Historical and contemporary perspectives of water culture in Tunisia

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Summary. Water culture in Tunisia is a secularly tradition. The remnant of many water harvesting and hydraulic structures across the country is a clear indication of the water historical wealth built up by the successive civilizations. Since the antiquity with the Roman period (Zaghouan aqueduct, water temple) passing through the Islamic age (Aghlabit cisterns) until the contemporary water harvesting and storage structures (meskat, jessour, hillside dams and large dams), water mobilization and management was amongst the concern of the societies. At present, modern Tunisia is engaged in holistic strategy for water conservation and management focused on the water demand master. Several projects were undertaken to enhance water distribution efficiency both for domestic and agricultural purposes. This paper addresses the historical review and contemporary perspectives of water culture in Tunisia.

***Keywords.* Water culture – Management – Irrigation – Harvesting - Tunisia.**

Perspectives historiques et contemporraines de la culture de l'eau en Tunisie

Résumé. *La culture de l'eau en Tunisie est une tradition séculaire. Les vestiges des ouvrages de collecte des eaux sont distribués dans tout le pays. Ils donnent une preuve indiscutable de l'expertise hydraulique des civilisations qui s'y sont succédées. Depuis l'antiquité avec la période romaine (aqueduc de Zaghouan, temple des eaux) en passant par l'âge islamique (citernes des aghlabites) jusqu'aux structures contemporaines de collecte et stockage des eaux (meskat, jessours, lacs collinaires et grands barrages), la mobilisation des eaux a toujours été la première préoccupation. Différents projets ont été entrepris afin d'augmenter l'efficacité de la distribution de l'eau, pour l'usage domestique et agricole. Cet article traite de l'historique ainsi que des perspectives de la culture de l'eau en Tunisie.*

***Mots-clés.* Culture de l'eau - Gestion - Irrigation - Collecte - Tunisie.**

I - Introduction

Water is vital to every human community and is an essential resource for economic development, agricultural productivity, industrial growth, and human well-being. The availability of a clean, safe, and secure water source has been, and will always be, a major concern for human populations (Kiersche, 2000).

West Asia and North Africa (WANA) region is by far the driest and most water scarce region in the world. The situation is expected to worse due to rapid population growth, increase of household income, irrigation expansion and climate changes. Therefore, the water issues are increasingly affecting the economic and social development of those countries (Yair and Lavee, 1985; Renard *et al.*, 1993; Oweis *et al.*, 2004).

Water management forms the most critical process in dry areas, as it impacts livelihood, food security, land conservation and productivity and society in general. Most of the WANA countries are dry and all in the developing world. These developing countries often do not possess the technical know-how, financial capacity or the social structure to undertake modern water management approaches. On the other side, societies in those dry areas have learned to cope with water shortage throughout centuries (El Amami, 1982; Boers, 1994; Oweis *et al.*, 2004).

Located in North Africa, Tunisia has a total land area of 16.4 million ha. Of this, the cultivable area is about 4.8 million ha, while forests and esparto grass (*alfa; Stipa tenacissima*) cover 1.7 million ha, and 3.7 million ha are used for grazing. In 1996, 34% of the cultivable area was planted with cereals, 29% with olive trees, 12% with fruit trees, 6% with forage crops, 3% with vegetables, 2% with pulses, and 2% with industrial and miscellaneous crops; 12% was left fallow (MEAT, 1998). The ratio of irrigated land to arable land is presently around 7%. Potentially this figure could reach 9%. This low ratio reflects the scarcity of water throughout the country.

The population of Tunisia reached 9.910 million in 2004 and is growing by 1.21% annually (average of 1994-2004) (INS, 2005). Agriculture plays an important role in the economy, despite its relative decline during the last three decades (as a result of rapid growth in other sectors, especially industry). Agriculture provided 24% of the gross national product in 1972 and 8% of the gross national product in 1996. Agricultural exports declined from 40% to 8% over the same period, during which agricultural imports also fell from 20% to 9%. Agriculture is, however, responsible for about 30% of national employment.

Because of chronic water deficiencies, a wide variety of large to small hydraulic techniques have been introduced over many centuries to make the land productive, irrespective of its geographical location.

This paper describes the various water harvesting and irrigation systems developed throughout the long hydraulic water history of the country. It presents, first, the agro-ecological zones of the country. It then highlights the basic natural and historical backgrounds of the different used techniques and describes their adaptation to local environmental and social conditions as well as the main related research works undertaken on those systems are reviewed. An overview was made also on the national efforts consented to water mobilization over all scales; mainly the national program of large dams construction, the implementation of complex water transfer system for reservoir regulation, the modernization of traditional irrigation networks and the introduction of water economy facilities in the irrigated agriculture. In parallel, specific focus was given also to the integration of the small scale traditional water harvesting techniques with modern large scale structures (large dams, hill side dams).

II - Agro-ecological background

Tunisia can be divided into three major natural regions; the northern, central, and southern zones (Karray, 1979). The northern zone is separated from the central zone by a branch of the Atlas Mountains called the *Dorsale* (Figure. 1). It covers 25% of the country's land area and is characterized by fertile plains stretching from the *Kroumirie* and *Mogod* mountains to the foothills of the *Dorsale*. Rainfall in the northern zone is relatively high. It varies from 400 to 800 mm in the agricultural areas and reaches a maximum of 1500 mm in the northwest corner of the *Kroumirie* forests.

Being the extreme eastern part of the Saharan Atlas, the *Dorsale* is composed of a fragmented series of the country's highest peaks - Châambi (1544 m), Semmama (1314 m), Zaghouan (1295 m) and Sidi Abderrahman (637 m) - arranged in a southwest-northeast transect from Kasserine to Cap Bon.

In the north, smaller mountains form the Tell (which is composed of the high Tell, *Khroumerie* and *Mogod*). The *Medjerda*, the only perennial river in the country, is embedded in the valleys of this area, along with some ephemeral streams. The dominant natural vegetation is relatively dense oak forest. Agriculture is based on rainfall and on irrigation using water collected in dams and hill lakes. The northern zone produces cereals, fruits, milk, meat and vegetables.

The central zone (15% of the country) is located between the *Dorsale* and a series of salt lakes (*chotts*), which form its southern border (**Fig. 1**). It receives between 200 and 400 mm of rainfall and is used, agriculturally, to grow olive trees, cereals, and as pasture. Traditionally, this zone is subdivided into three agro-ecological regions: the High Steppes, the Low Steppes, and the *Sahel*.

The High Steppes, consisting of plateaus of more than 400 m elevation, are dominated by esparto grass. They are drained by the famous, intermittent and turbulent *wadis* of the central zone (Sidi Aïch, Marguellil, and Zeroud) which subsequently cross large plains located in the Low Steppes areas and, finally, either come to rest within saline depressions (*sebkhas)* or flow into the Mediterranean Sea. In the Low Steppes, rainfed farming based on cereal cultivation and sheep rearing predominates, alongside the development of newly irrigated areas which are served by groundwater wells. The third agro-ecological zone of central Tunisia is the Sahel, where the landscape is dominated by rolling hills and by many small villages. In this area micro-catchment systems are widely used within olive tree plantations.

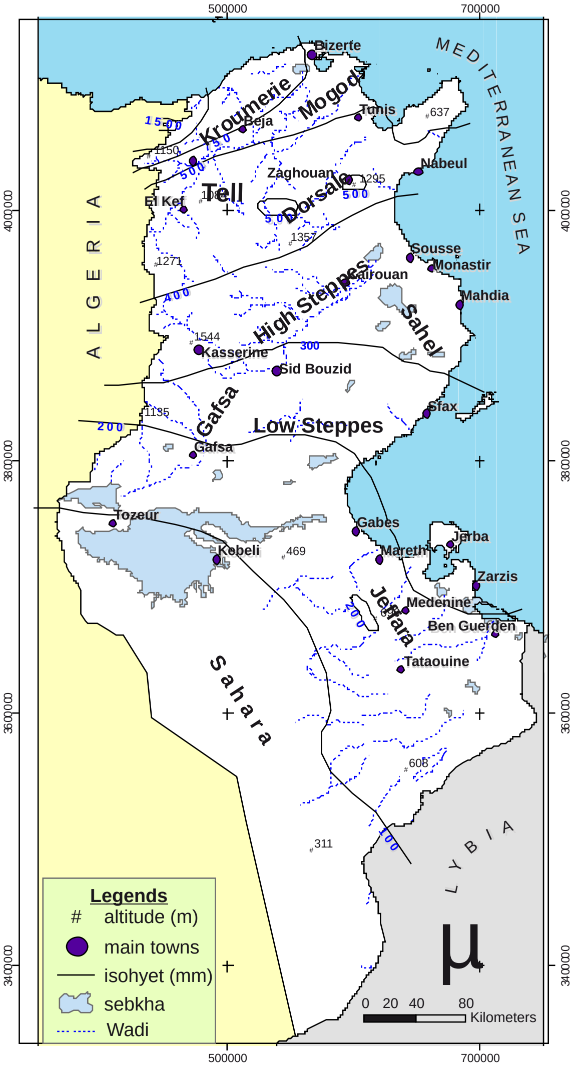

Figure 1: Agro-ecological zones of Tunisia, adapted from Karray, 1979; MEAT, 1998.

Southern Tunisia can also be divided into many sub-regions. The *Dhahar* is a calcareous plateau of 400 to 600 m in elevation, dissected by small *wadis* and ending in the east in a *cuesta* (landform with an inclined upland slope and a relatively steep escarpment descending abruptly from its crest). The *Jeffara*, which is a large plain made up of crusted quaternary deposits, stretches between the Matmata Mountains and the littoral (coast). Rainfall increases from 100 mm in the lowlands to 200 mm in the mountains. The area's natural vegetation consists primarily of degraded arid rangelands species. Besides some rainfed farming and irrigation in the oases, livestock husbandry is the main agricultural activity. The region of Gafsa is an area of *chotts* and *sebkhas,* with a series of mountains in a west–east orientation. The Sahara, found in the most southerly part of the country, is a xeric zone dominated by sand dunes.

The climate of Tunisia is principally Mediterranean type, influenced by the caprices of the Sahara desert and the variability of the Mediterranean. Semi-arid, arid, and desert climates cover more than two-thirds of the country. The rainfall regime is characterized by a very strong irregularity combining scarcity with the tendency to fall in torrents. Indeed, in the southern country the annual rainfall can be recorded in a single rainfall. The annual main is estimated to 207 mm, with a minimum equal to the third of this value and its triple as maximum. Beyond the variability in time, important differences occur in the rainfall spatial distribution (Aquastat,2005).This variability increases when moving from north to south The annual rainfall in the north is 594 mm, 296 mm in the center, 156 mm in south and even less than 100 mm in the extreme Southwest. Round about 80% of the rainfall is concentrated between months of October and Mars. The annual potential 'evapotranspiration' varies from 1200 mm in the north to 1800 mm in the south. The total amount of rainfall is estimated to be 35 billion m^3 annually, distributed unequally between th e three major ecological zones. Seventeen percent of the country, located in the 400 to 1500 mm rainfall zone, receives 41% of the total amount of rain. The area between the 200 and 400-mm isohyets constitutes 22% of the country and receives 29% of the total rainfall. Finally, the arid region in the south (not including the Sahara), which receives less than 200 mm of rain, constitutes 61% of the country, but receive only 30% of annual rainfall (Ben Mechlia *et al.*, 1996; Mamou, 1997). Under such climate, some periods of water shortage occur frequently and the irrigated sectors still, quite obviously, threaten by the water scarcity.

The mean annual renewable water resources of the country are estimated to be 4.6 billion m^3, which may be subdivided into 2.7 billion m^3 of surface water, 1.2 billion m^3 of water held in confined aquifers (deep groundwater) and 0.7 billion m^3 of water held in unconfined aquifers (shallow groundwater). Approximately 70% of this potential resource is mobilized at present. Agriculture is the largest water-consuming sector (using 84% of water consumed), followed by domestic use (13%). Industry, tourism and various other sectors make use of the remainder (Mamou, 1997).

Most agricultural systems are based on dry farming, with the cultivation of cereals and olive trees being the dominant agricultural activities. The raising of livestock is also very important in all regions, being practiced by 70% of farmers. Water harvesting ensures the best use of winter rains. Use of this technique is, therefore, essential to improve the yield of cereals and olives and enhance rangeland production within the country.

III - Surface water resources mobilization

1. Dams

Dam building in Tunisia dates back to the Roman period. In 100 AD, the Romans built a curved dam near Kasserine in central Tunisia for drinking water supply of *Cillium* city. Its height was 10 m, with a total length of 150 m. In the Steppe regions, the Middle Age Arabs showed a technical expertise in runoff water harvesting and storage. In fact, thanks to many small diversion dams built at *Oued Meguellil* tributaries, the famous *Aghlabides* Basins was realised in 862, covering an area of 11000 m^2 and having a full capacity of 63000 m^3 (Ennabli, 2001; Mahfoudhi et al., 2004).

With the French colonization period (1881-1956), started large concrete dams building. Indeed, the first largest dam in North Africa was built in Tunisia. It is that of *Oued El kebir*, 70 km south-eastern Tunis and had been functional starting from 1928 to supply the capital in drinkable water, with a storage capacity of 20 million m^3. Since that, began and still progressing an ambitious program of large dam's construction. *Bni Mtir* Dam (80 million m^3), built on *Oued El Ellil* and functional since 1955, dam Nebeur built on *Oued Mellegue* (1949-1956) with a multiple vault form, a total height of 65 m, a length in crest of 470 m and a storage capacity of 300 million m^3. The creation of this dam aimed to;(i) regulate the *Oued Mellegue* inter annual flood's in order to avoid *Jendouba* plain inundation, (ii) irrigation of the *Medjerda* low valley and (iii) the electricity production. Since the country's independence, government's emphasis on the water mobilization has been intensified and was notably focused on reducing the vulnerability of the agricultural sector to irregular rainfall and to recurrent droughts. In 1957, dam *El Aroussia* was built on *Oued Medjerda* to irrigate more than 50 000 ha.

Kasseb Dam, built on *Oued kasseb* and inaugurated in 1969, has a storage capacity of about 80 millions m^3 over a reservoir area of 437 ha. The total allocation of the water stocked is conveyed to supply Tunis City in drinkable water. A hydroelectric station established at downstream the dam produces nearby 3600 000 kWh/year. Nevertheless the largest dam in Tunisia still that of *Sidi Salem*, built on the *Oued Medjerda* (1977-1981), having 57 m of height, 340 m of length. Its storage capacity reaches 550 million m^3 over nearby 4300 ha of reservoir surface. Presently within the framework of the director plan of North water, about 29 large dams and 680 hillside dams had been achieved in the Northern country allowing the storage of 4100 million m^3 that equals to 88 % of the full available runoff water (MAERH, 2007).

2. Water harvesting

A comprehensive survey of traditional hydraulic works in the *Maghreb* countries was carried out by El Amami (1982). This document, written in Arabic, was followed by a second document, written in French, on Tunisia (El Amami, 1984). These manuscripts cover all the local small-scale irrigation techniques used in North Africa, with particular attention being paid to Tunisia. The English term ‘water harvesting’ was not specifically used by these reports to describe the indigenous systems of runoff water capture and use. The term was, in fact, only recently introduced into North Africa, the people in these countries being far more conversant with the French language. The terminology used in these reports refers to water harvesting techniques (WHT) as ‘small hydraulic structures or systems’. However, the techniques described exhibit the three main characteristics of water harvesting listed by Boers and Ben-Asher (1982): (1) they are applied in arid and semi-arid regions, (2) they depend upon local water, and (3) they are relatively small-scale operations. El Amami’s fundamental works (1982; 1984) have triggered increased awareness of the potential indigenous technologies have in terms of drought mitigation. Since the works were published, a large number of studies have been made of the methods used to induce, collect, store and conserve local surface runoff for agriculture in arid and semi-arid regions. A compilation of these techniques was recently produced by Ennabli (1993), Ben Mechlia and Ouessar (2004), Ouessar *et al.* (2006), and Ouessar (2007).

Undoubtedly, the various water harvesting techniques (which are used on approximately one million hectares within Tunisia) are considered to be an integral part of the country’s national heritage. Not only do these techniques contribute to the country’s wealth by increasing agricultural productivity and by enhancing natural vegetation, they play a key role in the protection of its natural resources (MEAT, 1998) and in the maintenance of social equilibrium in the different regions.

The main water harvesting techniques encountered in the country (**Fig. 2**) can be subdivided into three major groups: (1) runoff water harvesting that makes use of runoff as it is collected, thus eliminating the need for storage-included among such systems are the related micro-catchment techniques called *meskat* and *jessour*; (2) floodwater harvesting and spreading or spate irrigation using diversion dykes (*mgoud*); and (3) runoff water collection and storage in reservoirs of variable capacities, which provides drinking water for people and animals, as well as water for irrigation purposes.

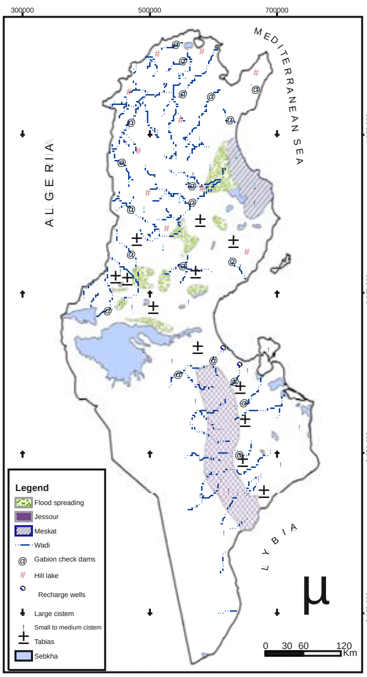

Figure 2. Geographical distribution of water harvesting techniques in the dry areas of Tunisia (adapted from El Amami, 1984; Ben Mechlia and Ouessar, 2004; Ouessar, 2007).

IV - Irrigation

Water irrigation management in Tunisia is an ancestral tradition. With instituting his water division's model, Ibn Chabbat (VII century) had been the precursor in the matter. The irrigation duration's measuring unit was the *gadous*, which equals to 3-5 min with a water flow varying from 30 to 50 l/s (Al Atiri, 2006).

In Southern country, under an arid climate, sedentary population within the oasis showed an ingenious know how in the catchments and the convey of shallow water aquifer from the piedmont plain to lower places. The *Foggara* represented an underground gallery draining the water aquifer and transferring it to the lower part oasis. Along the gallery trajectory, a wells series allows the water exploitation in several places, later they are used to care the *Foggara*. Today these old hydraulic structures relics represent an historical national patrimony, letting the place to the modern drilling and pumping station disserving the irrigated area over all the country.

On the other hand the water management traditions still perpetuated with the self water management conducted by farmers groups. These associations of common interest (AIC) had been officially created in 1933 (Bensalem et al, 2005). Presently there are called Groups of common interest (GIH) and their main intervention deals with water management (as well for irrigation as for drinkable water distribution within rural zones). Studying the case of *Ras El Jbel*, Ariana irrigated perimeter's, Mathlouthi and Lebdi (2007), reported that to improve water use efficiency, more effective involvement of Northern country framers in water distribution as first step, than in maintenance of networks will be required, that's is approved by administration, such as the case in the southern country oasis and the small perimeters in the centre. Bensalem et al (2005) underlined the necessity to supply more technical assistance to these groups in order to improve their efficiency in the water management.

Consuming the highest part of water resources mobilized (80%), the irrigated sector in contemporary Tunisia contributes with 30 to 35% in the total agriculture production. Since 1954, several programs aiming to improve irrigation network efficiency across the country were engaged (Al Atiri, 2004). E.g. In the regions of Kairouan, Kasserine and Sidi Bouzid, nearby 11000 ha of irrigated area were concerned. The impact of the irrigation network efficiency improvement is forecasted to enhance the contribution of irrigated sector in total production to 50 % within the eleventh economic and social development plan (2007-2011). Today thanks to the national strategy of water economy, irrigated area reached over than 400 000 ha while it was nearby to 270 000 ha in 1987. The water economy equipments ratio in the public and private perimeters approach 80 %, national objectives would be to reach 100 % at 2009 (MAERH, 2007).

So, to master the water demand, acting on the water use efficiency became evident. At this purpose, irrigation structures of Southern country were also subject to rehabilitation. The project of improvement of southern Tunisia oasis (APIOS) concerns 23000 ha (Gabes, Kebili, Tozeur and Gafsa). More than 14000 ha have already been rehabilitated. In addition, project of investment in water sector (PISEAU) had been engaged and had led to equipping oasis by stitched irrigation network, furthermore, reservoir for water partition were installed to regulate pressure and water flow during irrigation. According to Hamdane (2004), modernization of irrigation and drainage systems passes also, through the improvement of water use within farmers parcel's where an important water losses still occurring. That's why farmers, by the means of common interest groups (GIC), are more than more associated to the decisional process dealing with water management within the irrigated perimeters. In addition, water costs were revalorized, preferential costs were accorded to both of base's culture (cereals, fodder) and cultures irrigated with treated waste water. To intensify ratio of water economy equipments within farmer's parcels, several subventions had been proposed; 40%, 50% and 60% respectively for large, medium and small parcels (Hamdane, 2004).

V - Water transfer

Additionally to their exploit in water harvesting techniques, civilizations that succeeded in Northern Africa and notably in Tunisia, showed an ingenious technical how know in water transfer. The innumerable relics of various hydraulic structures that we inherited from our far ancestors give witness that the efficiency of those techniques was constantly improved during centuries. In Northern Tunisia, the *Zaghouan* Aqueduct's remains unmistakably the most prodigious hydraulic structure achieved through the Roman Empire presence in *Carthage* (Modern Tunisia), this edifice of major scale still as proof of the Romans hydraulic expertise. The water catchment's took place at the *jbel Zaghoun* source that is surmounted by a big temple in hemicycle, dominating a open air basin from where the water run to the aqueduct and was delivered through the aqueduct to supply Carthage in drinkable water, the flow occurred thanks to a low but definitely constant slope. The dimensions of the aqueducts section were 0.8 m in the base and 1.8 m vault included in height.

Today, the northern country is equipped with a modern complex water transfer system established within the framework of North water director plan and allowing water stocks transfer between connected dams (**Fig. 3**).

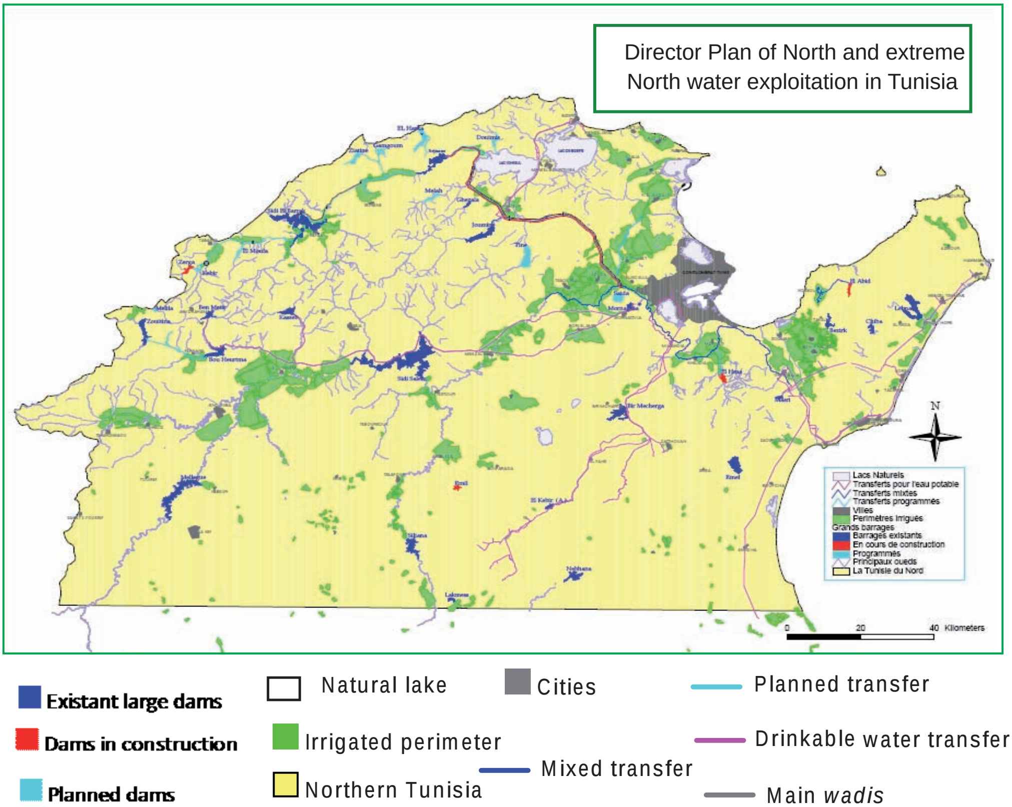

Figure 3. Map of water transfer system in North and extreme North Tunisia (Adapted from Louati *et al.*, 2001).

In this regard, the Company of Exploitation, Canalization and Adduction of the Northern Canal and Waters (SECADENORD) represents a master piece to cope with water shortage in some period, especially in summer and guarantee the equitable water distribution between regions. This society is ensuring the management and maintenance of the North West part of the network of water transfer (pipes and channels) from the extreme North West to the users located in the North East, Centre and South of the country where there is a fresh water shortage. The water adduction and interconnection network hydraulic components are the following: (i) Canal Medjerda Cap Bon (from *Laroussia* to *Belli*); (ii) transfer of *Sejnane* and *Joumine* waters; (iii) *Kalaat El Andalous* hydraulic complex; (iv) *El Herry* hydraulic complex; (v) *Nebhana* hydraulic complex; (vi) *Barbara* dam waters transferring; and (vii) *Sidi Barrak* dam waters transferring from extreme North (*Zouara* Basin's) to *Sejnane* Dam (Said and Elloumi; Louati *et al.*, 2007).

VI - Conclusion

The different techniques of water harvesting illustrated previously show that, according to constraints zones, their design method differs considerably across region's country: (i) Benches for retaining local water and sediments to agricultures purposes (*tabias*), (ii) *Impluvium* with mastered and conducted runoff (*Meskat*, typical water harvesting structure of Tunisian Sahel) (iii) crops terraces to reduce runoff, (iv) structures built on *Oued* beds to slow water flow and recharge groundwater aquifers (*jessour,* mainly in Southeast country, Matmata), (v) hillside water storage, (vi) derivation canals and floodwater spreading (*Mgoud*),(vii) underground water catchment by means of draining galleries (*foggaras,* technique developed in the Southern country oasis) and water distribution via canals (*Seguias*). Inspired by their ancestor, engineers improved major of these techniques which represent today an evident component implemented within the water mobilization national strategy.

However, despite the tremendous efforts consented to the accessible water mobilization, notably within the previous decade (1990-2001), Tunisia is aware that its water management policy must be presently turned to the demand master and within the framework of holistic approach aiming to guarantee the sustainability of the national hydraulic potential. Official forecast (Plan bleu, 2000) claimed that global water demand will regularly grow until reaching 2700 million m^3 at the horizon of 2030 while the agriculture demand, less than 1900 million m^3 in 2003 (80% of the global demand), will reach 2100 million m^3 and will face more competition with other water demanding sectors (urban and industrial). At this purpose, competent Tunisian authorities established a complementary work focused on the improvement of hydraulic infrastructure efficiency across the country.

The present decade (2002-2011) will also aims to take advantages of treated wastewater, development of non conventional water resources such as high saline water and sea water treatment. The two key words of the future national water policy are Efficiency and water economy over all level of hydraulics structures.

On the other hand, it seems to be evident that Tunisia, like other Mediterranean countries, has to cope permanently with risks of droughts and perspectives of water shortage that threaten constantly the water resources equilibrium and especially irrigated agriculture. Indeed, national forecasts predicts the frequency of dry year occurrence varying from 10 to 15 % in Northern country, whereas, it attempts 25 to 30% in the centre and the south. The probability to have two successive dry years still rather rare for the North (3%), while it reaches 10% in southern country. A three year drought sequence has a frequency of 1% in the North and 3% in the centre and the south (Louati et al., 1999).

The frequency of droughts has led Tunisia to acquire a relevant experience in water management under shortage conditions. Several practices and techniques were adopted to reduce drought negative impacts. It deals with irrigation modernization, cultures techniques improvement, management of the water demands. A national strategy of drought management was instituted; the applied guidelines represent a decisive alert tool to all concerned structures and allowing them to act in opportune time. That's why, today there is a concrete awareness about water scarcity and all stakeholders, involved in water management collaborate closely for a sustainable rational use.

Water culture in Tunisia is concretized through all historical and contemporary techniques and hydraulic structures, observable across the whole country. This relevant expertise reinforces Tunisia capacity to face with serenity, globalization future challenges that require more and more intensive pressure on water resources.

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