts (MARH 2016):

Table 2.1 Changes in irrigation technology (Country as a whole)

Year	Improved surface irrigation	Sprinkler irrigation	Micro-irrigation
1995	45%	47%	8%
2014	24%	31%	45%

Source: DGGREE (2015)

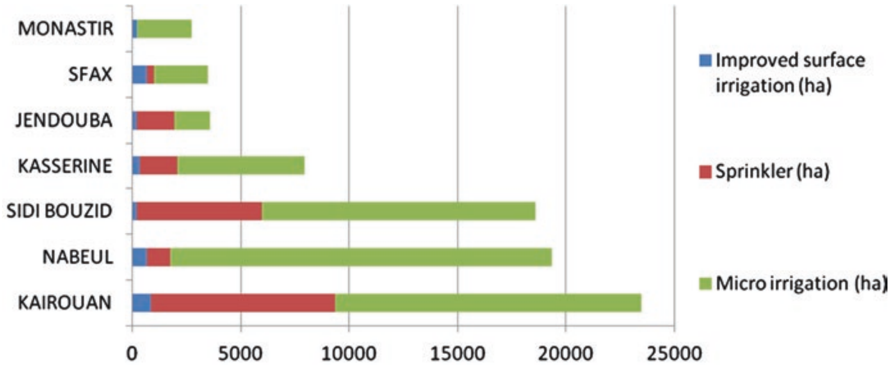

Fig. 2.3 Distribution of areas with water-saving irrigation techniques in some significant areas of the North and Center (Source: DGGREE 2015)

- In 20 years, the total surface area equipped with irrigation water-saving devices has almost tripled, and micro-irrigation has gradually replaced other types of equipment so that it now accounts for the largest share of the irrigated surface area (Table 2.1 and Fig. 2.3).
- On average, half of all irrigated systems have seen their water abstraction stabilize, while a third has seen it fall. There has, however, been an increase in water withdrawals for a small minority. The results are mixed in terms of a reduction in water use but should be compared with the high increase in crop yields in 70% of the farms.
- The value obtained from irrigation water has at least doubled for all crops. The PNEE has led to a considerable increase in water productivity, which has more than doubled in 20 years for fodder crops, vegetables, and tree crops, especially sprouted barley, chili, vines, and apple trees (see Table 2.2).

There is still some way to go when it comes to proficiency in the use of modern equipment. There are several other options that target more efficient use of irrigation water, and they should be explored and developed for the future (management tools, deficit irrigation, choice of crops that optimize water use, etc.), which means significant research and development efforts. Improved water management at farm level is still in its infancy, and the possibilities for reducing consumption and getting maximum value from the scarce resources available are real challenges for the future of the irrigation sector in Tunisia.

Table 2.2 Evolution of the economic performance of crops with and without the PNEE

	Production value per unit of water applied ($ /m^3)	Water cost/total expenses	Yield per unit of water applied (kg/m^3)
Cereal crops			
With PNEE	0.155	19.8%	1.756
Without PNEE	0.89	25%	1.073
Fodder crops			
With PNEE	0.78	13.9%	10.841
Without PNEE	0.48	16.6%	5.155
Vegetable crops			
With PNEE	0.43	14.1%	5.622
Without PNEE	0.29	13.5%	3.439
Tree crops			
With PNEE	0.462	14.7%	1.950
Without PNEE	0.165	25.4%	0.880

Source: DGGREE (2015)

2.3.5 Pricing Policy and Recovery of the Cost of Water

2.3.5.1 Water Pricing in Public Irrigated Schemes

Between 1990 and 2000, action was undertaken to strengthen irrigation water pricing in public schemes, including the small areas supplied by deep aquifers, working on three aspects: transparency over cost prices, flexibility (region-based pricing, variation according to the irrigated crops and the cost of supplying water, etc.), and related national objectives (preferential pricing for strategic crops and recycling of treated wastewater). From 1990 to 2000, there was a steady increase in water prices, amounting to a rate of 9% a year in constant value. Alongside these measures, considerable efforts have been made to test tiered pricing systems in large areas in the North (Abbas et al. 2005) and to generalize metering at the farm level.

The overall increase in prices between 1990 and 2002 served to cover a considerable portion of the rising water system operation and maintenance costs. The cost-recovery rate thus went up from 57% to 90% over the same period, and then prices were frozen as of 2002. The policy of a continued price increase was not well received, and there was sometimes strong resistance among irrigation users. Compensation measures, such as the application of preferential rates for cereal and fodder corps with low added value (rebate of 50% on standard rates, constant rate of 0.01 $/m^3 for treated wastewater, etc.), the deregulation of the price of irrigated production, and awareness raising among irrigation users about water savings on their plots, all gradually eased this resistance. However, the political decision to freeze irrigation water rates as of 2002 had a considerable impact on the financial balance of the GDAs, weakening their ability to fund servicing and maintenance work. "Political interventions" regarding pricing, bypassing regulatory bodies, viewing minimizing water charges as a way of improving farmers' revenues, has often had a negative impact on the sector.

Nonetheless, discussions on the development and application of new water pricing methods are underway, giving special consideration to the diversity in irrigation at local and regional level. Work has been carried out in this respect since 2015 (DGGREE/KfW).

The average price for irrigation water is estimated at 0.048 \$/m^3; the actual rate varies between 0.012 \$/m^3 (oases in the South) and 0.075 \$/m^3 (large areas in the North). Overall, the share of water fees in the total cost of growing crops remains significant at an average 14–15%, except for cereals where it reaches 20% despite the preferential rates for these crops.

2.3.5.2 State Fees in Private Areas

Tunisian regulations on the public hydraulic domain stipulate that authorizations and concessions concerning the abstraction of natural water come with a fee, to be paid to the State, based on the volume of water that may be extracted and applied regardless of the actual use of the water (Water Law: articles 63 and 53). This fee is currently set at a symbolic rate of 0.002 \$/m^3 with a minimum of \$6.5 for agricultural use and 0.022 \$/m^3 with a minimum of \$54 for other uses. This rate has no relation to the opportunity cost of water in regions where it is a rare commodity. In addition, there is a very low collection rate for these fees from users of individual or collective wells, boreholes, and abstraction points. The income generated by the State from these fees is very low, standing at between 5% and 10% of the theoretical amounts for groundwater. In addition, the authorities are not very responsive, which is both a consequence and an indicator of the major difficulties the State is faced with in managing the public hydraulic domain. Although financially marginal, the non-collection of these fees is a powerful symbol and constitutes an implicit subsidy benefiting water users in general and groundwater users in particular.

At present, there are no plans to introduce systematic volumetric metering at private water abstraction points because of the large number of devices required, their high cost (who would pay?), and burdensome maintenance constraints. Indirect measurement (through the area cultivated or the capacity of the well) appears to be the best advisable method in the country's current context.

2.3.6 Reuse of Treated Wastewater in Agriculture

Tunisia's experience with the reuse of treated wastewater for agricultural purposes goes back to the early 1960s (citrus fruit protection perimeter, Soukra-Tunis). In 2014, the total volume of treated wastewater produced by the ONAS was 240 Mm^3 and the volume reused 57 Mm^3, i.e., a recycling rate of 24%. The share for irrigation is just 26 Mm^3, a volume used to water around 9000 ha of crops, golf courses, and green areas. Tunisia has a quality standard for treated wastewater for irrigation and a set of specifications defining the role and responsibility of the various stakeholders involved in its reuse. The crops irrigated are defined in an order issued by the Ministry of Agriculture on 21 June 1991 and concern fodder crops and fruit trees (citrus, olives, pomegranates, peaches, etc.) for 55%, with the remainder being cereal and industrial crops. There is virtually no uncontrolled use of wastewater around towns because all urbanized areas have secondary-level water treatment plants.

Several studies and evaluations have been conducted on the reuse of treated wastewater in Tunisia (AHT 2009) and describe the emergence of technical, economic, and institutional constraints after the extension of this form of recycling. There are in fact an increasing number of difficulties with the process: irregular quality of the wastewater treated at secondary level only and supplied to irrigation, restricted crop choices for irrigation users, and so on. Contractualization between different stakeholders in the sector (ONAS, CRDA/GDA, and irrigation users) is considered pivotal in overcoming these difficulties.

2.4 Status of the Irrigated Sector

2.4.1 Mobilization of Water and Development of the Irrigable Potential

2.4.1.1 Context and Water Resources

Total rainwater resources for the country are estimated at 36 Bm^3/year, with 13 Bm^3/year of "green water" used by 5 million hectares of rain-fed agriculture. This potential reaches 19 Bm^3/year if we include evapotranspiration from vegetation on pasture land (5 million hectares) (Chahed et al. 2008).

Potential blue water resources are estimated at 4.86 Bm^3/year (see Table 2.3), divided between surface water (2.7 Bm^3/year or 56% of usable resources) and

Table 2.3 Development of conventional water resources in Mm^3

Nature of water resources	Potential resources (1)	Exploitable resources (2)	Mobilized resources (3) 1990	2000	2005	2010	2015
(A) Surface water	2700 (56%)	2500	1180	1876	2200	2400	2500
Major dams		2170	1170	1688	1927	2080	2170
Small dams		195	5	125	160	190	195
Lakes/reservoirs		135	5	63	113	130	135
(B) Groundwater	2155 (44%)	2155	1550	1860	1955	2015	2100
Shallow aquifers		745	700	780	805	810	815
Deep aquifers		1410	850	1080	1150	1205	1285
Total resources (A+B)	4855 (100%)	4655	2730	3736	4155	4415	4600
Mobilization rate (3/2)	–	–	(59%)	(80%)	(89%)	(95%)	(98%)

DGRE/DGBGTH

groundwater (2.17 Bm^3 or 44% of usable resources). In fact, these average values conceal wide regional disparities, and some groundwater resources have already been subject to intensive exploitation or are quasi-fossil water (MEDD/ANPE 2008).

Nonconventional resources are mainly limited to treated wastewater, estimated at around 240 Mm^3 in 2014 (ONAS 2015). Availabilities in 2030 are estimated at 450 Mm^3 and will only account for 9% of all water resources available at that time.

2.4.1.2 Irrigable Land Potential

In Tunisia, water resources – both groundwater and surface water – are limited, so the potential irrigable area with full controlled or intensive irrigation (requiring permanent water supply) stood at 410,000 ha in 2010 (425,000 ha in 2015), i.e., 8% of the actual agricultural area (UAA). Semi-intensive or supplementary irrigation and spate irrigation (with irregular water resources) have an estimated potential of around 150,000 ha. The irrigated areas are scattered across the country with concentrations in the Medjerda valley in the North, the Kairouan plain in the Center, and the oases in the South (see Fig. 2.4).

In terms of dynamics, the area with fully controlled irrigation was approximately 60,000 ha at the end of the 1960s and now reaches 410,000 ha. It is subdivided into (i) "public irrigated areas" (PIA) which are developed by direct investment of the State in collective infrastructures: 216,000 ha, 90% of which is managed by 1253 GDAs and 10% directly by the CRDAs, and (ii) the "private areas"[4] made up of individual systems generally supplied by shallow or deep wells and developed on the initiative of the farmers themselves (194,000 ha), with significant financial incentives from the State covering up to 25% of all private investments (Cf. Fig. 2.5).

2.4.2 Programs and Investment Budgets

In the 1970s, Tunisia opted for a water resource planning approach and developed water master plans for each of the three main natural regions of the country (North, Center, and South), backed by subregional strategies for water mobilization after 1990. Public investment for water has reached an average of 35% of total investment in the agricultural sector over the past few decades (Cf. Fig. 2.6).

From the above, we can conclude that huge efforts have been made to mobilize water: in 2012 hydraulic infrastructure included 33 large- and medium-sized dams (with a total capacity of 2.27 Bm^3), 253 small dams, 837 lakes/reservoirs, 5512

[4] The terms "public" and "private" mainly refer to the abstraction and conveyance infrastructures. Irrigated farms, including internal irrigation installations, are for the majority classified as "private."

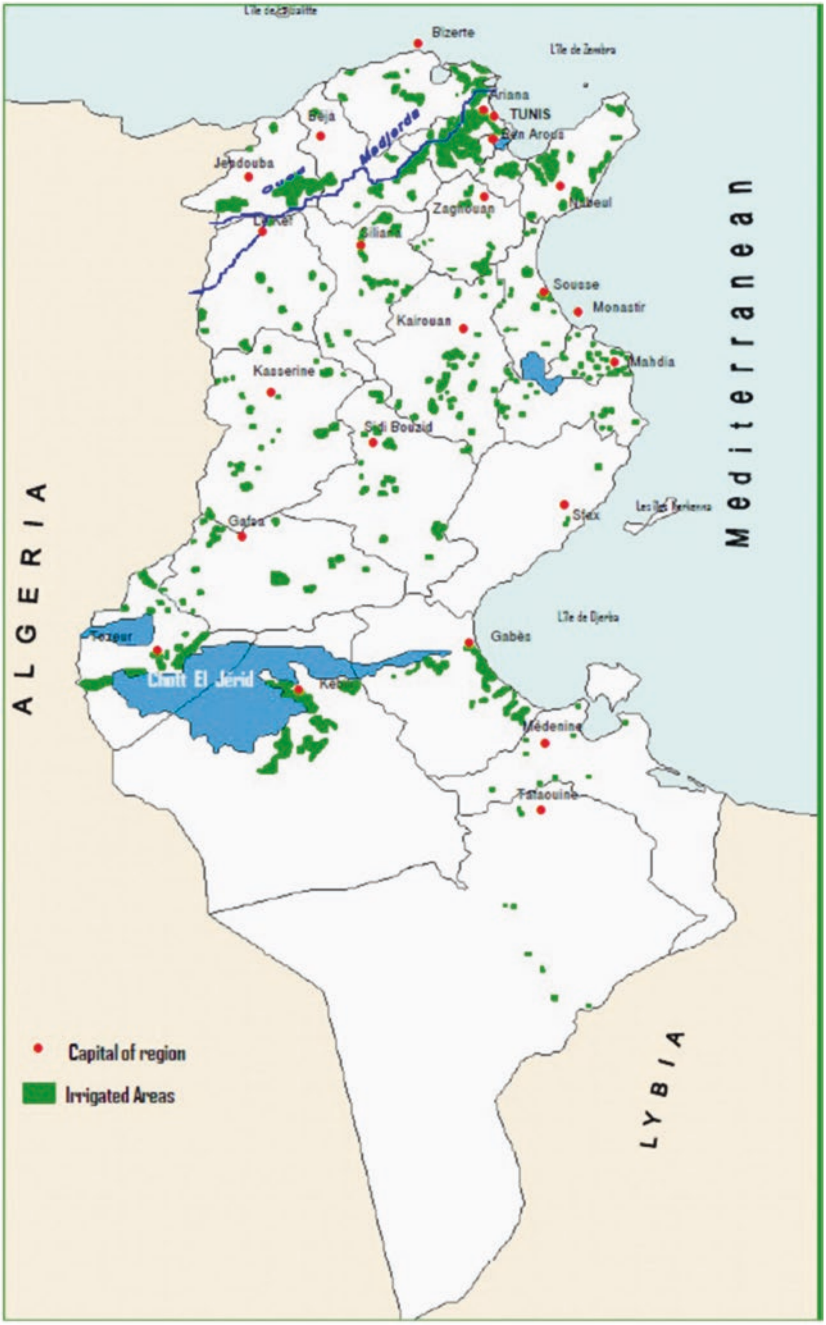

Fig. 2.4 Map of main irrigated areas in Tunisia (Source: DGGREE)

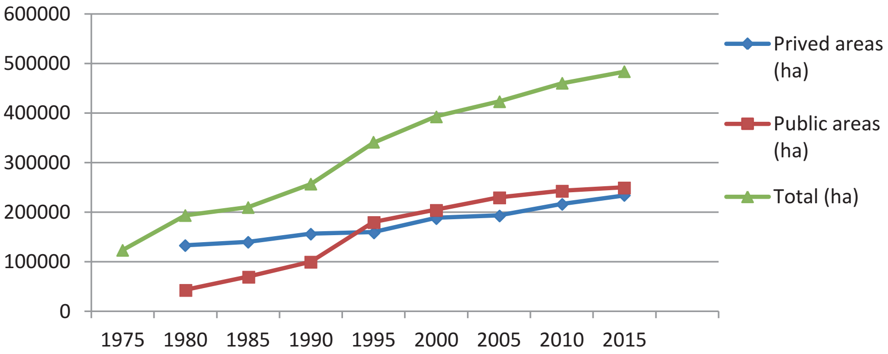

Fig. 2.5 Evolution of the total irrigable surface area (intensive and semi intensive) in (ha). (Source: DGEDA [General Management of Agricultural Studies and Development at the Ministry of Agriculture] 2012)

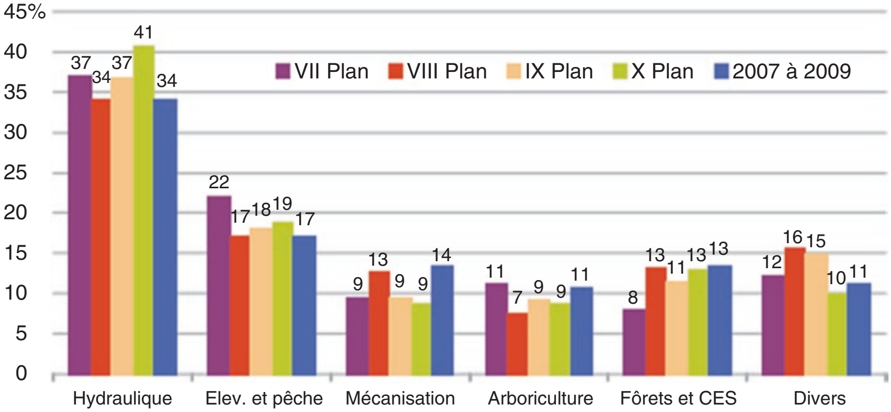

Fig. 2.6 Proportion of hydraulic investment in total investment in the agricultural sector, per Economic and Social Development Plan (Source: DGEDA, FAO-AFD)

boreholes, and 130,000 shallow wells.[5] The overall water resource mobilization rate[6] now exceeds 90%, and the country is thus approaching a relatively critical threshold for the mobilization of its resources. The negative impacts of climate change on resources have not yet been grasped at this level.

[5] Numbers are largely underestimated because of the difficulty to update such information after the 2011 Revolution.

[6] In reality, “mobilization of water resources” concerns resources made available in a sustainable manner. The overexploitation of groundwater resources only increases available resources for a limited time.

2.4.3 Agricultural Water Demand and Abstraction

Despite the lack of comprehensive data, in 2010, the total abstraction of water resources was estimated at 2688 Mm^3, 548 Mm^3 of which was to satisfy the demand for drinking water and 2140 Mm^3 the irrigation demand. The latter was met by groundwater (75%), surface water (23%), and treated wastewater (2%) (see Fig. 2.7).

The average share of irrigation in total withdrawals is only two thirds of what it was planned to be for reasons that are explained in another section. But average numbers conceal the fact that the main problem in Mediterranean environments is the very high yearly fluctuation of rainfall and runoff, which poses a challenge to dam management. The recent dry years 2015–2016 and 2016–2017, for example, illustrate this point.

The largest share of agricultural water demand comes from the coastal areas in the east, where population density is high, and in the oases where water consumption is very high. The coastal areas use more water than available, which means that water has to be brought from other better endowed regions in the north: in fact, the whole country is marked by long water transfers from the west and the north toward the east (164 Mm^3 in 2015 for irrigation and 400 Mm^3 in total on average).

Various studies have analyzed water strategies and prospects in Tunisia (Treyer 2002; ITES 2011). For the future, the balance between resources and use considered in the forward-looking study entitled "Water XXI" (MARH 1995) banks on a rather moderate evolution in domestic, industrial, and tourist demand for water. Although demand from the irrigation sector continues to prevail (78–82% of total withdrawals), the volumes allocated to irrigation are revised downward due to competition from other sectors. Hence, the average annual per hectare allocation would fall from 5200 m^3 in the 2010s to 4350 m^3 by 2030. Total allocation to the sector could thus be readjusted from 2140 Mm^3 in the 2010s to 2035 Mm^3 by 2030. Measures

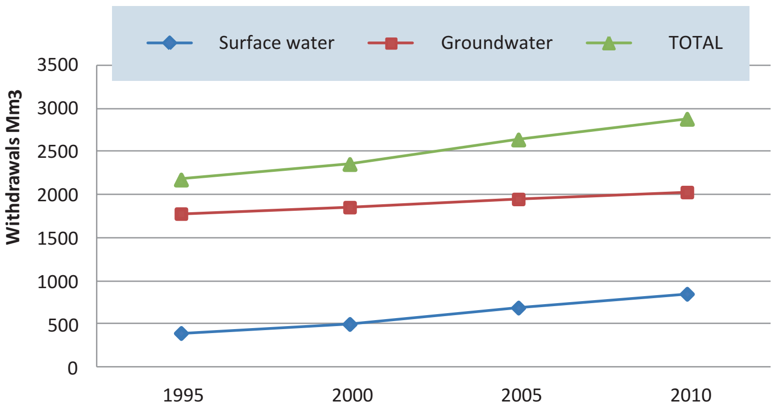

Fig. 2.7 Trend in water abstraction rates per type of water resource (Source: DGBGTH – DGRE)

encouraging farmers to use water-saving techniques and adopt crops that require less water could partially offset these imbalances which, otherwise, will likely be sourced from groundwater. Another alternative for the irrigated sector would be to make more use of treated wastewater: a volume of 220 Mm^3 of adequate quality should be made available for irrigation by 2030.

2.4.4 Irrigated Agriculture and Intensification of Irrigated Areas

2.4.4.1 Cultivated Surface Areas

Results from the latest study on irrigated areas, covering the 2011–2012 agricultural campaign, show that the total irrigable surface area subject to intensive and semi-intensive irrigation stands at 469,000 ha, of which 248,000 ha are found in public irrigated areas (i.e., 53% of the total surface area) and 221,000 ha in private areas (47% of the total surface area).

During the same campaign, the area of crops actually irrigated was assessed at 416,000 ha (taking into account "double cropping" practices and not including inter-cropping). Average cropping intensity[7] was 89%. This rate stood at 104% for the 2010–2011 campaign and 96% for 2009–2010. A more detailed analysis of the available data shows that cropping intensity is significantly higher in private irrigated areas, where the rate comes to 98% for 2011–2012, versus 80% in public irrigated areas.

It should be pointed out that the area actually irrigated is likely to increase in the future under the influence of two main factors: (i) one is related to the increase of the irrigable area allowed by the mobilization of still residual and local groundwater or surface water resources (DGGREE 2009), and (ii) on the other hand, the improvement of cropping intensity in existing perimeters, still lower than expectations because of significant constraints concerning the access to land, the financing of irrigated agriculture, the adequate water management of networks in order to secure water supplies, the lack of lead export markets, etc.

2.4.4.2 Irrigated Crop Type

Land use in irrigated areas is dominated by tree crops (olives, citrus, dates, pome fruit, and stone fruit), for which there has been the most significant increases. Over the 2011–2012 campaign, tree crops accounted for almost 40% of cultivated land, followed by vegetables (tomatoes, potatoes, chili, etc.) at 30%. Tree crops dominate because they better adapt to various climate and soil conditions. Changes in land use in the period from 2000 to 2012 are shown in Table 2.4.

[7] Ratio of the total surface area of irrigated crops to the total irrigable surface area

Table 2.4 Changes in land use (ha) in the period from 2000 to 2012

Crop type	2000	2005	2010	2012
Tree crops	155,000 (39%)	166,000	193,000	204,000 (41%)
Vegetables	123,000 (31%)	140,000	147,000	148,000 (29%)
Cereals and fodder	116,000 (29%)	120,000	170,000	148,000 (29%)
Industrial crops	4000 (1%)	4000	6000	4000 (1%)
Total	**398,000**	**430,000**	**516,000**	**504,000**

Source: PI Surveys by DGEDA

Analysis of the available data, most notably the results of studies of irrigated areas, shows that the same crops have been grown for several decades, with no new crop introduced on a large scale.

Greenhouse cultivation developed after 1970 and now accounts for 13,000 ha, with 10,000 ha in the Center, largely concentrated in the governorates of Monastir and Sfax. Crops grown under plastic tunnels cover an estimated 3000 ha, mainly located in the governorate of Sfax. Geothermal water in certain parts of the South (Tozeur, Kebili, and Gabes) has enabled vegetable growing under greenhouses on 150 ha.

The overall estimates available put yields at between 3.6 and 4 t/ha for cereals, 35 t/ha for fodder crops, 40–70 t/ha for field-grown tomatoes, 15–20 t/ha for potatoes, 30 t/ha for citrus, 15–20 t/ha for pome fruits, and 3–7 t/ha for date palms. However, a sustained growth in yields for certain tree crops and vegetables can now be observed, following the widespread introduction of micro-irrigation in the North and Center.

Innovations in cropping practices have not been particularly fast. However, the adoption of micro-irrigation by the majority of tree crop and vegetable growers, within the framework of the PNEE over the last 20 years, appears to have been a positive factor in the intensification of the irrigated production system.

2.4.4.3 The Problem of Low Agricultural Intensity

The general conclusion from the above analysis is that the current intensity and the value gained from irrigated agriculture remains quite low overall, when measured against the efforts made to develop land and water availability in certain regions (BM 2006). We can identify a paradox with newly irrigated farms in semi-arid areas. Generally speaking, irrigation allows for a threefold increase in gross output, but all too often, this only eventuates gradually. Even after several years, we frequently observe the presence of “residual” areas of dry crops in the middle of irrigated areas (Boussard 1972).

Analysis of the areas effectively irrigated shows that average horizontal intensity varies according to the year’s rainfall but has remained relatively stable over the past few decades. Average cropping intensity is 90%, but in reality it can vary from 40% to 120%, depending on the situation in the area and the socioeconomic context.

Design studies put this potential rate at 120–130% for the majority of irrigated areas, which would give a potential irrigated area of more than 500,000 ha, compared to 400,000 ha currently subject to intensive irrigation with the same water allocation.

This underutilization of resources, especially in certain large-scale schemes of the North, means that there are substantial volumes of water, especially in reservoirs, which had been allocated to irrigation but which have not been utilized as planned. For example, the two largest irrigated areas in the country, the Lower Medjerda valley (Ariana-Manouba) and the Upper Medjerda valley (Jendouba), only divert on average half of the volumes targeted at the planning stage, despite more than 30 years of "maturity."

As for the yields attained, it is estimated that the levels reached only account for 40–60% of the potential. There is considerable scope for improvement in "vertical intensity," which could be exploited in the future to achieve better productivity from irrigation water and higher incomes for farms, especially smallholders.

All in all, we estimate that the overall cropping intensity in irrigated areas amounts to approximately 60% of the potential. This unsatisfactory achievement is due to several constraints that include water shortages and soil salinisation due to a lack of drainage facilities, but also reluctance by some farmers to engage in capital-intensive agriculture when input and output markets are too uncertain, who prefer to stick to traditional agricultural practices (Hamdane and Bachta 2015).

2.4.5 *Irrigated Farming Systems and Structures*

Public policy on irrigation development and land reform, along with the dynamics of private agriculture, has resulted in a landscape where small- and medium-sized farms dominate (see Table 2.5). Large-scale irrigated agriculture mainly emerged when state-owned estates established with colonial land confiscated in the 1960s were leased out to private companies (SMVDA). Although they are relatively

Table 2.5 Irrigated surface area according to the size of farms

	1994–1995 survey			2004–2005 survey		
Farm size	Area (1000 ha)	%	Irrigated/ cultivated (%)	Area (1000 ha)	%	Irrigated/ cultivated (%)
Less than 5 ha	71.9	24.4	17.1	82.6	25.0	16.0
5–10 ha	52.3	17.8	9.7	65.6	19.8	9.8
10–50 ha	99.7	34.0	5.9	108.8	32.9	6.3
50–100 ha	19.0	6.5	4.2	20.9	6.4	4.5
Over 100 ha	50.9	17.3	5.7	52.6	15.9	6.4
Total	293.8	100	7.5	330.6	100.0	7.8

Survey DGEDA

efficient in technical terms, these business-oriented farms have not had the expected impact on development, and their influence within irrigated areas remains very limited.

On the other hand, the development of irrigation has led to the emergence of quite different landscapes and farming systems from one region to another, through a combination of soil and anthropogenic factors (Elloumi 2016):

- In the Medjerda Valley, multi-cropping systems have developed with cereal and fodder in the upper valley and vegetables and tree crops in the mid and lower valley.
- The north-eastern coastal areas are dominated by an intensive system of citrus cultivation and vegetable production (tomatoes, strawberries, etc.).
- Central Tunisia has vegetables crops (chili, melons, watermelons, etc.) and high-added value tree crops (table grapes, peaches, apples, etc.).
- The Sahel is home to greenhouse crops and early crops.
- The oasis system in the South is typified by date palms, tree crops (e.g., pomegranates), and fodder (alfalfa).

2.4.6 Overall Performance of the Irrigated Sector

Despite the limited size of irrigated areas, which only account for 8% of the country's cultivated area, the irrigated sector is strategic in terms of its impact on food security and its economic and social role:

Economic weight: the irrigated sector has diversified its production and is one of the pillars of the agricultural economy, which remains largely rain-fed. The irrigated sector accounts for 35–40% of all agricultural output, 95% of vegetable crops, 70% of tree crops, and 30% of all dairy output. From a socioeconomic viewpoint, the irrigated sector contributes to 20% of agricultural exports (citrus, dates, early crops, etc.). Apart from its role in the economy, irrigation helps farmers remain on their farms by providing a relatively regular income, which is on average three times higher than in rain-fed agriculture. Intensity could definitely be stepped up in irrigated areas, while low water productivity means that resources are not exploited to their full potential. Nonetheless, the technical advances made in irrigated agriculture over the last 20 years are undeniable. Nearly one in four farmers in Tunisia is now involved in irrigation, and this proportion is even higher for small farms.

Social impact: the irrigated sector accounts for approximately 20% of the labor force, confirming the sector's role in employment. Irrigation has an impact on employment in all upstream and downstream sectors (supplies, agri-food business, services, etc.) with a positive influence on rural development in regions with irrigated agricultural activity.

Political weight: Although the weight of agricultural GDP is generally falling, irrigated agriculture still forms the core of small-scale agriculture, which has maintained its position despite the major technological and economic changes that have transformed the sector over the past few decades. It is unfortunate that the emergence of irrigated agricultural poles, which drain considerable investment to the sector, is still not fully integrated with small-scale farming. Moreover, GDAs are emerging as farmer representation groups and management structures in a sector that generally suffers from a lack of professional representation.

2.5 Sustainability Challenges for Resources and Uses and Institutional Reform

2.5.1 Salinity and Irrigated Land Use

In Tunisia, conventional water resources are naturally characterized by their varying degree of salinity. The water available often exceeds international health or agricultural standards on salinity. This affects crop yields and, in the long term, is likely to damage the structure and fertility of irrigated soils, sometimes irreversibly (CRUESI 1970). Presently, approximately 60,000 ha of irrigated land are sensitive to salinization and 75,000 ha subject to a rise of saline water tables in certain areas of the North and South. It is estimated that around 60% of the soils in public irrigated areas in Tunisia are moderately or highly sensitive to secondary salinization after irrigation; this rate reaches 86% in private areas (DGACTA 2005). Salinization linked to hydromorphy concerns 26% of public irrigated areas to a varying degree. Over the long term, these constraints are likely to cause sustainable damage to the country's irrigation potential, leading to a reduction in the intensity of irrigated cropping or loss of soil fertility in certain areas developed at great expense.

Currently, attempts to use increasingly saline water on newly developed land come with several risks, and management of previously developed land sometimes causes serious issues with regard to sustainability: unsuitability of cropping practices in a context of high salinity, insufficient soil leaching, inadequate maintenance of drainage systems, and so on. These problems are heightened in private irrigated areas on coastal aquifers, in public irrigated schemes in the Medjerda Valley, and in the oases.

2.5.2 Fertility Loss and Pollution of Irrigated Land

A survey carried out in 2007 (DGACTA-Directorate of soils), as part of a study to assess types of soil degradation in irrigated areas, revealed the following: (i) lower fertility in irrigated soils is a dominant type of degradation linked to the modification of certain physical properties in 50% of the public irrigated areas surveyed and 63% of private areas; (ii) chemical pollution is mainly caused by the excessive or inadequate use of mineral fertilizers and crop protection products. In the long term, it is a threat to 28% of public areas where there are very localized, low to medium pollution risks; (iii) biological pollution is apparent where soils are affected by disease (nematodes, fusariosis, etc.). This is primarily observed in vegetable-growing areas subject to intense cropping (Ras Djebel, Chott Mariem, etc.).

2.5.3 Uncontrolled Urban Expansion

Tunisia is experiencing increasingly rapid urbanization with considerable impacts on regional development.

Irrigated areas form islets of economic growth that often require relatively high urban concentration to provide the usual range of social and economic services, along with the specific services required in these areas. However, unplanned urban expansion, combined with the development of industrial zones, is encroaching on agricultural areas and, in some cases, on private irrigable land or even public schemes (e.g., *Grand Tunis*, despite regulations to protect this type of land). Where land developed for irrigation is converted, agricultural production disappears completely from certain urban fringes, and there is disruption of agricultural activities in suburban fringes. These phenomena affect almost 28% of the large public irrigated areas in one way or another.

2.5.4 Intensive Use of Nonrenewable Resources in the South

Southern Tunisia has a significant share of the country's total groundwater resources (38%), especially deep aquifer resources (58%). The volume exploited from stocks with few or no recycling possibilities comes to 800 Mm^3/year, mainly used for agriculture, compared to just 650 Mm^3 in the 1980s.

This situation is mainly found in the oases and irrigated areas in the South (MEDD 2010). Despite planning and rigorous monitoring of resources, signs of overexploitation and loss of artesianism can now be seen with worrying consequences for the future of some areas (especially with the wide, unauthorized extensions of the oases in Kebili). This is likely to seriously affect the quality of the resource and increase the energy burden of its exploitation after a rapid fall in the piezometric level of the water table. These are very serious constraints for the future of the South and a challenge to the sustainability of oasis agriculture, the basis of the region's economy (MEDD/ANPE 2008).

Working with the three countries concerned by groundwater in the Sahara (Tunisia, Algeria, and Libya), the Sahara and Sahel Observatory (OSS) introduced the SASS program in the 1990s (i) to develop awareness within the basin through an update of the status of water resources and the long-term development scenarios and (ii) to prepare the setup of a consultative body involving all three countries to lead discussions and joint initiatives of mutual benefit (Besbes et al. 2003).

2.5.5 The Overexploitation of Groundwater Resources

In Tunisia, the use of groundwater resources is subject to fairly unrestricted access, with relative checks and ex post verifications by the authorities. Groundwater pumping has developed over the past few decades to satisfy the demand for irrigation water, mainly in private areas and especially in the coastal areas and the Center, leading to overexploitation of groundwater in some of these private areas, a drop in piezometric levels, salinization of water resources (seawater intrusion in some coastal areas in the governorates of Cap Bon and Bizerte) and irrigated land, and an increase in pumping costs, borne by farmers. Groundwater resources are currently used in more than 60% of irrigated areas and have a considerable effect on the country's food security. The productivist agricultural policy implemented over the past few decades, with financial incentives from the State, drove the intensive exploitation of readily available groundwater resources (Lavenus et al. 2016).

Several measures have been adopted to stem this trend, some of which are of a legal nature (declaration of perimeters of protection/prohibition), while others concern supply-side management (groundwater recharge or water transfers from the North to ensure conjugated management of groundwater and surface water in certain protection perimeters) and demand-side management (expanding water-saving systems at plot level). However, the results are quite mixed, although there are some positive trends in certain regions: stabilization of abstraction levels (Monastir, Sidi Bouzid) or, indeed, a fall (Nabeul, Kasserine). In other areas (Kairouan), the phenomenon is worsening (MARH 2016) (Fig. 2.8).

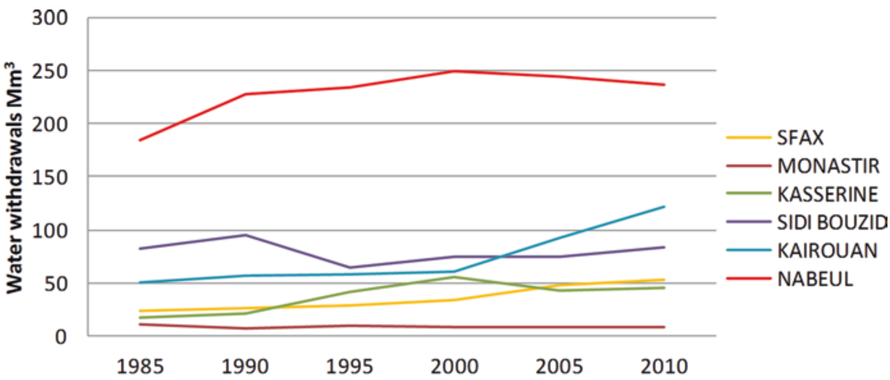

Fig. 2.8 Trends in groundwater abstraction in certain governorates (Source: Groundwater directory DGRE 2012)

From an environmental viewpoint, studies evaluating the cost of water degradation in Tunisia (BM 2007) have estimated the cost of overexploiting water tables. Overall, the total cost of this phenomenon comes to $19 million, or 0.1% of Tunisia's GDP. Other authors previously indicated a higher cost, equal to 1.3% of GDP.

The south-west and the Kebili governorate in particular are most affected, with 43% of the national cost of degradation due to intensive exploitation of quasi-fossil groundwater.

Since the 2011 revolutionary movement, the public authorities are less present and less active in rural areas, and impacts on the public hydraulic domain are becoming more frequent, especially with the creation of deeper and deeper water abstraction points (Elloumi 2016).

It should be noted that overexploitation is likely to spread to all shallow but also deep aquifers in the future if effective regulatory and protective measures are not taken. Large-scale expansion of the phenomenon is likely to have a considerable long-term impact on socioeconomic conditions in the regions affected and on the country's food security.

Several studies and research projects[8] have been conducted or are underway to determine the most suitable approaches and methods to stem overexploitation phenomena in the different socioeconomic contexts encountered in public irrigated areas. However, political commitment remains timid in light of the complex and volatile social situation in the areas concerned (BM 2003).

2.5.6 Irrigation/Energy Balance

From technical and economic angles, energy will be a complex challenge for Tunisia in the future. As is the case everywhere, fossil fuel reserves are running out. State subsidies for energy are already dwindling. Energy will therefore weigh more heavily on the water exploitation balance sheet. Three main factors will directly increase the share of energy consumed for irrigation: (i) the deepening of wells and boreholes, especially in areas where groundwater resources are subject to intensive exploitation, and in the Saharan areas where resources are suffering from a loss of artesianism; (ii) modern irrigation techniques are often energy-intensive, and their widespread adoption will see an overall increase in energy for irrigation; and (iii) an improvement in agricultural intensity will also increase overall demand for irrigation water, leading to a rise in the energy used to pump water to satisfy this additional demand in regions in the North where resources are still available (MIT/ANME 2011).

When it comes to irrigation, water and energy always go hand in hand. It is therefore vital that their management is coordinated to respond to the environmental,

[8] See the research project on groundwater governance in Tunisia (El Haouaria-Cap Bon water table), IWMI-USAID/INRGREF2013–2016. http://gw-mena.iwmi.org

economic, and political challenges raised by the expected growth in demand for water and energy.

2.5.7 The Impact of Climate Change

According to recent studies on climate change-related impact on Tunisian agriculture, the main consequences of climate changes are likely to include an increase in water requirements resulting from an increase in temperature (between +0.7 and 1.5 °C depending on the region) and more unpredictable and declining precipitations (−4 to −12%), resulting in a reduction in available water resources.

In general, the vulnerability of water resources to climate change leads to a worsening of the imbalance by 2030, in particular a 28% decrease in groundwater availability in coastal aquifers, nonrenewable aquifers, and high salinity groundwater, as well as a 5% reduction in surface water. This reduction in quantity is associated with a decline in the quality of water resulting from the intensive exploitation of groundwater, most notably for coastal aquifers subject to a risk of seawater intrusion (MARH/GTZ 2007).

The direct impacts on the sector of irrigation usually occur at different levels. In the first place, agricultural water demand is much more sensitive to climate change than demand in other areas of use. Temperature increases generate a shift and a shortening of the period of crop growth. Increased needs for irrigation water are expected as a result of the increase in evapotranspiration under thermal action and the stimulation of photosynthesis. Overall, with the coupled decrease in available water resources and increase in crop needs, we must expect a decrease in the irrigable area.

To face climate change and its impacts, better management of supply and demand appears as an effective means of adaptation. Actions are already implemented at various levels of decisions and are focused in particular on a demand management policy that aims at reducing demand or at least slowing down its growth.

2.5.8 Ongoing Institutional Reforms

As for long-term measures, they address in particular issues likely to lead to deep reforms of the modes of administration and resource management (institutional, geographical framework of resource management, privatization, etc.). The recent study of the water sector has analyzed all of these questions but does not provide definitive answers (Cf. Sect. 3.1). It offers guidance in the form of recommendations or general management guidelines, and most of the crucial issues with regard to developing a new water policy remain open. New directions are likely to be given by a new study, currently in its start-up phase, (“Water Study 2050”), which is expected to address recent sectoral constraints.

Despite the difficulties experienced by the country after the revolutionary events of 2011, in particular the crisis of state authority and the weakening of its means of control to protect water resources, especially groundwater, against illicit abstraction in several regions, some progress is being made regarding:

- The development of a new Water Code, currently under debate at the national level, which aims in particular at planning for integrated resource management at the river basin level; strengthening the participation of the different stakeholders, empowering the National Commission of water; creating regulatory bodies; strengthening the role of the regions in water management; and providing a more effective regulatory framework for the protection of groundwater resources (DGRE/CNEA 2009).
- A change in the legal framework of the GDAs to give them real autonomy.
- The participation of civil society in water management, etc.

2.6 Conclusion

Considerable efforts have been made in Tunisia to promote irrigated agriculture, and technical progress in the past 30 years is unquestionable. However, results remain below potential and expected performance. Weaknesses in agricultural development (technical advice to irrigators, agricultural credit, value chains, etc.) are found in the majority of large-scale irrigated schemes. The degree of agricultural intensification in these areas and the productivity of water remain to be enhanced. Overall, the situation of agricultural development is not satisfactory for a country that has not yet reached an acceptable level of food security.

While a key sector of Tunisian agriculture and a central means of agricultural intensification, irrigation comes with its specific problems. It is an asset for ensuring a high level of coverage of future food needs but also a concern with regard to sustainable management of water and the durability of infrastructure.

Tunisia will face the need in the near future to rehabilitate and modernize part of its water infrastructure that has become obsolete, adopting a more radical water demand management policy and more efficient economic instruments, taking into account climate change and strengthening local and collective water management. Indeed, the building of new infrastructure becomes increasingly marginal, and the valorization of the huge investments already made a priority.

As a final remark, irrigation is still expanding in Tunisia, and the governmental policy has to support this process by better organizing the sector and making use of its potentialities but without stimulating the mobilization of new water resources. On the other hand, Tunisia is really turning to demand-side management but with varying degrees of success and enthusiasm and despite a powerful inertia of the supply-side model.

It is to be hoped that the sacrifices of the Revolution will provide a better basis for the development of the irrigated sector.

References

Abbas, K., et al. (2005). *Impacts des formules tarifaires binômes sur les systèmes irrigués de la Basse Vallée de la Medjerda*. Montpellier: IAM.

Achour, H. (2012). *Status and new developments on the use of brackish water for agricultural production in the Near East: Tunisia country report*. Cairo: FAO/Regional Office for Near East.

A*f*DB (BA*f*D). (2011). *Usages agricoles des eaux souterraines et initiatives de gestion au Maghreb: Défis et opportunités pour un usage durable des aquifères*. Note Technique.

AHT GROUP AG. (2009). *Identification et élimination des goulets d'étranglement pour l'utilisation des eaux usées dans le cadre de l'irrigation ou autres usages*: Rapport national –Tunisie, RG/2008-01/FTF, Pays Meda – Euro Med/BEI.

Bachta, M. S. (2006). *De l'eau aux dattes: aperçu sur la filière-datte tunisienne et perspectives d'interventions*, SIRMA-Deuxième atelier Régional, Marrakech-Maroc, 29–31 Maui 2006.

Bachta, M. S., et al. (2000). *Environnement institutionnel et relations physiques pour une gestion intégrée de l'eau dans le milieu semi aride: le cas tunisien*. In PHI-V/Documents Techniques en Hydrologie N° 51. Paris: UNESCO.

Banque Mondiale (BM) (2003). *Tunisie – Analyse de la performance environnementale*, Report N° TN 25566.

Banque Mondiale (BM) (2006). *Tunisie: examen de la politique agricole*, Rapport N° 35239-TN.

Banque Mondiale (BM) (2007). *Evaluation du coût de la Dégradation de l'eau*, Rapport N° 38856-TN.

Ben Boubaker, A. (2007). *Evaluation participative du PISEAU: Synthèse des résultats*. FAO/BM.

Ben Mustapha Jacox, A., & Jamin, J. Y., 1015) (2016) *Action collective analysée par ses acteurs: une association d'irrigants en Tunisie*. Nature Sciences Sociétés.

Besbes, M., et al. (2003). *Système aquifère du Sahara Septentrional, gestion commune d'un bassin transfrontalier*. La Houille Blanche, N°5.

Besbes, M., Chahed, J., & Hamdane, A., (2014). *La sécurité hydrique de la Tunisie-Gérer l'eau en conditions de pénurie*. Paris: Editions l'Harmattan.

Bessaoud, O. (2005). *Les organisations rurales au Maghreb: un essai d'évaluation de leur rôle dans le développement agricole et rural*. Séminaire SFER, 7-9 Novembre 2005.

Blue Plan (Plan Bleu) – UNEP. (2002). *Analysis of strategies and prospects for water in Tunisia, Sophia Antipolis/Marseille*.

Boussard, J. M. (1972). Economie de l'adoption de l'irrigation, *Bulletin Technique d'Information-* Juin 1972; Ministère de l'Agriculture, France.

Canesse, A. A. (2010). Gestion des ressources naturelles et système institutionnel de gouvernance en Tunisie, Maghreb-Machrek, N°202, Hiver 2009-2010.

Chahed, J., Hamdane, A., Besbes, M. (2008). A comprehensive water balance of Tunisia: Blue water, green water and virtual water. *Water International*, *33*, n°4.

Chemak, F., et al. (2010). *Farming system performance and water use efficiency in the Tunisian semi-arid region: Data development analysis approach*. In International Transactions in Operational Research. May 2010.

Cherif, A., & Kassah, A. (1995). *L'eau et l'agriculture irriguée en Tunisie*. Tunis: Publication de la Faculté des Lettres de la Manouba.

Chevalier, L. (1950). Le plan de modernisation de l'équipement en Afrique du Nord. *Population*, 50 ème année, N°1 (1950).

CIRAD. (2011). *Analyse comparative de l'expérience tunisienne et de plusieurs expériences internationales en matière d'associations d'usagers gestionnaires de périmètres irrigués*. Société du Canal de Provence- France.

CRUESI. (1970). *Recherche et formation en matière d'irrigation avec les eaux salées*. Rapport technique 1962–1969 – UNESCO/UNDP.

DGACTA (MA). (2005). *Examen et évaluation de la situation actuelle de salinisation des sols et préparation d'un plan d'actions et de lutte dans les périmètres irrigués de Tunisie*, Programme PISEAU.

Direction Générale des Etudes et du Développement Agricole (M.A.R.H). (2006). *Contribution à la revue de la politique du secteur agricole* -Partie: Agriculture irriguée- J. Blanken/FAO.
Direction Générale des Etudes et du Développement Agricole (MA). (1990–2012). *Résultats de l'enquête sur les périmètres irrigués*- Rapports annuels.
Direction Générale des Ressources en Eau – CNEA (M.A.R.H). (2009). *Etude de révision et d'amendement du Code des Eaux*.
Direction Générale des Ressources en Eau (M.A.R.H). (1999). *Etude du secteur de l'eau*. Bechtel/SCET- Tunisie.
Direction Générale du Génie Rural (M.A). (1997). *Etude de la gestion et de la tarification de l'eau d'irrigation au niveau des périmètres irrigués*. Groupement CNEA/BRLi.
Direction Générale du Génie Rural et de l'Exploitation des Eaux (DGGREE). (2009). *Diagnostic de l'évolution des taux d'intensification dans les périmètres irrigués*: Etude des cas des gouvernorats de Kairouan, Sidi Bouzid et Kasserine, Rapports des phases I et II, KfW/Biche.
Direction Générale du Génie Rurale et de l'Exploitation des Eaux (DGGREE). (2012). *Evaluation de la situation actuelle des Groupements Hydrauliques* (in Arabic)
Direction Générale du Génie Rural et de l'Exploitation des Eaux (M.A.R.H). (2013). *Elaboration des approches et concepts pour la pérennisation de la gestion et de l'exploitation des systèmes d'eau* – Mission 1, Quatre rapports (C1, C2, C3, C4), KfW/IGIP.
Direction Générale du Génie Rural et de l'Exploitation des Eaux (DGGREE). (2015). *Rapports et études sur le secteur de l'irrigation*. Tunis.
El Amami, S. (1984). *Aménagements hydrauliques traditionnels en Tunisie*. Tunis: CRGR.
Elloumi, M. (2016). *La gouvernance des eaux souterraines en Tunisie*, IWMI Project Report-Groundwater governance in the Arab World- Report N°6. http://gw-mena.iwmi.org/outputs
FAO. (2007). *L'irrigation en Afrique en chiffres*- Enquête AQUASTAT 2005.
Faysse, N., et al. (2011). Agricultural use of groundwater and management initiatives in the Maghreb: Challenges and opportunities for sustainable aquifer exploitation (A. U. Ordu, J. Kolster, & N. Matondo-Fundani (Eds.), Economic Brief). Tunis: AfDB, 23 p.
Feuillette, S. (2001). *Vers une gestion de la demande sur une nappe en accès libre: exploration des interactions ressources-usages par les systèmes multi agents*. Application à la nappe de Kairouan, Tunisie Centrale, Thèse de Doctorat, Université Montpellier II- France.
Gauckler, P. (1897). *Enquêtes sur les installations hydrauliques romaines en Tunisie, Imp*. Tunis: La Rapide.
Gharbi, N. (2009). *Aménagements hydrauliques et améliorations de la gestion de l'eau dans les oasis*, CIRAD, Actes de l'atelier SIRMA, 25–27 février 2009- Tunisie.
Hamdane, A. (2002). *L'irrigation en Tunisie*- Institut Méditerranéen de l'Eau-Marseille.
Hamdane, A. (2006). *Suivi des progrès dans le domaine de l'eau et promotion de politiques de gestion de la demande*: Rapport national de Tunisie, Plan Bleu /CMDD.
Hamdane, A., & Bachta, M. (2015). *Etude sur l'intensification des périmètres irrigués en Tunisie*, Banque Mondiale/FAO.
Hassaïnia, J. (1991). *Irrigation et développement agricole: L'expérience tunisienne*, CIHEAM-Institut de Montpellier.
INECO. (2009). *Institutional framework and decision-making practices for water management in Tunisia: Towards the development of a strategy for improved groundwater management*. Tunis: International Center for Environmental Technologies.
Institut National de Recherches du Génie Rural, des Eaux et Forêts (INRGREF). (2002). *Cartographie de la bioclimatologie de la Tunisie*. Tunis: INRGREF.
ITALCONSULT. Ministère de l'Agriculture. (1993). Economie d'eau 2000- GMBH/GKW/Coyne &Belier/ CNEA.
ITES. (2011). *Etude stratégique, Eau 2050 en Tunisie*, Rapport de synthèse Juin 2011.
Kress, H. J. (1977). Eléments structuraux andalous dans la genèse de la géographie culturelle de la Tunisie. *Revue IBLA*, 1980, N°145 (Traduction).
Laghrissi, H. (2013). *Impact de la dynamique institutionnelle sur la gestion d'une nappe côtière souterraine*: Bsissi-Oued El Akarit Projet de fin d'études, Ecole Supérieure d'Agriculture Mograne.

Latiri, R. (2005). *Analyses des politiques hydrauliques – Cas de la Tunisie*. Actes du séminaire Euro Méditerranéen sur les instruments économiques et modernisation des périmètres irrigués, 21–22 novembre 2005, Sousse, Tunisie.

Lavenus, S., et al. (2016). *Gestion des ressources en eau souterraines comme bien communs*. AFD, note technique N°18, Juillet 2016.

Le Gal, P., et al. (2008). *Impacts de la chaîne d'approvisionnement export sur la valorisation de l'eau pour les dattes dans les oasis du Sud de la Tunisie, CIRAD, SIRMA*. Actes du 3ème atelier régional, Nabeul 4–7 juin 2007.

Lebdi, F. (2009). *Contraintes de l'agriculture irriguée aux opportunités du marché: cas de la Tunisie*. Notes d'analyse du CIHEAM N°51, Sept. 2009.

MARH-GTZ. (2007). *Stratégie nationale d'adaptation de l'agriculture tunisienne et des écosystèmes aux changements climatiques*. GOPA-Exaconsult.

Ministère de l'Agriculture. (1970). *Etude du plan directeur de l'utilisation des eaux du Nord*.

Ministère de l'Agriculture. (1998). *EAU XXI: Stratégie du secteur de l'eau en Tunisie à long terme 2030*.

Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche (BPEH/DGGREE). (2016). *Etude d'impact (évaluation) du programme national d'économie d'eau en irrigation*, Phase I et Phase II- LB/SCET-Tunisie/OIE.

Ministère de l'Agriculture et des Ressources Hydrauliques (AFA) (2006) *La reforme agraire en Tunisie*, Conférence Internationale sur la reforme agraire et le Développement Rural (ICARRD)- Tunis, 2006.

Ministère de l'Environnement et du Développement Durable (MEDD). (2010). *Etude sur la gestion durable des systèmes oasiens*, GTZ/OTEDD.

Ministère de l'Environnement et du Développement Durable (MEDD)- ANPE. (2008). *Gestion durable des ressources en eau*, GTZ/OTED.

Ministère de l'Industrie et de la Technologie –ANME. (2011). *Etude du Développement et de la maîtrise de l'énergie dans le secteur de l'agriculture et de la pêche- Alcor 2010–2011*.

Office National de l'Assainissement (ONAS). (2015). *Rapport annuel d'activités de l'ONAS de 2014*. Tunis: ONAS.

Poncet, J. (1956). La mise en valeur de la basse vallée de la Medjerda et ses perspectives humaines. *Annales de Géographie*, t65, n°349, 199–222.

Sander, J., et al. (2008). *Water balance and evaluation of water saving investments in Tunisia*. BIRD/Waterwatch.

Schiffer, M. (1997). *Agriculture irriguée au Maghreb: limites et perspectives*. Berlin: Institut Allemand de Développement (IAD).

Treyer, S. (2002). *Analyse des stratégies et prospectives de l'eau en Tunisie*, 2 rapports, Plan Bleu- PNUE.

Watson, A. M. (1984). Agricultural innovation in the early Islamic world. *Journal d'agriculture traditionnelle et de botanique appliquée*, 31 ème année, bulletin n°3–4.

Xanthoulis, D. (2013). *Etude stratégique des formes de réutilisation des eaux usées en Tunisie*-Programme de Coopération FAO-Banque Mondiale (PISEAU II).

Websites

AQUASTAT – FAO water and agriculture information system: http://www.fao.org/nr/water/aquastat/main/index.stm

Institutional aspects of water management in Tunisia: http://www.semide.tn/bodyinstitution.htm

National Agricultural Observatory (ONAGRI): http://www.onagri.nat.tn/

Research on Journal Officiel de la Republique Tunisienne: http://www.cnudst.rnrt.tn/wwwisis/jort.06/form.htm

Statistical record of the Ministry of Agriculture (CNS): http://www.cnudst.rnrt.tn/wwwisis/jort.06/form.htm