Integrated Water Management in Tunisia: Meeting the Climate Change Challenges

N. Omrani and M. Ouessar

Abstract As a southern Mediterranean country, Tunisia is located under an irregular climate. With a mean annual rainfall of 230 mm, the country sustains a water scarcity context. While the present annual water resource average is estimated to be 450 m^3 per capita, it is expected to be barely 315 m^3 beyond 2030. With the increase of the living standards as well as the development of the agriculture, industry, and tourism sectors, the water shortage will be exacerbated. Given that situation, the Tunisian water policy had been engaged toward an integrated approach. Coordination between the main stakeholders involved in the water management became effective. One of the main tools of this strategy is already the demand management. It assumes an important issue for the case of the agriculture sector consumption (more than 83 % of the available water resources). However, Tunisia is also strongly concerned by the climate change. Official forecasts report an expected increase of the annual average temperature by 1.1 °C (0.9 °C in the north and 1.6 °C in the south), a loss of nearly 20 % of the arable lands and a decrease in the water resources by more than 28 % beyond 2030. It seems evident that the national integrated water policy will require further commitment with the spectra of the climate change impacts. The preparedness of Tunisia to meet such challenge is a precondition to its water resources reliability.

Keywords Tunisia • IWM • Irrigated sector • Climate change • Water policy reform

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R. Choukr-Allah et al. (eds.), *Integrated Water Resources Management in the Mediterranean Region: Dialogue Towards New Strategy*,
DOI 10.1007/978-94-007-4756-2_2,

1 Introduction

Regarding its geographical context, Tunisia has to constantly cope with the climate uncertainties. Surrounded at the south by the Sahara and the Mediterranean Sea at the north, the annual rainfall differs highly in time (between seasons) and space. The main value in the north is 594 mm, 296 mm in the center, and less than 100 mm in the extreme south (Aquastat 2005). Nearly two thirds of the total area is located under semiarid to arid climate. The country is often submitted to drought sequences that could be regional or generalized. Under such climate, the irrigated sector is still obviously the most threatened by the water scarcity (Omrani and Ouessar 2008b). The annual evaporation ratio is 1:200 mm while it reaches 1:800 mm in the southern part with the occurrence of quasi-permanent hydric deficit.

Considering these precipitation gradients, four natural regions had been identified (Fig. 1). The extreme north with less than 3 % of the total country area contributes with a surface water amount of 960 million m^3, which represents 36 % of the national country potential. The north represented by the basins of *Medjerda*, Cap Bon, and *Meliane* contributes with regular surface water inputs estimated to be 1,230 million m^3 that is equal to nearly 46 % of the total surface water potential. The center entitling the basins of Nebhana, Marguelil, Zeroud, and Sahel is presenting irregular water surface inputs with 320 million m^3 or 12 % of the national potential. The fourth region is the south which has the lowest surface water potential, nearly 190 million m^3 or 6 % of the total water surface potential; nevertheless, it encloses more than 58 % of the underground water resources potential (MAREH 1998).

Added to the limited water resources, the future water policy should manage with permanent desertification risks across the center and the southern country. Moreover, the climate change impacts that had been already perceptible are definitely a new challenge to be taken. The institutional traits of the integrated water policy will certainly shape the potential for the adaptation to climate change over the coming decades.

To tackle the coming challenges for the national water policy, it became mandatory to undertake a drastic reform toward more water service performance (Horchani 2007).

In the irrigated sector as well as for the drinking water, the key element of the future water policy would be the demand management and the efficiency guarantee.

The rehabilitation of the hydraulic facilities remains insufficient in the absence of the user's community engagement. The intensification of the water-saving campaigns in the irrigated sector coupled with the drinking water supply network diagnosis had been in that sense conclusive.

More than the technical approach, Tunisia water policy needs to formulate large-scale program of water valorization. The integrated resource management remains the key tool of such policy with stronger commitment and participatory approach in the decision-making process. For the coming decades, the decentralization in the water management seems to be highly recommended. Nevertheless, such step should be strongly prepared by the allowance of the needed capabilities in terms of budget and technical know-how.

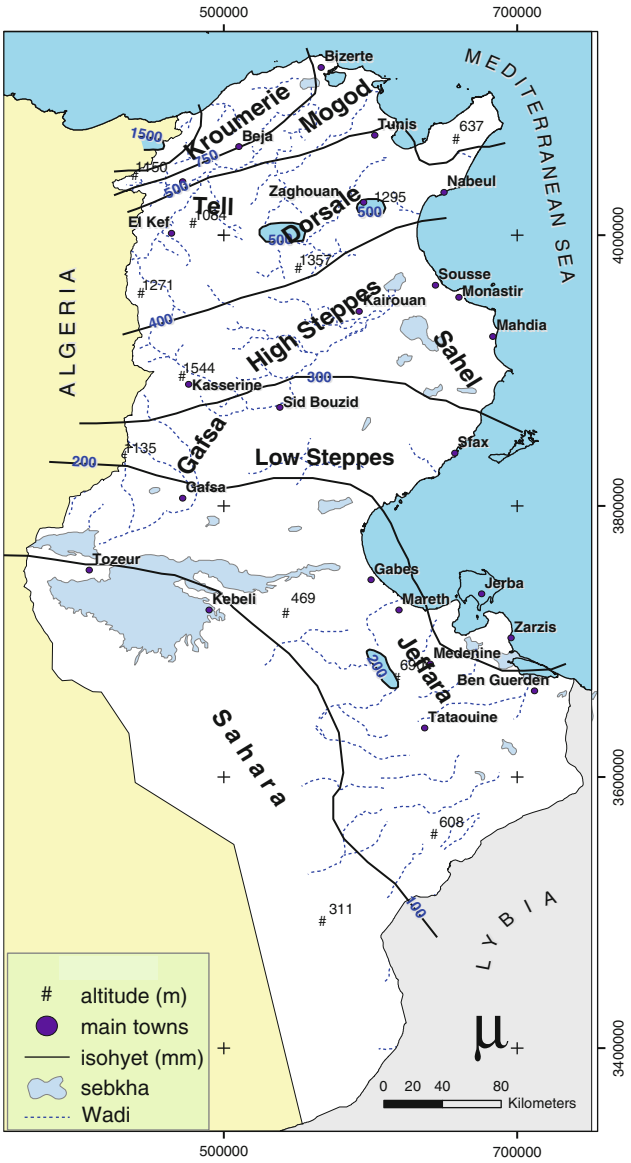

Fig. 1 Annual rainfall gradient and natural regions in Tunisia (MEAT 1998)

The prevailing context of the irrigated sector as a concrete case study clearly revealed the weakness and the quasi absence of self-reliance by the farmer groups or GIC. The lack of capacity building and the absence of strong institutional support to such initiative condemned these groups to be permanently tributary to the development authorities for the maintenance of the irrigation facilities.

Our approach in this chapter aims to emphasize on the achievements of the water policy as well as an inventory attempt of the real weakness that could be omitted. Indeed, the capabilities of the Tunisia water policy to cope with the climate change impacts remain tributary to the effectiveness of the integrated water management approach as well as the relevance of the reform measures to be implemented.

2 Tunisia Integrated Water Management

Through successive decades of water mobilization, Tunisia had acquired a relevant experience in the water resources management. The establishment of an institutional framework to the water policy dates back to 1971 with the institution of the water code. It represented the legal framework that will thereafter define the main milestones of the Tunisia water policy. An assessment of the available water resources allowed the institution of three-director water plan for the north, the center, and the southern country. While the north and the center water plan focused on the development of large dam's facilities and their networking and the multiplication of the collinear lakes in the center, the southern Tunisia observed a tremendous development of the underground resources exploitation. This mobilization phase allowed satisfying the growing water demand without having to ration water even during periods of acute drought.

The total available water resources range from 2,700 to 3,100 million m^3; therefore Tunisia water strategy is targeting to master the demand at 2,800 million m^3 beyond 2030 (Fig. 2). Maintaining such balance between will certainly require an integrated water policy that encloses all sectors involved in the water management. To promote such policy, several measures had been implemented in order to reform the water

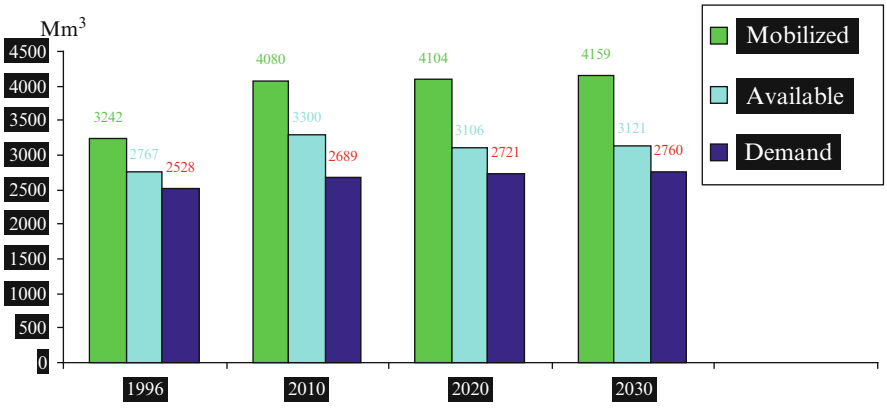

Fig. 2 Available water resources in Tunisia and projected future water demand into 2030 (MAREH 2009)

sector and to enhance the water productivity, especially in the irrigated sector where the efficiency and intensification still facing many institutional and technical hindrances.

In this regard, the mobilization of water resources phase had been followed by several measures to promote more efficient water management. The introduction of the water-saving plan aimed to enhance the distribution efficiency with the introduction of water-saving methods and to decrease the demand by 30 %. The financial subsidy allocation contributed to perform such approach, and more commitment from farmers had been gained (Louhichi 1999). Nevertheless, the necessity of an integrated water reform had been progressively recognized as a precondition to a sustainable development of the water resources. The high concurrency between all sectors in the water consumption reinforced that choice and imposed a close collaboration between all sectors. An integrated reform that takes into account technical, economical, and institutional aspects seemed to have significant impacts on the water management and conservation (GTZ 2007).

2.1 Treated Wastewater Reuse

Since 2000, Tunisia undertook further measures toward an integrated water resources management. With the increasing water demand among the different sectors and the climate uncertainties, the recourse to the nonconventional water resources became a key tool of such strategy. The reuse of treated wastewater for irrigation became progressively a viable option with the development of the treatment wastewater facilities as well the water supply reliability, and the implementation of the wastewater treatment station across the country highly reinforced the capabilities of the wastewater reuse plan. The competent authorities managing the treated wastewater in Tunisia are represented by the ONAS which is the National Sanitation Utility. It supervises the functioning of nearly 106 operating plants with a total volume of 238 million m^3 of treated wastewater which is equal to 5 % of the total mobilized water resources. Such contribution is enhancing crescendo and expected to reach 480 million m^3 or 10 % of the total mobilized resources at the horizon 2030. The portion used for reuse ranges between 20 and 30 %, while the rest remains released into the natural environment. The major used water comes from the domestic use (80 %) while the industry and tourism sectors contribute with, respectively, 15 and 5 %. The major reuse fields are the agriculture irrigation, the golf course irrigation, and landscape irrigation in urban areas as well as the aquifer recharge. The total area irrigated by the treated wastewater represents 8,065 ha divided into 27 irrigation schemes and dispatched between 15 governorates across the country. The development of the wastewater reuse had been shaped under control of strict legislation that defined the legal framework of such water resource reuse. Indeed, since 1975, the reuse of raw wastewater for comestible vegetable irrigation had been prohibited. In 1989, a decree defined the outline of the treated wastewater in agriculture through the following prerogatives: (a) strict interdiction for vegetable irrigation, (b) the

reuse of the treated wastewater should be authorized from the agriculture ministry in agreement with the environment ministry, and (c) severe bacteriologic standards have to be fulfilled through frequent monitoring of the water sampling (monthly for physical-chemical parameters, 6 month for trace elements, and every 2 weeks for helminth eggs).

For the coming decade, the wastewater treatment capabilities are called to be reinforced with the creation of 18 new treated wastewater irrigation schemes (7,010 ha) as well as the extension (1,480 ha) and the rehabilitation (5,000 ha) of some existing schemes. On the other hand, more than 30 million m^3 will be used for artificial groundwater recharge.

Despite the relevant efforts consented into the development of the treated wastewater plan in Tunisia, a strong reluctance from the population that still persists. On other hand, the state of art indicates the necessity of further improvement of the treatment process toward friendlier environment approach. Recurrent conflicts remain being signaled in several governorates; in the absence of long-term utility storage, the huge effluent production amounts became out of sight of some treatment plants and could resume the ongoing situation of the treated wastewater reuse in Tunisia. Furthermore, the modernization efforts of the treatment plants have enormous costs that would certainly remain uncovered regarding the low potential use of the treated wastewater. It is also evident that, as long as the impacts on human health remain not yet clearly identified, such reluctance is called to subsist. The national experience in the treated wastewater reuse remains laudable and aspires to play greater role in the coming decade with the development of the treating technologies. For the case of Tunisia, more research efforts should be deployed for better assessment of the treatment plants on the local environment. The integration of the socioeconomical dimension is also highly recommended for more sustainable integration of the marginal water use in the irrigated sector.

2.2 Drainage Water Reuse

As the irrigation practice, the implementation of the drainage networks is a secular practice within Tunisia irrigated lands. Since the 1980s, the entire irrigated perimeter had been equipped by dense drainage network (open surface canal and buried pipes) to evacuate the excess water toward the depression surfaces.

The maintenance of these networks is subscribed within the farmer groups' attributions, and their dredging is regularly scheduled before the winter season when the water flow becomes important. Nevertheless, with the continuous extension of the irrigated areas, the shallow water table significantly rises up (Ben 2003; Mamou 2009). Such situation became drastically alarming in the southern Tunisia oases. Indeed, while the multiplication of the private parcels enhances the pressure on the underground water resources and contributes to create a chronic waterlogging context, their consumption slips totally through the development of authority controls (Omrani and Burger 2011a, b). Important drainage water amount is still

Fig. 3 Important drainage water amount collected in downstream oases in southern Tunisia (Prinz and Loeper 2008)

being collected downstream the irrigated lands. They represent imminent risks of backflow toward the farmer's plots and threaten the soil contamination by high-saline water (Zammouri et al. 2007; Schmidt et al. 2006) as illustrated in Fig. 3.

There is a real awareness about the potential of this water as complementary resource to be exploited (Edmunds et al. 1995). The possible mixing with the irrigation water for the irrigation of salt-tolerant crops could be a viable option to be followed. Moreover, the use of this marginal water for the irrigation of some tree species as a green barrier in the struggle against the desertification is already effective in several regions and could be qualified as conclusive action in the valorization of such resource.

Despite the promising potential of the drainage water, there are some technical constraints that should be treated as a prerogative to their sustainable reuse in irrigation. Indeed, the intermittent regime of this water availability builds yet a relevant constraint to their valorization. While their volume becomes important in winter with suitable quality, it considerably decreases in the summer period with an important rise in their salinity. Furthermore, the importance of the collected drainage water amount remains de facto tributary to the drainage network performance and directly submitted to the irrigation good governance as well (Prinz et al. 2005). Nevertheless, with the development of the social conditions and the technical evolution, the drainage network cleaning out had been progressively neglected from the local population. The financial allocation provided to their maintenance by the farmer groups is still rudimentary and at the latest priority. Such low performance influences on the drainage water use sustainability and does not facilitate its implementation as a concrete option in the marginal water reuse.

In this regard, more promotion of such alternative will also pass through the enhancement of the drainage network efficiency. Such task should be further followed from both research and development stakeholders.

3 The Irrigated Sector Reform

The irrigation sector had been always a key tool of the national water strategy. Under the intensive tempo of the water resources development, the irrigated area observed a tremendous extension. From nearly 143,000 ha in 1976, it evolved to

380,000 ha in 2001 and estimated to be more than 400, 000 ha today with a surface water system fully operational. More than 226,000 ha are irrigation systems under public management. The private systems, created around shallow wells, cover 175,000 ha. About 52 % of the irrigated area is located in the northern part of the country, 31 % in the center, and 17 % in the south. More than 40 % of the irrigated area is used for fruit trees (40 %) and about 36 % for vegetables (21 % tomatoes and 15 % potatoes) production. The cereal cultivation extends to over 14 % of the irrigated area, while the feed crops cover 10 %. It contributes also with 95 % of the vegetable production, 77.5 % of the fruit production, 30 % of the dairy products, and 25 % of the national cereal yields. The irrigated sector also contributes 20 % of the agricultural export value and employs about 26 % of working forces (Al Atiri 2007).

Knowing that the irrigated sector contributes with nearly 35 % in the total agricultural production, such contribution is expected to reach 50 % in the coming decade with the development of the irrigation network (Horchani 2007).

On the organizational aspect, the main irrigation systems are collectives and have a regulated water service. They are managed by the public administration. About 62 % of the irrigated areas under public administration are supplied from dams, while 38 % are irrigated from deep groundwater wells and treated wastewater. Listed by the nature of the water source, the irrigated perimeters under public administration consist of 142,000 ha irrigated from dams, 47,000 ha (only intensive) from groundwater abstractions, 30,000 ha are oases irrigated by deep groundwater abstractions, and 8,000 ha from treated wastewater. The private perimeters are supplied from shallow wells made by farmers (Al Atiri 2007). This variety has led to differences in the sizes and configurations of equipment and diversity in the management of individual irrigation schemes. As a result, production and productivity levels vary, depending also on local and regional climatic and socioeconomic conditions (Hamdane 2004, 2008).

The current agriculture consumption ratio is more than 83 %; it represents the highest sector of water consumption and indicates by far the pressure that could be applied on the water resources within a context of growing demand and acute concurrency between the tourism, agriculture, and industry sectors. As a response to such evolution, a reform of the irrigated sector toward more efficient performance became evident. The first step in that direction already undertaken by the development actors could be qualified as a rehabilitation phase. Since 1990, a program of irrigation water conservation had been established. The main focus aimed to rehabilitate the irrigation facilities and to reinforce farmer's skills for more efficient water management mode (Seddik 2009). Through the experience feedback, it became clearly evident that a technical approach could not overcome the different constraints that strangle the irrigated sector development. The implementation of an integrated approach could bring to bear more efficient solutions and will definitely contribute to meet the expected objectives.

The irrigated sector reform could be conclusive only by further active commitment from the farmer's community. Relevant efforts have been consented before to engage the farmer groups as active partner in the irrigation water management. The creation of the common interest group (GIC) contributed to involve the farmers

in the irrigation network management (SAPI 2005; Sanyo Consultants Inc 1996). Such initiative strongly reinforced the cooperation between development authorities and farmer groups. The introduction of more efficient irrigation techniques became easier as the farmer groups became a real partner in the irrigated area development. Despite such advances, many constraints still exist such as the low technical skills of some farmer groups and the absence of the private sector in the irrigation equipment services and maintenance.

For the coming decade, the irrigated sector reform should associate more the farmer community in the decision-making process. Furthermore, the decentralization has to be preceded by relevant irrigation technical skills building. The state disengagement could be then progressively undertaken.

The enhancement of the water productivity as well as the water cost recovery should be strongly targeted within such reform. Indeed, the ongoing water-pricing policy is not covering the real costs of the water mobilization and does not militate for more water resource valorization.

The achievements of the irrigated sector require further engagement from both of the development and the farmer's community to reach a sustainable development of such sector. The isolated technical approach should be replaced by more integrated farmer-oriented initiatives. The improvement of the farmer groups' income and their irrigation practice skills reinforcement are precondition of their commitment.

4 Climate Change Challenges

Beyond the water demand satisfaction, the integrated water management policy in Tunisia is called to deal with further challenges; the most important is the climate change impacts. Indeed, as a southern Mediterranean country, Tunisia is located in transition geographical zone between a tempered and arid climate; the management of natural resources and especially the water remains always a crucial task in a context of permanent fragility. On the other hand, the downscaling of the climate change impacts for the Mediterranean region revealed that Tunisia had been strongly concerned. The official forecasts of the IPCC (Intergovernmental Panel on Climate Change) are expecting a steady rise in the mean temperature (Fig. 4a) and more frequent drought sequences with also a steady decrease in the main annual rainfall (Fig. 4b) for the long term (2050).

Under such context, the first sector that would be affected is definitely the agriculture. The water resources management in the irrigated sector is called to undertake ambitious measures given the importance of the prevailing challenges. The first prospective of the climate change impact on the agriculture revealed severe impacts to be observed with the horizon 2030 with an increase in annual average temperature by 1.6 °C in the south and 0.9 °C in the northern country. The first declared impact would be a decrease of nearly 28 % in nonrenewable underground resources. The production in dry periods is expected to decrease by 50 %; this is equal to 800,000 ha for rain-fed agriculture with an estimated loss of nearly 20 % in arable land (GTZ 2007). These impacts will be considerable also on livestock

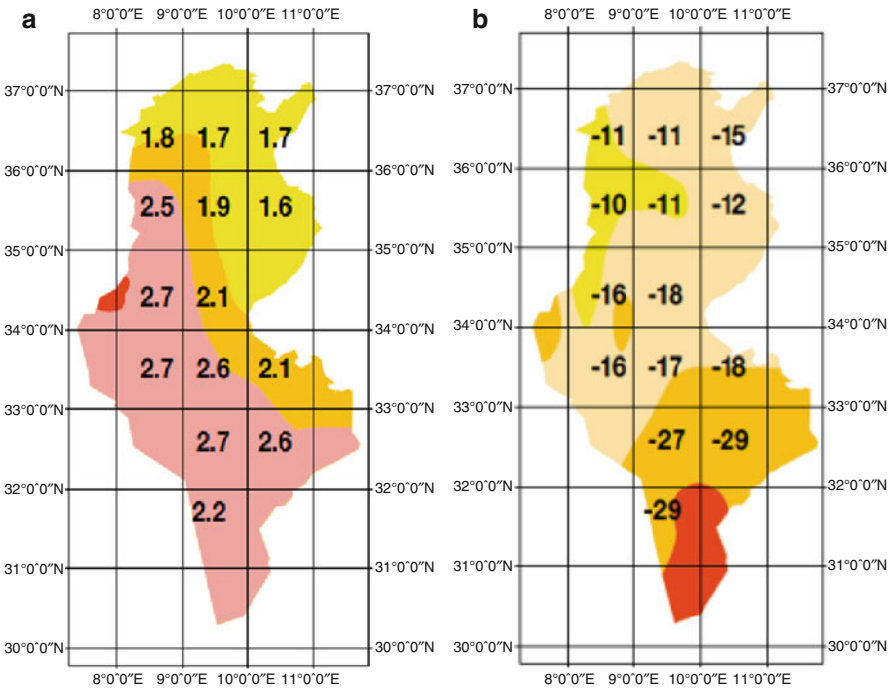

Fig. 4 Scenario of the mean temperature and the annual rainfall evolution in 2050 (GTZ 2007). (**a**) rise in the mean temperature (°C) (**b**) variation in the mean annual rainfall (%)

production which is predicted to decrease by 80 %, both in the center and southern country (OSS 2009a, b).

To tackle these impacts, Tunisia elaborated a national strategy of adaptation to climate change with first declared objective decreasing the agriculture and the water resources vulnerability to such phenomenon with the research and application of efficient tools toward strengthening the adaptation capacity of these sectors to the coming changes. In the elaboration of such adaptation strategy, the development of the mean climate indicators will be taken into account for the future natural resources management plan. The alert systems for both flood and drought events are already established, with a network of climatic and hydrological stations across the country.

Furthermore, as key tool of the national adaptation strategy, the water resources management is called to play greater role in such adaptation strategy. The first declared priorities would be the intensification of the water-saving plan in the irrigated sector. The implementation of more efficient irrigation system remains out of expectation (Treyer 2000). The situation remains extremely critical in the southern Tunisia, where the oases irrigation management problems seem to persist despite the several successive rehabilitation projects (Omrani and Burger 2011b).

Despite the different subsidies allowed to the farmer groups for the introduction of the water-saving techniques at the plot scale (irrigation equipments cost coverage

of an average of 40, 50, and 60 % to extensive, middle, and small farmer's plots, respectively), the water consumption inside parcels remains extremely high. Current practice of water use on parcels demonstrates that the applied water volume is more than the effective crop requirement. Traditional irrigation methods are still widely used within farmers' parcels. The absence of any field leveling and the overapplication of water during irrigation, up to three times the actual crop requirements, cause relevant water losses (Mechergui and Van Vuren 1998). The water is still not enough valorized, and the prevailing water-pricing policies are still forfeited and do not militate for a water-saving approach.

With the reform of the irrigated sector, the national adaptation strategy emphasizes also on the institutional change in the water management aspects. The ongoing collaboration between the agriculture and the environment ministries requires further coordination. It needs also further transparency and good governance approach for the following steps.

5 Concluding Remarks

With a relevant experience in the water management, Tunisia is called to confirm the precious progress in the water policy achievements. The learned lessons from the multiple decades of water resources mobilization should define the outline of the future orientations.

Indeed, the water in Tunisia represented definitely a precious and scare resource that had been always the angular stone of the development program. Within a context of fragility, it had been and certainly remains primordial to guarantee the water supply among the concurrent development sectors. Nevertheless, the country had been always self-sufficient in that task and had been able to guarantee the water security even during the most acute drought sequences avoiding the recourse to the water rationing.

For the coming decades, the water policy should be strongly reconsidered within the framework of an integrated approach. The prevailing situation of the irrigated sector spots the light on such reform evidence. Indeed, the critical exploitation ratio that is the soil and water resources sustaining became alarming and announces an uncertain future. The current mode of natural resources management shows an evident gap between the traditional farmer's knowledge and the technological transfer into practice. This assessment is particularly addressed to the irrigation stakeholders. The approach followed to resolve the irrigation problems remains isolated as well as strictly on the technical level and still not supported by a global approach. The conciliation between both engineering thinking and farmer's group perception should be implemented in the future orientations.

The new challenges addressed to water policy development (climate change, population, and standard growth) invoke a drastic reform of the water resources management. Moreover, it should certainly pass through the strengthening of the social and human aspects in the decision-making process. The improvement of the

social conditions within the irrigated perimeters seems to be a key issue to guarantee the population involvement and to reach the sustainability quest. An appraisal of the main local population expectations should be engaged to set the main development milestones.

As one of such strategy reform tools, the role of the capacity building should be strengthened for the farmer groups. They still represent the first stakeholders effectively managing the water resources, and their cooperation with the research development partners remains occasional.

The implementation of such approach would require more funds from the current allocation budget; it should also to control the dependency to foreign donors' agency, and a strict survey of the financing modalities remains crucial to avoid any eventual corruption practices.

In order to achieve the water resources management policy goals, taking into consideration the particular environmental context of the agriculture sector is still irrevocable (more than 83 % of the water resources). The high social impact of every action should be considered before its effective implementation.

In order to tackle the future climate change uncertainties, Tunisia water resources sustainability depends heavily on the effectiveness of the undertaken measures into more water value promotion. While the major efforts had been consented to the irrigation sector development, the future options have to focus on the productivity enhancement and the water cost effective recovery (Sghaier 1995). However, as a precondition of such policy achievement, the orientation toward more prepared decentralization process will bring to bear more efficient and adequate solutions to the water user's community.

The prevailing political context in Tunisia should also not be omitted regarding the new opportunities that are being created to the coming generations. The water policy in Tunisia would definitely be a key tool of the next development strategy and should be in a democratic way clearly discussed. The definition of the strategic choices could be in further collaboration and participatory approach with the population mandated. Nevertheless, the need of a successful decentralization in the water resources management remains clearly evident and requires the commitment of all partners involved in the water management. Finally, the achievement of more decentralized and autonomous water resources management in Tunisia seems to be a crucial precondition to meet the future challenges such as the climate change impacts.

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