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The oasis of Moghrar (southwest Algeria): water resources and management

A. Hadidi, B. Remini, M. Habi and D. Saba

ABSTRACT

The oasis of Moghrar is located in the wilaya (province) of Naama, in the southwest of Algeria. It is well known for its Ksours, its palm groves and the good quality of its fruit and vegetables, especially the dates and their varieties. This region contains important groundwater and surface water resources. For several centuries, domestic water supply and irrigation have been carried out using traditional techniques of water harvesting such as pendulum wells and foggaras. Currently, this hydraulic heritage is meeting technical and social problems, particularly with the contribution of drilling and motor-pumps. The main issues are water table drawdown, the drying-up of water sources and degradation and decay of traditional techniques. The objective of this study is to make an inventory of all water sources in the study area, to study the impact of the contribution of modern techniques on ancestral techniques and finally to propose recommendations for safeguarding the hydraulic heritage.

Key words | foggaras, irrigation, Moghrar, oasis, traditional drilling techniques

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INTRODUCTION

An oasis is a fertile area with a living plantation in the desert, where the groundwater is close enough to the surface to allow springs to appear. It represents an oasis of life, mainly by the association of sun, man, water, date palm and camel. The oasis has become an artificial space and represents intensive production systems of great complexity, now in an almost fragile balance. The word oasis, of Egyptian origin meaning an inhabited place, was used by Herodotus around 450 BC. Worldwide, date palm oases cover an area of 800,000 ha. Several studies on water management in the North African oases have been carried out, such as that of Todgha-Ferkla in Morocco which suffered a poor water management and control system (Janty 2013; Plusquellec & Bachri 2013). There is also the issue of the significant international migration of nomads. There is talk of a revival of agriculture by investment in motor-pumps (De Haas 2003). Many studies were carried out by Ben Amor (2010) in the oasis of Gafsa. He noted that irrigation water remains the cornerstone of this oasis and continues to play a vital role in the economic, social and even cultural activity of its population. The problems associated with this essential factor of life in this oasis are very complex and require rational solutions that must be compatible with new economic developments in the world. In Algeria, the agricultural zone of the oasis is mainly occupied by the palm orchards. In the region of Adrar, the palm dominates the whole region. In that of Ouargla, the palm occupancy rate is 80% and it is about 50–60% for the rest of the oases. Lavie (2009) gave a complete diagnosis of the management of water in the oasis of Mendoza (Argentina), including, water management and water quality, stakes, and sustainability. Years after Algerian independence, traditional management of water resources in an oasis has been fundamentally questioned. In public and even academic discourse, the most likely 'water crisis' (drying up of wells, springs and foggaras) that characterizes an oasis is generally

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linked to exogenous biophysical factors such as climate change and desertification.

Messaoud (2013) studied the water chemistry of foggaras in the region of Adrar. He stated that a comparison of the results of the analyses of 1960 and 2011 showed a strong evolution of the chemical elements: Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-} of the foggaras' waters, which reflects the high salinity of the waters of the region.

The term foggara refers to several types of structure: simple channels, collecting water from sources (falaj 'aynî), dykes derived from floods of wâdî (falaj ghaylî) or drainage pipes (Charbonnier 2013).

Foggaras exist in 52 countries around the world (Remini *et al.* 2014a, 2014b). In the Algerian Sahara, several foggaras were constructed in the Ahaggar (Remini *et al.* 2014a, 2014b), in the region of Naama (Hadidi *et al.* 2016), in the Mzab valley (Remini *et al.* 2014a, 2014b), in the Ouled Said Oasis (Remini *et al.* 2014a, 2014b), in the Kenadsa region (Remini *et al.* 2014a 2014b) and in the Saoura Valley (Rezzoug *et al.* 2016). In the Touat and Gourara regions in the Algerian Sahara, foggaras have been developed for more than 10 centuries (Remini *et al.* 2014a, 2014b). More than 1,400 foggaras were dug around the Tadmaït plateau. The qanat is a traditional artificial waterway located in the regions of Touat and Gourara. A flow of 3 m^3/s in a continuous manner, in more than 2,000 km of passages, has allowed the development of about 200 palm groves. The management of water resources is at the heart of the oases issues. It is therefore natural that rehabilitation efforts have been directed towards improving the management of water resources (Bellal *et al.* 2015; Rezzoug *et al.* 2016). The lack of effective governance exacerbates the problem of water management in the oases. Improving governance can lead to the better management of water resources, which is urgently required. The actions described in this paper are necessary to make the implementation of effective management possible. This article discusses the origin and development of the model in large areas of agricultural production (Michel-Dansac & Caubet 2013). The participatory approach must be the rule at all stages of development and also in the rehabilitation of oases. From this analysis, it is possible to find solutions to the water management issues in three oases, particularly concerning the responsibilities and the role that the State should play in these processes, to study the impact of the contribution of ancestral techniques compared to more modern methods, and finally to propose recommendations for the safeguarding of the hydraulic heritage (UNESCO 1972; Rhouma 1993).

MATERIALS AND METHODS

Study area

Moghrar is situated in Naama province; it is about 50 km from Ain Sefra City (Figure 1). It is a province depending on the daira (division) of the same name with 3,540 inhabitants in an area of 1,792 km² with a density of 2 inhabitants per km². It is characterized by two oases, Moghrar Tahtani and Moghrar Foukani, connected by an important river, the Namous Wadi (Figures 2–4). The oases are located on the southern reverse of the Ksour Mountains where the regs, hamadas and wadis are usually dry. In this region of Moghrar the precipitation is not more than 100 mm/year. The most important palm plantation is that of Moghrar Tahtani with 40 hectares (Figure 5). This palm grove is spread out over two banks of the Moghrar Wadi, and in addition to its 16,000 palm trees, has staged crops of fruit trees such as fig, apricot, olive, pomegranate, apple and pear and vegetable crops for the city's needs. It is also interesting because of its history. In addition to the varieties of palm trees – the appellation of the fruit (date) is ' H'mira' and ' El Hartan', they have good flavour and a good reputation. There are some specimens of two varieties of date palms called 'Feggous' and 'Aghrass' with black ovoid fruit, soft or elastic, fibrous and fragrant. This variety is only found in small quantities elsewhere in the Atlas Mountains. The people of Moghrar Tahtani appreciate and make great efforts to save this variety as it is a source of pride to its owners (Bellal *et al.* 2015; Rezzoug *et al.* 2016).

Soils

Moghrar oasis is located in the Naama province and this Upper Jurassic site consists of dolomitic limestone formations of sandstone and clay. The majority of the soil is made up of materials produced by the weathering of sandstone, abundant parent rock or limestone coming from the

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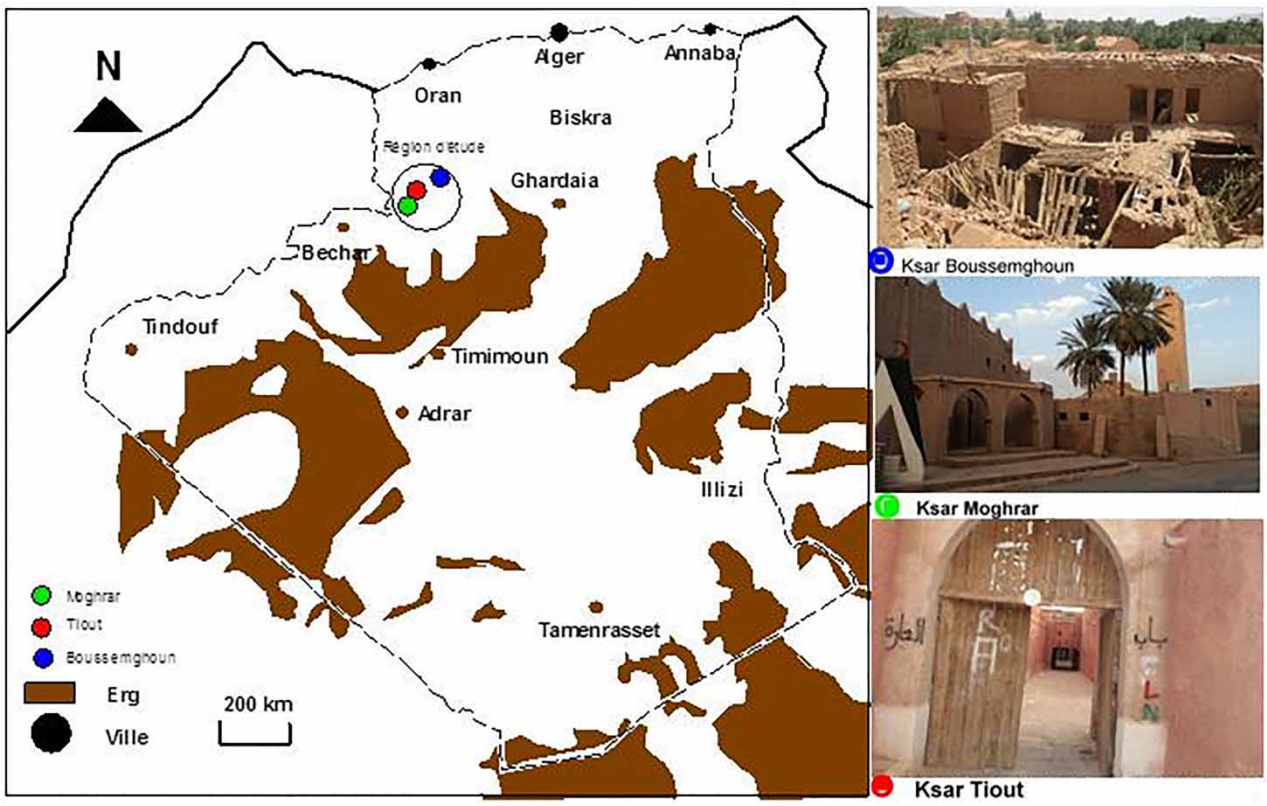

Figure 1 | Location of the Moghrar oasis (Photograph: Remini & Achour 2017).

Figure 2 | Synoptic diagram of two oases: Foukani oasis and Tahtani oasis (Remini & Achour 2017).

Figure 3 | A general view of the oasis of Moghrar Foukani.

surrounding solid masses. They are not very thick soils and contain little organic matter content (De Haas 2003). The soils that occupy the accumulation areas, including application areas, offer the best potential for development (De Haas 2003; MRE-Algerie 2017).

Hydrography

The Moghrar valley has an important watershed draining the whole Aïn-Sefra region. The wadi of the same name flows towards the south and joins the Rhoubia Wadi

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Figure 4 | A pendulum well symbol in the Moghrar Tahtani oasis.

Figure 6 | A water source in the Moghrar Wadi of the Tahtani oasis.

Figure 5 | Palm grove in the Moghrar Tahtani oasis.

Figure 7 | A view of the Tiout oasis.

which extends to the south to form the Namous Wadi with another tributary, the Smar Wadi, with many smaller wadis coming from the foothills of the southern Ksour Mountains.

The surface flow is large and the total water reserves are 16 L/s. The oasis has 65 wells for irrigation of the palm grove gardens. The rational exploitation of the irrigation system through the traditional foggaras system has allowed crops to be grown under palm groves (Figures 5 and 6). An important river connects the two Moghrar oases, the Wadi of Rhoubia, a large flow of rainwater that supplies the small oasis of Tiout (Figure 7).

Climate

The region experiences an arid climate, with a cold winter. The wet period lasts only three months and the dry period is spread over the rest of the year, which indicates a water balance deficit. The average annual rainfall is approximately 210 mm. The average annual temperature is approximately 16 °C; the highest temperature of the warmest month is 36 °C. The average daily amplitude is 2.14% (November, December and January). The number of days of white frost per year is 24 on average, which occur through the coldest

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months, from December to February. The winds blow most frequently from southwest to northeast (ONM 2013).

Assessment of water resources at the regional level

The rational exploitation of irrigation water, by the foggara system, allows cultivation under the palm groves. A major wadi, Rhoubia Wadi, connects the two Moghrar oases in Tiout, and gives rise to a fairly large flow of rainwater (during floods), supplying the small oasis of Tiout, a place of relaxation with a playground for children (Figure 7). Water requirements are generally covered by the use of foggaras.

Type of irrigation system

The types of irrigation system at the Moghrar oases are:

- gravity fed irrigation;
- sprinkler irrigation;
- drip irrigation;
- tank irrigation.

A comparison of the useful agricultural surface (UAS) for each system was made and showed the following:

- The UAS for sprinkler irrigation was 13 hectares.
- The UAS for localized irrigation was 42 hectares.
- The UAS for gravity fed irrigation was 151 hectares.
- The UAS for tank irrigation in 2006/2007 was 0 hectares.

Cultivation

The region of Moghrar is characterized by its oasis agriculture with traditional plantations located in the bottoms of steep sided valleys or along wadis. There are orchard oases of date palm cultivation and palm tree oases with crops under the palm orchards, fruit trees and rustic trees, as well as market gardening (see Tables 1 and 2).

RESULTS AND DISCUSSION

According to our survey of the Moghrar region and consultation with the officers of the Moghrar Subdivision, it was determined that there are 38 boreholes, 126 wells, four springs and 97 wells or boreholes equipped with motor pumps in this region.

With regard to groundwater, shallow aquifers occur at 9 m depth, and deep aquifers occur at 40 m depth.

Surface resources

Despite the very low rainfall, there are several areas with superficial resources in the region. Several wadis cross the region of the Ksour Mountains to the north: Wadi Ber Remard, Oued El Atrech and Oued El Korima and flow (during the flood) into the Chott el Gharbi. These wadis flow only very temporarily and randomly during the year. It should be noted that a significant portion of these resources actually comes from groundwater.

It should also be noted that an important part of these resources actually comes from subterranean water, insofar as the great majority of the flow in wadis (small rivers) comes mainly from underground sources and not from superficial water.

Underground resources

Groundwater accumulates and constitutes large reservoirs (deep and superficial aquifers). Deep aquifers are exploited by drilling, and shallow aquifers with wells of depth generally varying from 4 to 30 m. An initiative, on behalf of an associative movement, brought together a team of specialists from the region (foresters, geologists, hydraulic engineers, etc.) curious to reveal the mysteries of the Ksour Mountains and gather knowledge on the identification of biocenoses (Bellal *et al.* 2015; MRE-Algeria 2017).

In the extreme south of the region, there are deep exploitable aquifers belonging to the Northern Saharan Aquifer System (SASS), but with very little recharge, and the Complexe Terminal of the Continental Intercalaire (including the aquifers in the Albian, Aptian and Barremian regions). However, the exploitation of the Higher Jurassic layers, the Albian, Barremian (or Barremo-Aptian) is restricted, and these layers are now protected, due to the observed drawdown of these aquifers, and the need to preserve the water resources for water supply. The drilling of wells is now subject to authorization and reserved for drinking water supply.

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Table 1 | Crops grown and irrigation development in Moghrar (MRE-Algeria 2017)

Irrigated crops (surface area cultivated in the year in ha)			
Irrigated cereals	18	Market gardening (ha)	
Irrigated by drilling	13	1st crop	91.5
Industrial irrigated crops	0	2nd crop	34
		3rd crop	0
		Total for market gardening	125.5
	Young plantation	In crop production	Under development
Irrigated arboriculture (rosaceous) (ha)	6	21	0
Irrigated citrus fruits (ha)	0	4.5	0
Irrigated olive trees (ha)	14	0	0
Other irrigated rustics (ha)	9	0	0
Irrigated table vines (ha)	1	2	0
Irrigated vines (ha)	0	0	0
Date palm (ha)	20	40	0
Other irrigated cultivations		0	
Numbers of irrigated greenhouses (units)			
Including	1 crop per year	0	
Including	2 crops per year	0	

Springs are not very numerous in the region; however they are for the most part resurgences of fossil groundwater. Groundwater is exploited with wells and boreholes (Messaoud 2013). There is, over the whole area, only one functional foggara in the Albien formation hanging wall (Unesco 1972; Rhouma 1993).

Hydrogeology units with an untapped aquifer are as follows, the piezometric companions highlight three currently exploited water tables which are, in order of importance:

- water table of the Tiout sandstones formation;
- water table of the Tiloula sandstones formation;
- alluvial layer of ancient and recent alluvial deposits.

The groundwater of the Tiout sandstones formation is the most important exploited aquifer of the Moghrar syncline. The direction is northeast-southwest with variations of the piezometric level from 975 to 945 m towards the southwest. The drainage axis follows the syncline's between Jebel El Kifane, Bram and Tameda. In the southern part of the studied area a secondary axis drains the groundwater towards the synclinal axis which centres on Djebel Tameda and Tismert in the same direction, northeast-southwest. At the level of the anticlines of Djebel Tameda, the current lines converge in the direction of the synclinal dips. The existence of a local piezometric peak at the northwest extremity coincides with the prolongation of the secondary anticlinal axis. The hydraulic gradient, which is 0.0013 in the northeast part of the piezometric map, has a value of 0.0026 in the centre and 0.0008 in the south, indicating a decrease of pumping

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Table 2 | Drilling irrigation (source Sogreah 2009)

Name of drilling	Date of realisation	Depth (m)	Discharge (L/s)	Irrigated area (ha)	State of drilling
Sebai	1990	200	20		Not exploited
Nessissa	1989	200	12	54	Exploited
Nessissa	2006	150	10		Not exploited
Sidi Brahim1	2003	160	5	85	Not exploited
Sidi Brahim2	2004	160	32		Not exploited
Sidi Brahim3	2004	160	30		Not exploited
Sidi Brahim4	2006	200	14		Not exploited
Baliata1	2004	120	20	50	Not exploited
Baliata2	2004	100	25		Not exploited
Oglat1	2000	75	17	240	Not exploited
Oglat2	2000	160	14		Exploited
Oglat3	2001	200	20		Exploited
Oglat4	2001	120	55		Exploited
Oglat5	2001	120	62		Exploited

and a permeability upturn while going towards the south. The water requirements for oases are satisfied by the rational use allowed by the water coming from the sources and wells of the underground water (the underground capture known as foggaras), which by accumulating reconstitute the reserves of vast aquifers, deep and superficial. The deep aquifers are exploited by drilling and the more superficial ones by wells in which the depth generally varies between 4 and 30 m.

Moghrar Foukani (municipality of Moghrar)

This dense grove of 5,000 palm trees on 20 ha is supplied by two sources, 10 traditional functioning wells out of 40, and one borehole with three basins (data from Naama Agriculture Division). Date production (generated by 60 families) is 300 quintals/year (30,000 kg/year), sold mainly at Aïn Sefra and Bechar. The 2.25 cultural intensification factor is the highest of all plantations.

The seguias system was rehabilitated by the Assemblée Populaire Communale (APC4) and the High Commission for the Development of the Steppes (HCDS) in 2000 and has benefited from a rehabilitation program following the damage caused by the exceptional flood of March 2008.

Moghrar Tahtani (municipality of Moghrar)

This is the sole palm grove supplied by the underground irrigation system (foggara) (see Figures 8–10), two sources and 20 traditional functioning wells out of 60 (the others having been flooded). The water shift is 1 h per family, with resumption between 4 and 6 days, for each of the 100 families. The production of dates from the 8,000 palm trees, grown on 40 ha, is 3,000–4,000 quintals/year (300,000 – 400,000 kg/year) (Agricultural Services Division – ASD). The cultural intensification coefficient is 1.7. It is noted that following an action of the ASD, it was removed leaving it exposed to the winds. A study of redevelopment of the palm grove has just been carried out by the Commission for Agricultural Development of the Saharan Regions (CDARS). It has also benefited from a rehabilitation programme following the silting caused by the exceptional flood of March 2008.

Impact of modern water extraction systems

Influence of motor pumps

There are 97 motor pumps. These new practices are exploited inside and outside the oases. In fact, on the

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Figure 8 | Seguia of the foggara of the Moghrar Foukani oasis.

Figure 10 | Madjen of the foggara of the Moghrar Tahtani oasis.

Figure 9 | Seguia of the foggara of the Moghrar Tahtani oasis.

expanding areas, new farms using pumping irrigation techniques and specializing in water-intensive crops have been established. Indeed, the current situation of these oases suffers from a set of issues related to the degradation of natural resources. These oases essentially exploit the potential of groundwater that has been held in the geological layers for millions of years. The fall in availability is serious and requires more efficient water harvesting.

Influence on groundwater

The free use of groundwater by pumping in oases poses the issue of the sustainability of the traditional sources that supply these oases. Generally located in areas with arid climates, where alternative water resources are lacking, fossil water should, for example, be used only for the supply of drinking water or for safeguarding the local ecosystem. However, the massive exploitation of these non-renewable waters, fossil waters, constituted by very old infiltration waters under climatic and morphological conditions different from the current ones, risks the existence of traditional springs.

To protect the aquifers, the plantations have been designated by the Wali's decree to control their overexploitation by drilling and sinking wells, to control the drawdown in the aquifers and to preserve the resource for drinking water supply.

Influence on the environment

The exploitation rate, the irrigation techniques and the succession of years of drought raise the question of the sustainability of groundwater resources in this area and the very existence of the oases.

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Influence on social life

The Moghrar region palm tree is already threatened by extinction. It is the main reason for the establishment of the population in the region. The disappearance of this tree will generate sociological, economic and ecological problems, limit input and introduce areas of conflict such as disputes over the right to water between villages and new users.

Traditional water distribution techniques are being lost, while the oasis communities are gradually disintegrating. Only a handful of older people still know how to use the sundial. They are usually paid by other irrigators to look after their land. The younger generations study and then go to work in the city. They often keep plots (as a property) in the oasis but live there only occasionally. Community ties are loosening and people no longer feel the need to build social relationships around water distribution. The oases of Moghrar are currently powered by motorized wells (motor pumps). These make it possible to obtain water without limitation and the owners are freed from the constraints of sharing and joint management of the resources.

RESULTS ACHIEVED AND RECOMMENDATIONS

The direction of the underground flow of the two layers is along the synclinal axis, with local disturbances of the flow lines due to the presence of a network of faults. On the other hand, the underground flow of the alluvial aquifer follows the surface flow of Mellah River. Domestic sewage, currently discharged in wadis, will start to be treated for distribution to the agglomeration of Moghrar. This sewage needs to be treated, using the system of wastewater lagoons. Catchment site protection using the appropriate techniques is mandatory for natural springs; there is a total ban on sinking wells to prevent the exploitation of a high concentration of mineral water. The installation of a complete weather station is needed.

CONCLUSION

The southwestern Algeria oasis region, particularly the Moghrar region, represents an important date production potential. In a sustainable way, many constraints limit the development of these zones. Nearly 65% of gravity irrigation has been developed in the areas where all the traditional plantations are located and where this practice is ancestral.

Living and working conditions in middle oases are difficult and tedious. The sudden shift in the Moghrar region of deep transfers due to the attraction of extra-agricultural, better-paid activities, water potential and opportunities for diversification of agricultural production offer new prospects for development. In this context, the protection of the two oases should be based on an overall socio-economic diagnosis. The area needs more and more use of the most advanced techniques in irrigation, fertilization, above ground cultivation, mechanization, crop control and livestock breeding, as well as phytosanitary protection, both physico-chemical and organic.

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