FOLIA ORIENTALIA 61 (2024)
DOI 10.24425/for.2024.152389

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Ethnography and Traditional Hydraulic Systems of the M'zab, Algeria: An Integrated Approach to Water Resource Management

Abstract Situated in the Algerian Sahara, the M'zab Valley is a limestone plateau crisscrossed by intricate branching ravines, earning it the Arabic name *šabka* ('network'). This region is characterised by long periods of drought, interspersed with rare high floods. Unlike other oases in the Sahara, the water tables in the M'zab Valley have a very limited natural regeneration capacity. The inhabitants, therefore, had to demonstrate remarkable ingenuity in managing water through highly sophisticated hydraulic systems. Paradoxically, the local population (called Mozabites) had to face periodic floods that were and still are infrequent yet extraordinarily violent. This study shows that the Mozabites used the groundwater as underground reservoirs, protected from evaporation during hot spells and infestation of insects. The water tables were recharged by the water of dams built by the local population. An efficient distribution network ensures equitable irrigation within the palm groves and prevents water wastage. All possible means were put to use to rationalise water consumption. Another finding of this study is that the hydraulic structures for collecting, drawing, and distributing water operate as a cohesive unit, where each component relies on the others to function properly and efficiently.

Keywords Algeria, M'zab, groundwater, *seguias*, dam, *foggara*, irrigation system, Mozabites

1 Introduction

The M'zab Valley is situated in the heart of the Sahara in Algeria in an isolated region endowed with natural defences to deter potential invaders. The Mozabites chose a site that was highly unfavourable to urbanisation, but at the same time well isolated and perfectly sheltered from possible attacks. The Mozabites were professing particular religious beliefs within the Islamic community, known as the Ibadite faith. Because of this, they were compelled to flee persecution and violence, as the massacre they suffered in Tihert during the 10th century and seek refuge in a desert valley that now carries their name. What used to be a pristine area started to undergo urban development in the early 11th century until it reached the number of five fortified towns known as *ksour*, namely: Al-ʿAṭf ('the bend'; El Atteuf) established in 1011, Būnūra ('the luminous'; Bou Noura) in 1046, Ġardāya ('inter-mountainous place'; Ghardaïa) which is the main town and established in 1053, Banī Yazgan ('the middle people'; Beni-Isguen) in 1124, and Malīka ('the royal'; Melika) in 1347 (Saʿīd 2014).

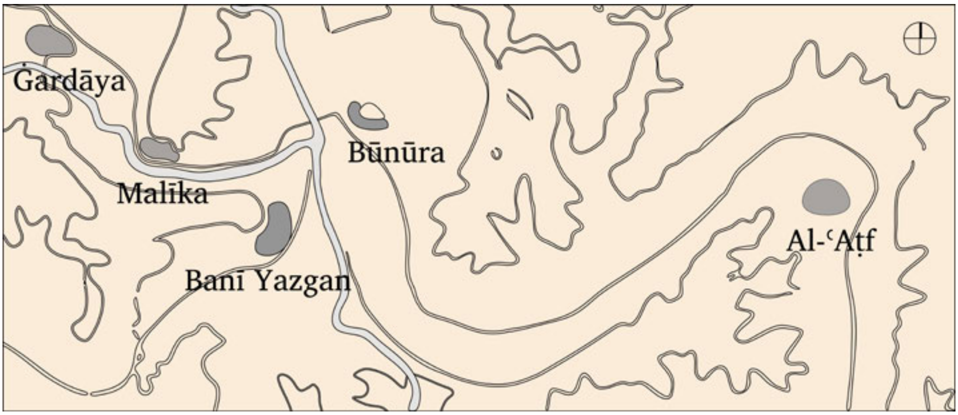

Figure 1. Map of the M'zab Valley and its five ksour (map by A. Kasmi)

This cluster of five small towns is widely referenced as an example of original building design, tailored to semi-desert conditions and founded upon strict rigorous religious, social and moral ideals. Indeed, religion plays a central role in the lives of the Mozabites. The *ksour* are designed to facilitate religious practice. The great mosque has a central geographical position dominating the whole town, and Quranic schools are carefully integrated into the neighbourhoods. Socially, sacred rituals and religious festivals punctuate the daily life of the Mozabites, who share specific practices of the Muslim religion.

These five small towns or *ksour* are much more than mere urban settlements. They have very specific planning principles. First, they are all built on a rocky spur, impervious to erosion. They are all perched on a hillside, topped by a mosque featuring a minaret with a specific shape. Moreover, unlike the classic Islamic city layout, they all have *souks* located far from the great mosque, but near the city gates in order to control access to the city. In fact, to this day, no foreigner is allowed to wander freely in the city without a guide or escort.

The M'zab Valley is characterised by a scarcity of surface water, contrasted by infrequent but destructive floods. The local builders, therefore, had to construct anti-flood dams not only to contain high-water overflows and reduce damage, but also to allow water to stagnate and thus infiltrate the soil, feeding the groundwater table (Rezig and Shevtsova 2022: 2; García-Rodríguez, Antón, and Martinez-Santos 2014: 20). This latter supplies the 3,000 wells in the region, which were extracted using draught animals (Delaval 1974: 256; Ravereau 1981: 110).

These wells were a natural source of clean water, which was conveyed by *seguias* ('earthen channels for distributing water') to various palm groves. Thus, the hypothesis put forward is that the remains of these traditional water management structures bear witness to a far more elaborate layout than what is described in the scholarly literature. The techniques for collecting, extracting, and distributing water form a coherent and interdependent system, as each component is essential to the smooth functioning of the overall system.

2 The *wadis* and floodwaters

The palm groves in the M'zab Valley were artificially planted by local inhabitants with palm trees brought from neighbouring regions toward the end of the 9th century. These palm groves extend along the dry bed of Oued M'zab. However, this river is not constantly dry. The flash floods of *wadis* posed major challenges for the Mozabites who had to anticipate and protect themselves against their ravages. They anticipated these events by developing an understanding of flood cycles. They also closely monitored warning signs, such as heavy rainfalls in the surrounding mountains, ensuring the most appropriate preparation. To protect their lands and homes, the Mozabites built dams along the *wadis*. These structures served to contain the raging waters during floods. Nonetheless, they did not stop at taking preventive measures against floods, they turned this challenge into an opportunity to secure water for their communities. They harnessed *wadis* floods as one of the main water resources to support their development and prosperity.

Indeed, in the M'zab Valley, unlike the main oases of the Algerian Sahara, the groundwater tables have a very limited replenishment capacity. The only external agent with which they regenerate is the *wadis* floods, the most notable of which are: Oued-Soudan, Oued-Baulek, Oued-Madeur'a, and Oued-Zergui. These floods remain rare events that recur irregularly, lasting only a few days and sometimes do not occur for several years. When they occur, torrential rains cause the *wadis* to flood, resulting in enormous damages and destroying everything in their path (Petruccioli 1990: 92). It should be noted that the most devastating flood to hit the area in recent years was that of October 2008, which caused the death of 43 people.

The floods reoccurrence reveals the usefulness of certain structures, such as bridges spanning Oued M'zab. These crossing structures bear witness to the frequency of floods in the past, which required footbridges to connect the two banks. They were essential for the inhabitants, enabling them to cross the tumultuous waters during floods and maintain the continuity of daily life. These bridges were, therefore, key elements in the Mozabites' adaptation to their environment, allowing them to maintain their agricultural and commercial activities despite episodes of river flooding.

Figure 2. Bridge over the old course of Oued M'zab (A. Kasmi)

3 The dams and their ingenuity

Along the winding curve of the Oued M'zab, the Mozabite builders built a series of dams. The purpose of these dams is to break the flow of the swollen river and collect this water, directing it throughout the various palm groves. In addition, the dams allow water to stagnate and infiltrate the soil, thus contributing to the recharge of underground aquifers (Delaval 1974: 256; Hamed et al. 2022: 138–139). Therefore, the palm groves were protected upstream by masonry dams that mitigate and break the impetus of the current during floods. They slowed down the river force, preventing flood damage. This technique also helped to preserve the soil and limit erosion. The location of these dams was not random: they were built on calcareous-alkaline rocky massifs, to avoid any risk of erosion. They are often undulating in shape for structural reasons. Indeed, the sinuous shape enhances their resistance against soil pressure and the force of floodwaters. They are regularly whitewashed with lime to prevent the masonry from being directly exposed to water, and thus from being weakened by the disintegration of the masonry of which they are composed.

Built between the 13th and 16th centuries, the great Beni-Isguen dam is called *Ahbass*, a name that was later given to the entire surrounding palm grove. The dam is located on Oued N'tissa's riverbed, not far from its confluence with Oued M'zab. Over 400 metres long, it was built in the narrowest section of the *wadi* bed for prac-

Figure 3. Overview of the dam of Beni-Isguen (A. Kasmi)

tical reasons, such as minimising its length and reducing construction times, using less building material, and structural stability. Thereby, the dam also serves as a passageway connecting the two riverbanks, but mostly providing the shortest route across Oued N'tissa, which, thanks to the dam, can be crossed on foot or by donkey.

This great dam of Beni-Isguen is adorned, along a large part of its length, with vertically standing stones. These stones break the speed of the water current and retain debris carried by floods. However, their main role is quite distinct. Because of the inclination of the dam along its length, these stones are used to measure the severity of great floods, based on the stone reached by the water level. A member of *oumanas* ('the floodwater management commission') verified the level of water if it has risen to the sixteenth or twentieth stone, for instance. At the upper limit of the dam, a marker of a specific height, locally known as *šamʿa* ('candle'), indicates the dangerous flood level. This measurement is used to announce the warning level. In fact, if the water reaches the top of this marker, the commission of *oumanas* issues an evacuation alert for the surrounding palm groves.

4 The wells and well-drawing techniques

Groundwater tables are natural reservoirs, mainly replenished by dams, as explained above. These natural reservoirs are protected from water evaporation during periods of high temperatures, making them reliable sources even dur-

Figure 4. The passageway of Beni-Isguen dam (A. Kasmi)

ing periods of drought. Moreover, unlike *wadis* and lakes, groundwater tables are hidden beneath the earth's surface. This subterranean position protects them from excessive evaporation caused by the scorching Sahara sun. Consequently, stored water remains available for community needs. There is also no risk of exposure or stagnation. Unlike surface water, which can stagnate and become breeding grounds for insects and diseases, groundwater is in constant motion. It flows slowly through soil layers, preserving its quality.

To exploit this underground water, the Mozabites dug wells, not far from the dams, and sometimes right in the *wadi* riverbed. These wells, known as *tirest*, were dug to great depths, with some reaching up to 50 metres (Cherid, Drias, and Benouis 2017: 79; al-ʿArabī 1983: 22). Remarkably, the Mozabites were able to dig such deep wells in rocky soils using rudimentary means. This achievement itself is a remarkable technical feat, often taking several years to reach the water table.

Figure 5. View of a well showing the basin (A. Kasmi)

The wells are used together with temporary water retention basins. The well openings are often bricked up and flanked on either side by two uprights that support the pulley. In the palm grove, water is drawn by animal traction along a towpath. The traditional method of drawing water was as follows: a sloping path, generally paved, was laid out over a length equal to the well's depth. A donkey, led by a man, descended the slope, pulling a rope on a pulley, to which was attached a large goatskin water bag that carried the water upwards. This goatskin water bag, which holds 30 to 50 litres, has an opening with a spout. The spout remained elevated using a second rope. Once the water bag is out of the well, a second small, flat, pulley lowered the spout above the basin, and the operator handling the rope successively releases the second rope to pour the water into the basin. The operator then turns the donkey around and climbs it back up the slope, while the empty bag sinks back to the bottom of the well.

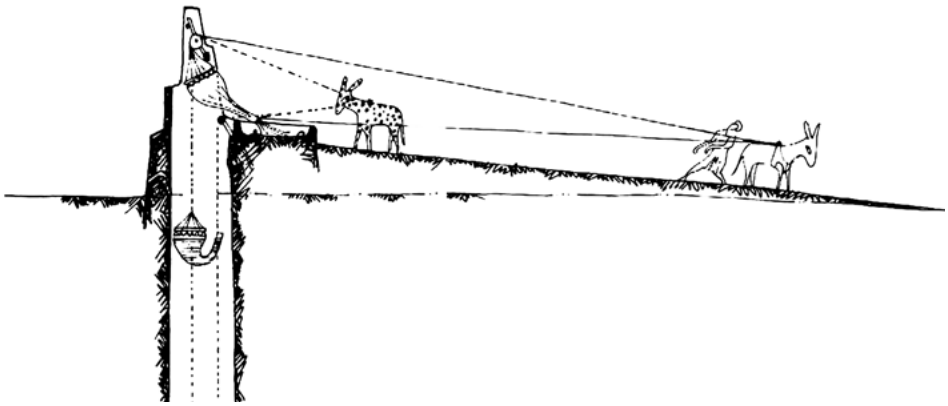

Figure 6. Well-drawing technique in the M'zab region (drawing by A. Kasmi)

5 Water distribution and the *foggaras*

The drawing wells included basins containing the water that the *seguias* channels conveyed to the base of the palm trees, where each garden received an appropriate amount of water adapted to its needs without any wastage. Run-off water is captured and then distributed along the valleys. When the *wadi* flows, a water distribution device in the shape of an inverted comb (*kesria*) regulates the flow between its teeth. This device captures the water upstream and distributes it to the palm grove canals, which in turn branched into smaller distribution canals. These latter follow the general layout of the grove, and the water is collected through openings projecting 45° angle from the walls and stored in private cisterns (Petruccioli 1990: 92; Cataldi, Abdelhamid, and Selva 1996: 66). This system is associated with another ingenious one that allows palm grove pathways to operate as canals. Indeed, *wadi* runoff carries water into alleyways that function like canals. These alleys/canals border private gardens and serve as water distributors, supplying the palm grove gardens (Roche 1973: 60; Remini, Achour, and Albergel 2015: 360; Martínez-Medina, Gil-Meseguer, and Gómez-Espín 2018: 3; Lightfoot 1996a: 322).

Therefore, all irrigation systems are designed to serve a single purpose: optimising water consumption. The water distributed to each garden is meticulously calculated by a designated expert who swears on the Quran to use it justly. To achieve this, the intervals between the teeth of the water distributor (*kesria* or inverted comb) are proportional to the shares of the entitled parties, which, in turn, depend on the size of the gardens. No garden will receive more water than it is entitled to. If the garden slopes even slightly, a spillway will be located in the lower wall, allowing excess water to flow to the neighbouring garden below (Roche 1973: 60; Hamamouche et al. 2017: 117).

This complex distribution system is also, in turn, combined with another device: the *foggaras* (*l-fugārāt*). Widely adopted in the Algerian Sahara, *foggaras* are defined as tunnels punctuated by a series of ventilation and cleaning wells, and whose inclination allows underground waters to be directed to the surface for gardens located below the tunnels (Bensaada and Remini 2017: 351; Dahmen and Kassab 2017: 1268; Lightfoot 1996b: 261). The origin of this extraction system dates back to the Canaanites in the Near East, around the 3rd millennium BC (Zarqa 1999: 63). Its name varies across the Arab world, but during the Middle Ages, it was referred to as *qanāt*. According to ar-Rūmī's words (1866: 182): *wa-l-qanāt abār ḥufira taḥta l-arḍ wa-yuḫriqu baʿḍuhā ilā baʿḍi ḥattā taḏhara ʿalā wağh al-arḍ ka-n-nahr* '*al-qanāt* is a chain of wells dug into the ground and penetrate each other until it appears on the surface like a river'. However, the *foggaras* of the M'zab region differ somewhat from the rest of the Arab world (Remini, Achour, and Kechad 2010: 112). They are mainly replenished by the floodwaters of Oued M'zab. Thus, these *foggaras* do not have continuous flow like those in the rest of the Sahara. They are located upstream of the *seguias*, mainly to collect as much floodwater as possible, while the rest of the water is captured downstream by the palm grove dams. This ensures optimal collection of these waters and creates a cohesive floodwater harvesting system.

6 Conclusion

Although the groundwater tables in the M'zab have a very limited natural regeneration capacity, the Mozabites used them as underground reservoirs, protected from loss by evaporation, risk of contamination, and infestation of unwanted insects. These groundwater tables were fed by floodwaters which, thanks to dams, stagnated over large areas, allowing enough time for infiltration and replenishment. Drawing water from wells was the only means of accessing this water, which was then conveyed through a distribution network, carrying the precious liquid from the wells to various palm groves. Each garden received an exact amount of water that corresponds exactly to its needs, without surplus or any excess. Everything was done to rationalise water consumption. In other words, the meticulous management of these water tables was essential to the survival of the M'zab communities. It reflects their ancestral know-how and deep respect for this vital and precious resource that is water. It also embodies their ingenuity in transforming an arid environment into a flourishing oasis.

However, unlike ancestral practices, modern drilling methods with high pumping rates are drying up the groundwater tables, not allowing them enough time to regenerate (Remini, Jean, and Bachir 2015: 56; Heiß et al. 2020: 6). In fact, although a number of traditional hydraulic structures in the M'zab have survived the ravages of time, the gradually forgotten mastery of these ancient devices led to a situation where their use is becoming less and less systematic (Idda et al. 2017: 2). Their gradual abandonment in favour of more easily accessible modern techniques is a cause of great concern. No *foggara* or *seguia* is currently operational; they have been neglected due to their deterioration and the drying up of riverbeds. This degradation is both the cause and consequence of long-standing neglect and abandonment, which has become the rule. Furthermore, uncontrolled urban growth is encroaching not only on an extraordinary hydraulic heritage, but also on the *wadi* beds and, above all, on the palm groves that historically have always been the region's main source of wealth and prosperity.

In 1982, the M'zab Valley was classified as a UNESCO World Heritage Site (UNESCO 2004). Since then, only the five *ksour* have been affected by regulatory measures. More recently, renewed interest has been clearly shown by the Algerian government, which published a decree on 4 June 2005, establishing a perimeter for the protected area. In 2007, the Ministry of Culture and the Wilaya (or province) of Ġardāya launched a safeguarding and enhancement plan, under which an action program was implemented to rehabilitate the traditional hydraulic network.

Disclosure statement

No potential conflict of interest was reported by the author.

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