A Comparison of the Traditional and Contemporary Water Management Systems in the Arid Regions of Tunisia

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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 (Kierche, 2000).

Middle East and North Africa (MNA) region is by far the driest and most water scarce region in the world. The situation is expected to worsen due to rapid population growth, increase in household income, and irrigation expansion. The water issues are increasingly affecting the economic and social development of MNA countries (Renard *et al.*, 1996; Oweis *et al.*, 2001).

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 MNA 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 positive side, societies in dry areas have learnt to cope with water shortage through the centuries (Oweis *et al.*, 2001; Ben Mechlia & Ouessar, 2002).

In the southeastern region of Tunisia where the annual rainfall ranges between 150 and 230 mm, the areas treated with traditional water harvesting techniques (WHT) (mainly jessour: small retention dam) were limited to the upper parts of the *wadi* catchment zones (El Amami, 1984). However, with the independence there has been a gradual extension of the cultivated fields, mainly olive trees, to the neighboring areas thanks to the confection of *tabias* (same as *jessour* but practiced on foothills) and water spreading structures in the foothills and surrounding plains *(jeffara*), exploited normally as rangelands. In parallel, the soil and water conservation service of the Ministry of Agriculture has also introduced new techniques (gabion units, ground water recharge wells, etc.) especially during the last decade, which witnessed the implementation of the national soil and water conservation strategy and the water resources mobilization strategy (Mini. Agri. a & b., 1990). Then, the enrichment of the existing traditional techniques has raised the question of the nature of the linkages between the traditional and the newly introduced WHT, are they complement or conflicting?. What are the perceptions of the local communities of these changes in the landscape occupation?

General Characteristics of the Watershed of Wadi oum Zessar

The study watershed (SWS) belongs to the region of south eastern Tunisia (province of Médenine). It stretches out from the south-west, in the mountains of Matmata, the highest point (Kef Mzenzen 690 m) near the village of Béni Khdache, going into the Jeffara pla in, via Koutine, into the Gulf of Gabès, and ends in the saline depression (Sebkhat) of Oum Zessar (Fig. 1.). The general characteristics of the SWS are mentioned in Table 1.

Table 1. General characteristics of the study site.

Area (km^2)	367
Annual rainfall (mm)	180
Mean annual temperature (°C)	20
Altitude (m)	0-690
Population (inhabitants)	24188

By its position, the climate in the SWS is of the Mediterranean type. It is influenced by that of the Dahar and the Matmatas (*continental arid*) on the one hand, and by the presence of the Mediterranean Sea (Gulf of Gabès) (*maritime arid*) on the other.

The temperature in the SWS is affected by the proximity to the sea and the altitude. The coldest months are those of December, January and February with occasional freezing (up to -3 °C). June-August is the warmest period of the year during which the temperature could reach as high as 48°C.

Having an arid climate, the rainfall in the SWS is characterized by low averages, high irregularity (both in time and space) and torrentiallity. It receives between 150 and 240 mm per year with an average of 30 rainy days (Derouiche, 1997). The 'wet' season stretches out over the months of November, December, January and February, and the remaining period is dry. The summer months (June-August) are almost rainless. Highly intense showers (more than 50 mm/h) could occur at any moment during the period September-March (Fersi, 1976).

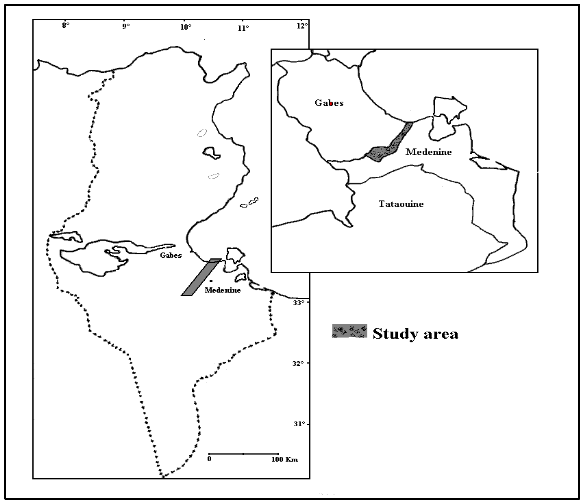

Figure 1: Location map of the watershed of Wadi Oum Zessar

The farming systems are marked by their diversity from the upstream to downstream areas of the SWS. These systems are essentially distinguished by (Sghaier *et al.*, 1997; Labras, 1996; Rahmoune, 1997):
- a non regular agricultural production that varies from a year to another depending on the rainfall regime,
- the development of arboriculture and the extension of newly cultivated fields at the expense of rangelands,
- gradual transformation of the livestock husbandry systems from the extensive mode, highly dependent on the natural grazing lands, to the intensive mode,
- development of the irrigated agriculture exploiting the surface and deep ground water aquifers of the region,
- the predominance of the olive trees (almost 90 %) and the development of episodic cereals.

According to are (Sghaier *et al.*, 2002), the main encountered farming systems:

The system "Jessour"

These are essentially developed in the upstream areas of the SWS in the mountainous zone of Beni Khédeche. These systems are based on runoff water harvesting thanks to the millennium technique of "Jessour". They are marked by the fruit arboriculture notably the olive. Annual crops such as cereals, vegetables and some annual crops (beans, small pea, etc.) are also occasionally practiced. The cropping areas are extremely small and rarely exceeded 0.25 ha. Tree densities are relatively high and can exceed 60 trees/ha. The average parcel number by farmer is 6. Recent researches (Labras, 1996; Sghaier, 1997) have revealed that the annual agricultural income by farmer is estimated to 1,195 TND with 69 % of the vegetable production source. The gross margin per hectare is relatively low floating around 110 TND (Labras, 1996). The yearly non agricultural income is estimated to 200 TND with 69 % due to migration.

System of irrigated perimeters

Two subsystems could be distinguished:

The subsystem of private irrigated perimeters: It is based on surface wells. It is localized in the upstream area of the SWS (at Ksar Hallouf) and in the downstream areas as well. The agricultural production is based on cash crops, greenhouses, vegetables and fruit tress. The cropping area varies between 0.2 and 10 ha (Rahmoune, 1997).

The subsystem of public irrigated perimeters: It is based on collective drilling created normally by the State. The water management is insured by a collective interest association known by the 'AIC'. These perimeters are situated in the downstream zone of the SWS, such as the irrigated perimeter of Kosba.

The system of olive trees

This system is marked by the dry arboriculture dominated by the olive trees. It is mainly encountered in the plain and in the piedmonts. The area varies from 5 to 46 ha. Other tree species such as, almond and apples are also present.

The system multicrops - breeding

This system is weakened by the climatic irregularities. The agriculture is of the rainfed type associated to an important livestock husbandry component. Two subsystems could be identified:

The subsystem of the marginal agriculture: It is marked by its small area and the most part of income is of non agriculture sources.

The subsystem of the agro-breeders: They are former breeders which are transforming their system by introducing an agricultural component which becomes increasingly important at the expense of livestock husbandry. It is mainly found in the downstream area of the SWS on fragmented average areas of 25 to 85 ha. The livestock is comprises 20 to 150 goats and sheep, and 100 dromedaries grazing in the saline range lands of the *sebkhats* (saline depressions).

Water Harvesting: Description and Inventory

Wide varieties of water harvesting techniques are found in the SWS. In fact, the hydraulic history of this watershed is very ancient. Carton (1988) witnessed by the remnants of a small retention dam, supposed to be built in the Roman era, near the village of Koutine and the abandoned terraces in the uphills of wadi Nagab in addition to numerous flood spreading based structures (henchir Zitoun, henchir rmadi, etc).

Photo 1: *Storage dam dating from the Roman era near the village of Koutine.*

Photo 2: *New terraces on the jebel of Tajra.*

Terraces

Like in other regions of the country and the world they are constructed on steep slopes. They are formed of small retaining walls made of rocks to slow down the flow of water and control erosion (Oweis *et al*., 2001). It seems that this technique is the oldest adopted WHT in the area. However, they are completely abandoned and only some remnants are still found in the upper extreme area of wadi *Nagab*. Nevertheless, they have been recently readopted for small scale afforestation works or olive trees plantations in the mountain ranges (Photo 2.).

Jessour

This system is also an ancient WHT widely spread in the region of the mountains of Matmata (Ben Ouezdou *et al.*, 2001). It is practiced in the inter mountain and hill water courses to intercept runoff and sediments. The *jessour* is the plural of a *jesr* which is a hydraulic unit made of three main components; the dike, the terrace and the impluvium.

The impluvium is the area destined for collecting and channeling of the meteoric water. It is bounded by the natural water dividing line.

The terrace is the cropped area. It is formed progressively by the decantation of the carried sediments. Generally, the fruit trees (olive, fig, almond, date palm, etc) and the legumes (pea, chickpea, lentil, broad bean, etc) are planted in the neighborhood of the dike while the remaining areas are cultivated with cereals (barley, wheat).

The dike *(tabia, sed, katra)* is a barrier destined to block the sediments and run-off water. Its body is made of earth equipped with a central *(masraf)* and/or lateral *(manfes)* spillway assuring the evacuation of the excess water.

The jessour are mainly found in the upstream mountain area of Béni Khdache and Moggar (Photo 3).

Photo 3: *Traditional typical Jessours of the region.*

Photo 4: *Newly installed tabia on the piedmonts area.*

Tabias

Tabias are essentially situated in areas with more or less profound soils with the slope not exceeding 3%. In the Oum Zessar watershed this means the area between Bhayra and Koutine. The tabia is formed by a principal bank situated along contour lines, of 50-150 m and at the ends lateral bunds with a length of about 30 m. Water is stored until it reaches a height of 20 to 30 cm, after which it is diverted, either by a spillway or at the upper ends of the lateral bunds. The tabia gains its water directly from its impluvium (K values between 6 and 20), or by diversion of wadi runoff by a *mgoud* (Alaya *et al.*, 1993). In general annuals and fruit trees are cultivated on it (Photo 4).

Cisterns

These techniques, locally known by *fesquia* or *majel*, are built for the collection of rain water and its storage for different purposes like animal drinking, domestic uses and irrigation.

A cistern is a hole dug in the soil with a gypsic or cement coating to avoid vertical and lateral infiltration. Generally, each unit is made of three main components; the impluvium, the decantation basin, and the storage and pumping reservoir.

Small to large (5 to 50 m^3) cisterns can be found in the entire SWS (Photo 5).

Photo 5: *Cisterns for drinking water and animal watering.*

Gabion units

These structures are made of blocks of galvanized nets (gabion) filled with rocks. They are built in the wadi beds. In general, they have the form of a rectangular spillway. They are used for two purposes:

- slow down the runoff flow so as to increase the infiltration rate to the underground water tables; and/or
- divert a portion of the runoff to neighboring cultivated fields (tabias).

These units are encountered as small check dams on the main intermittent water courses (Photo 6).

Photo 6: *Gabion unit on wadi Naguab.*

Photo 7: *Recharge well installed behind a gabion unit on wadi Koutine (after a rainfall shower).*

Recharge wells

When the permeability of the underlying bedrock is judged too low, casting tubes could be drilled in the wadi beds to enhance the infiltration of runoff water to the ground aquifer. In our SWS, these recharge wells were installed behind gabion units at the level of Koutine (Photo 7).

Water harvesting realizations

The massive water harvesting projects in the province of Médenine, and particularly in the watershed of wadi Oum Zessar, started in the 1980s. During the period 1990-1997, this intervention has concerned the micro watershed treatment and the maintenance of existing structures over an area of 35918 ha (7200 ha in the SWS) and 39147.5 ha (11000 ha in the SWS), respectively. Besides, 271 recharge and spreading units (238 units in the SWS) have been installed (Table 3). These interventions have required, during 1980-90, the mobilization of an investment of 9.71 millions TND for the province and 2 millions TND in the SWS. There has been the generation of 4,300,000 working days (WD) of which 96, 4615 WD in the SWS (CRDA, 1998). Then, the SWS represented a main focus for the implementation of the various practices undertaken. In fact, more than 70% of the water mobilization units have been installed in this watershed and the remaining works represent more than 20% of the total carried out actions.

During the last decade (1990 - 2000) the regional services of soil and water conservation executed two main national programs, namely the soil and water conservation strategy and the water resources development strategy. The works undertaken were mainly the confection of jessour, tabias and terracing. The temporal distribution is shown in the figure 2.

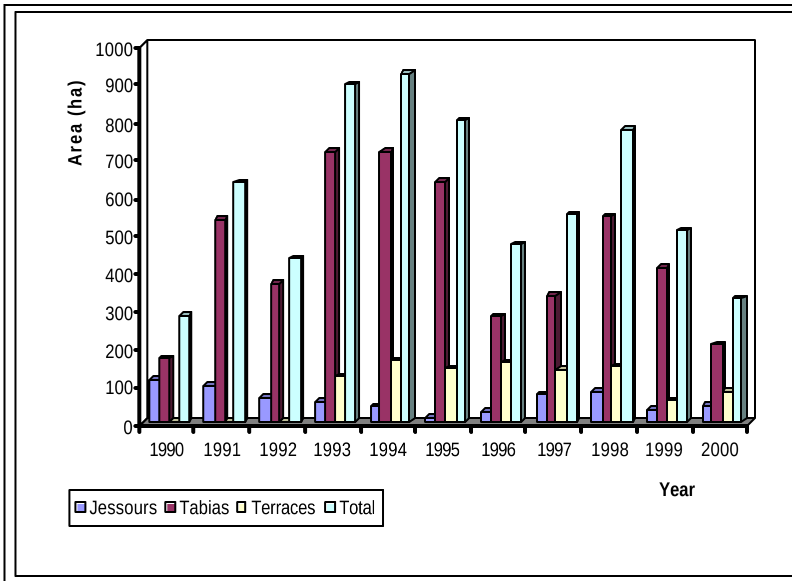

Figure 2: Undertaken works for the period 1990-2000.

The works related to the mobilization of surface water have been mostly undertaken between 1990 and 1993. By the end of year 2000, they concerned in fact the confection of 243 recharge units and 27 spreading units in addition to the installation of 3 recharge wells.

Water Harvesting Techniques Perception

Methodology

The local community's perception towards each technique (traditional or modern) concerned:

- land use and tenure,
- production and productivity (yields, incomes, charges, etc.),
- appreciation of the newly introduced techniques compared to the traditional ones (efficiency, land use, farming systems, incomes, environment, well-being, etc.)

To do so, the SWS were divided, at the level of the village of Koutine, into two main zones: upstream area and downstream areas. Agro-socio-economic surveys were prepared and carried out. The geographical distribution of the surveys is indicated in the table 2.

Table 2. Composition of the inquired groups.

Region	Zone	Inquired farmers
	Upstream area	
Bénikdache	Extreme upstream area: - Sub watershed of wadi Naguab. - Sub watershed of wadi Hallouf	*Beneficiaries of the WH works * Surface wells * herders
Bénikdache + Méd Nord	Piedmonts	*Beneficiaries of the WH works * Surface wells * herders
Méd Nord	- Sub watershed of wadi Koutine	*Beneficiaries of the WH works * Surface wells * herders
	Downstream area	
Sidi Makhlouf		* Irrigators on borehole wells * Irrigators on surface wells * Beneficiaries of the WH works
	Sebkhat: Halophyte ranges	* herders
	Coast	* Fishing men

The farmers were asked whether the works have had some impacts or not on:

- Yield increase,

- Water erosion control,
- Ground water recharge,
- Runoff reduction,
- Flooding control,
- Cropping diversification,
- Biodiversity improvement,
- Clovis (sea food) population reduction.

Results

The preliminary conclusions of this first investigation are summarized in the following table.

Table 3. Preliminary results of the farmers' appreciation of the WH work impacts in the SWS.

Group	**WH impacts**[a]					
	Yield↑	Erosion↓	Recharge↑	Runoff↓	Flooding↓	Diversification↑
Beneficiaries of WH works	56%	100%	100%	33%	100%	100%
Irrigators on drillings wells	87%	100%	100%	38%	75%	88%
Irrigators on surface wells	100%	100%	100%	50%	75%	100%
Herders	Rangelands degradation	Rangelands area ↓	Species disappearance	Runoff↓	Flooding↓	Diversification↑
	80%	60%	0%	75%	100%	-
Fishing men	Clovis↓	Erosion↓	Recharge	Runoff↓	Flooding↓	Diversification↑
	50%	100%	100%	75%	100%	-

[a]: *expressed as per centage of inquired farmers in favor of the statement.*

The WH works beneficiaries are largely in favor of the positive impacts regarding ground water recharge, soil erosion control and cropping diversification. However, they are still skeptical on the role of these works on yield improvement and runoff control. The livestock breeders and the irrigators have been found to be less sensitive. In fact, they are considered the first 'losers' of this intervention because the runoff waters are almost totally retained in the watershed which affected negatively quantitatively and qualitatively the halophyte vegetation of the *sebkhat* used as the main grazing area for camels during the winter.

With regard to the order of preference of the different techniques (jessour, tabias with natural impluvim (NA), tabias on spreading unit (SP) and gabions), here also the farmers reacted differently as shown in the figure 3.

In fact, in the upstream area and since the farmers are used to the jessours, the first order (67%) is given to this technique followed by the tabias and then the gabion. In the piedmont zones, however, the priority is given to tabias NA (80%) and tabias SP (80%) then jessours. In the downstream area, the order is reversed and both tabias are ranked first (50%) followed by gabion and then jessours.

It is clear that perception of the population of the used techniques depends largely on the tradition of the group and its location in the watershed.

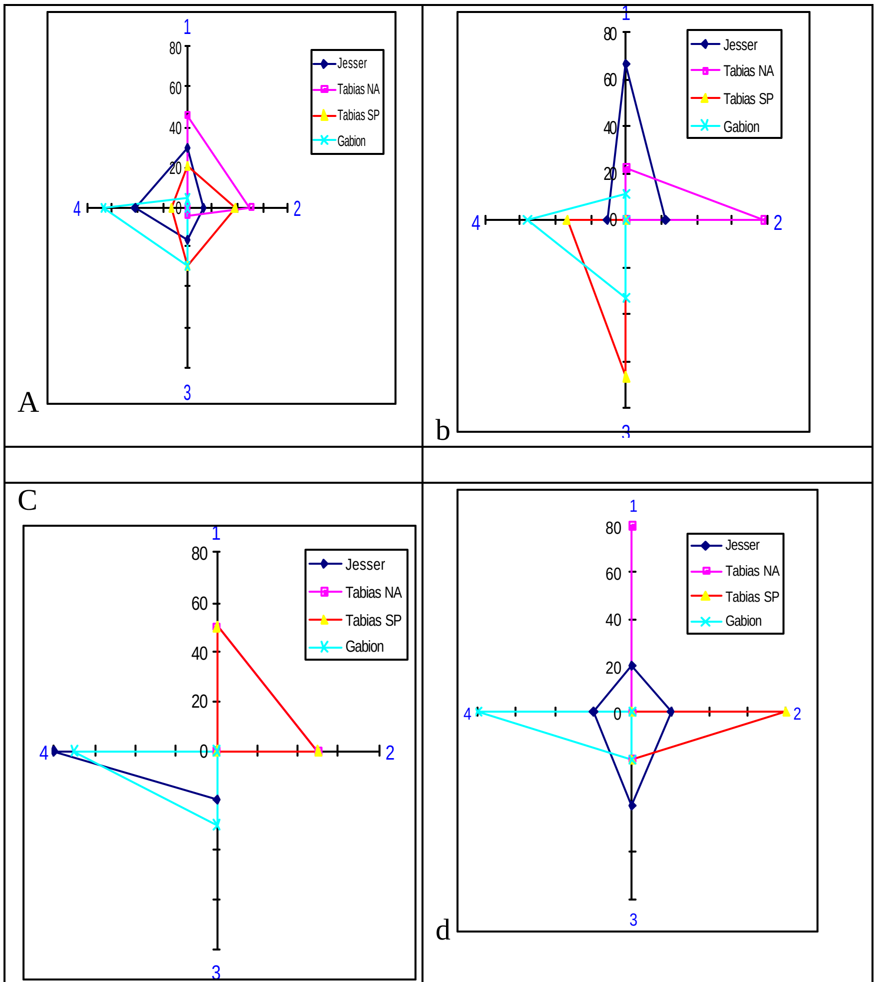

Figure 3: Order of WHT preference (1: first order; 2: second order, etc…) in the different compartments (a: whole watershed; b: upstream; c: downstream; c: piedmont) of the watershed.

Conclusion

In the arid regions of Tunisia, considerable investments are being made in maintaining the old water harvesting techniques (WHT) and introducing new ones to capture the scarce amount of rainwater (100 to 230 mm annually) for agricultural, domestic and environmental purposes.

A large variety of traditional (jessour, cisterns, etc.) and contemporary (gabion, tabias, recharge wells, etc.) WHT are encountered in the area. They have been playing various roles with regard to the mobilization and exploitation of rainfall and runoff waters (soil water, vegetation, flooding, aquifer recharge, etc.).

The local population is, in most of the cases, aware of the environmental impacts of the introduction of new WHT. However, the real perception depends largely on the activity of the farmer (rainfed farming, irrigation, livestock, etc.) and his location (upstream, piedmont, downstream, coast) in the watershed.

However, further refinements are needed to better include all possible impacts (positive and negative) that would occur as a result of the installation of the WH structures. The interactions between upstream and downstream areas have to be addressed thoroughly to ensure partitioning of natural resources between different end users.

The use of geographical information systems (GIS) and information technology (IF) would be of great value in transforming the obtained results as tool for decision-makers. The latter will be used in order to assess under which agro-ecological and socio-economic conditions, investment in water harvesting measures could be a viable undertaking in dry areas.

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