

Timimoun's foggara (Algeria): an heritage in danger

Boualem Remini · Bachir Achour · Jean Albergel

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Abstract Timimoun is located in the hyper-arid zone of the Sahara, with an annual rainfall not exceeding 100 mm/year. To fill the shortage of rainfall, the oasis has developed a traditional means for mobilization of the groundwater. In the foggara with this hydraulic system, oases have been developed throughout the region of Timimoun over ten centuries. Today, we witness the gradual disappearance of foggaras; we lose about one to two foggaras per year for over half a century. The discharge of the 250 functional foggaras shows a significant drop: 850 l/s in 1960 and 355 l/s in 2001, enough to irrigate 350 ha. The causes of declining foggaras are technical, social, and environmental. The surveys that we have led nearly with the population in the ksour during two missions in 2007 and 2008 in the oasis of Timimoun reveal that socio-economic problems (Heritage and depopulation) are common to both types of foggara (foggara of the Erg and foggara Albian).

Environmental problems (silting and flooding of the galleries by wild plants) are the main causes of the disappearance of foggaras of Erg. Technical problems (collapse of tunnels) are mainly the causes of degradation to Albian's foggaras. Attempts to introduce changes to foggaras are temporary solutions. The modern collection of water (pump and drilling) is gradually replacing the traditional hydraulic system.

Keywords Foggara · Gallery · Collapse · Silting · Drilling Timimoun

Nomenclature

Kasriates	Plural of kasria: A small triangular basin, led division boxes in the form of a comb.
Souagui	Plural of seguia: canal land
Kialines El Ma	plural of Kial el Ma: The person who is in charge of flow measurement.
Chouhouds	Plural of Chahad. It is the witness.
Ksar	Housing oasis.
Zemmam	Register of the Kial El Ma

B. Remini (✉)
Department of Water and Environment, Faculty of Engineering,
Larhyss Laboratory, Blida University,
Blida 09000, Algeria
e-mail: reminib@yahoo.fr

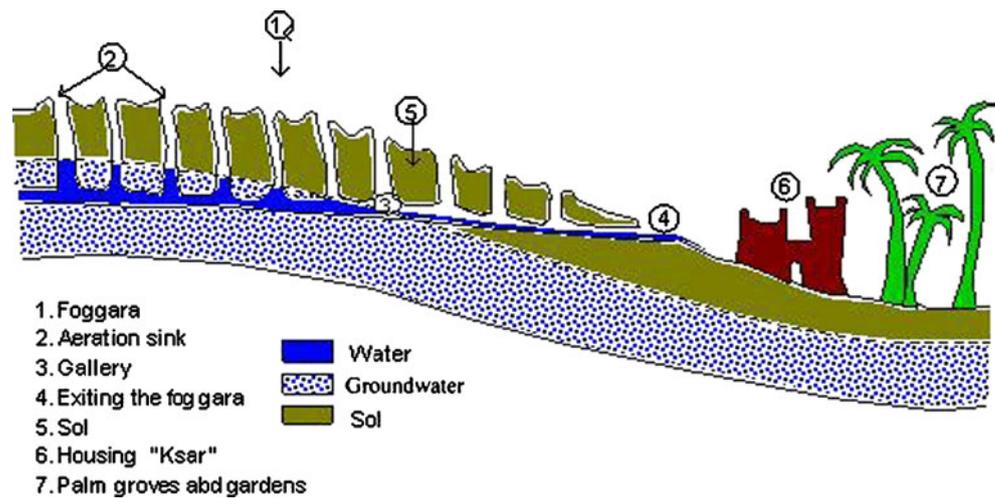
B. Achour
Department of Hydraulics, Biskra University, Larhyss Laboratory,
Biskra 07000, Algeria
e-mail: bachir.achour@larhyss.net

J. Albergel
Institute of Development Research,
Montpellier, France
e-mail: jean.albergel@ird.fr

Introduction

Known under different names; Khettara in Morocco, Qanat in Iran, Falj in the Sultanate of Oman and the Karez in Afghanistan, Algeria the foggara in Algeria is an underground gallery with gentle slope, which drains water from the upstream aquifer to the drier land downstream towards the palm (Fig. 1). This process uses a system of tunnels with slope length that may reach 20 km, equipped with a series of vent wells spaced 5 to 22 m (Fig. 2). The foggara

Fig. 1 General outline of a foggara



as a technical system is associated with social work led by a committee of wise men, called Djemaa, whose role is to direct and oversee the maintenance of the foggara and the distribution of its water (Fig. 3).

In Iranian origin, qanat developed in the Iranian plateau for over 3,000 years (Goblot 1979; Wulf 1968; Wessels 2005). It is broadcast in 35 countries worldwide (Boustani

2008). It is found in northern Africa, southern Europe, Latin America, Central Asia, and Arabia; however, this World Heritage hydraulic deteriorates from one year to another. The number of these galleries draining decline following the various technical and social problems. In Iran, qanats decreased from 50,000 (Ghorbani 2007) to 32,000 in 1950 (Bonine 2006) and at 22,000 in 2006 (Larson and McLaughlin 2006). In Oman, the number of aflaj (plural Falaj) decreased from 4,112 to 3,017 aflaj in 2007 (Al Gharfi 2003; Al Murshudi 2007). In southeastern Morocco, in Tafilalet, the number of khattaras decreased significantly from 300 in the early twentieth century to 150 in 2000 (Ben Brahim 2003). In 1997 there were 190 functional khattaras (Menjo et al. 2007). The abandoned khattaras until 2004 were 262 out of the 308 counted khattaras in 1967 (Ouhassain 2004).

We discuss in this article the technical, environmental, and socio economic problems that threaten the functioning of the foggara. Timimoun is in the central area of hyper-arid



Fig. 2 A well of foggara in downtown Timimoun (photography Remini and Achour 2008)



Fig. 3 The large comb (flow splitter) of the foggara El Meghier (Timimoun) (photography Remini and Achour 2008)

Sahara, a region known by low rainfall not exceeding 100 mm/year. To address this lack of rainfall, the use of aquifer water is the only solution. The foggara acquisition technique of groundwater has been the technique most appropriate in a region hostile to life. The development and spread of foggara throughout the region of Timimoun helped install and maintain an oasis for many centuries. Today, this socio-cultural heritage, the pride of all the oasis population, is endangered that each year we lose one to two foggaras. The functional foggaras have difficulties in management and maintenance. The flow of the 250 foggaras still functional in the Timimoun region shows a significant drop: 850 l/s in 1960 and 355 l/s in 2001 at the last census conducted by the National Agency of Water Resources.

Study area: observations and evidence

The last inventory conducted between 1998 and 2001 by the National Agency of Water Resources (NAWR) gave a number of 250 foggaras in use throughout the region of Timimoun. This number will be lowered, because each year, one to two foggaras on average are abandoned.

To understand the problem of regression of this ingenious system, we carried out two missions in 2007 and 2008 in the oasis of the Timimoun region (Timimoun Center, Aghlad, Ouled Said, and Kali).

Timimoun is a tourist region dubbed as the red oasis located 1,200 km southwest of Algiers (Fig. 4(a and b)). It is known by its beautiful palm trees, dates of good quality, and more than 200 ksours.

Our study in 2007 and 2008 was based on observations and surveys of local people, owners of foggaras and members of the “Jemaah” (Committee of Wise Men).

Results and discussion

By visiting the different periphery oases of the sebkha of Timimoun, we found the presence of two types of foggaras: one that captures the waters of the Continental Intercaler (deep water), called an Albian foggara and is located in the center of Timimoun, and the foggara which captures the water of the Occidental Erg Large, a sheet located under the immense sand dunes and that feed the Ouled Said oasis of Ouled Said, Aghlad, and Kali, called Erg’s foggaras.

According to field observations and interviews conducted with the population, it appears that the socio-economic problems are common to both types of foggara (Erg and Albian). Unlike environmental problems that are the main causes of the disappearance of foggaras of Erg, technical problems are largely the causes of degradation foggaras of the Albian.

Social problems

The legacy, the rural exodus, the non-transmission business, and the modern technique of irrigation in the oasis are the main problems affecting foggaras of Timimoun. Palm groves and gardens were abandoned for several years without maintenance because of the legacy. The cases that we encountered in the oases of Timimoun are:

- The foggara is a family possession. It is found that members in this family are opposed to the maintenance and work of foggaras.
- The death of the owner of the foggara stops the functioning of the foggara because of disagreement with the granting of water shares between family members.
- When the flow of a foggara decreases, each member of a large family receives a small part of water that will remain insufficient to irrigate his garden.

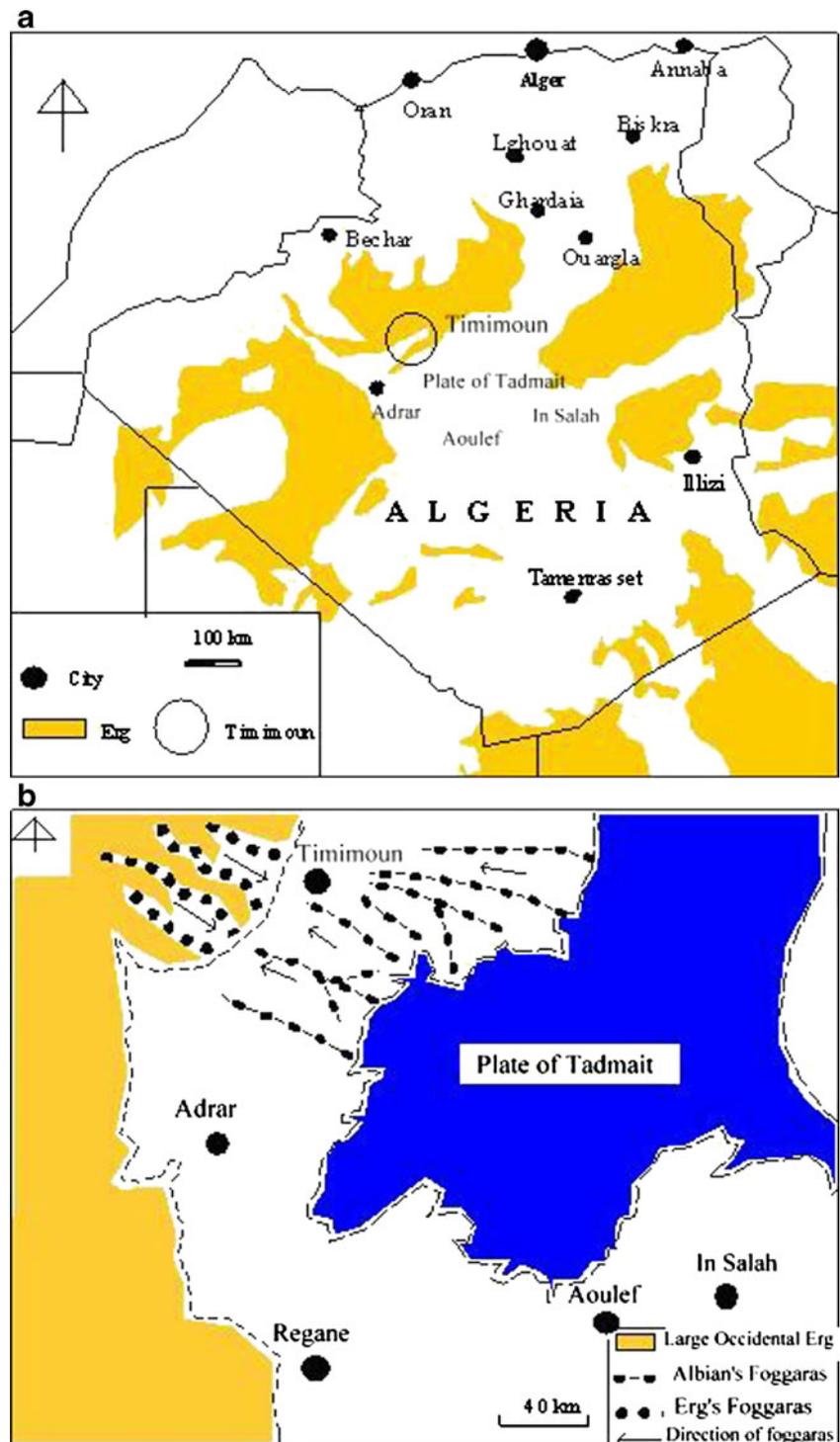
The non-transmission trades foggara to younger generations. For example, the scarcity of Kial El Ma has become a thorny social problem. The sharing of water from a foggara is provided by a team of Kial El Ma and Chouhouds. The measurement units of water from the foggara each varying flow caused by the dissection or the collapse of the gallery, requires the intervention of El Ma Kial. All measurements and computing operations of legal and real part are recorded in Zemmam of foggaras. Currently, this character is endangered in the region of Timimoun. There are 15 Kialines El Ma throughout the region of Timimoun, and they provide measurements of flows over 250 functional foggaras.

Charmed by the abundance and ease of acquisition of water, the oasis population uses more and more pumps in wells and boreholes. The population moves away from group irrigations (foggara) at the expense of individual irrigation (Pit to pump). Two phenomena that have grown in recent years are abandoned gardens, fertile lands delivered to the water and wind erosion, synonymous with the heritage and population migration to large cities. The consequences of these problems have adverse socio-economic life of the oasis causing the abandonment of irrigated agriculture, nonfood sufficiency, growing unemployment, and poverty.

Technical difficulties

Contrary to the environmental and socio-economic problems, which are common to both types of foggaras, Timimoun’s operational and technical problems particularly affect the foggaras of the Albian, primarily the collapse and landslides of galleries, lower water level, and drying up of foggaras.

Fig. 4 a Location of the study area; b Timimoun's foggaras



Collapse of foggaras

The collapse and landslides of wells and galleries is a process that often takes place at a foggara. In recent years, several foggaras in the region of Timimoun were discontinued or their flows have reduced because of deposits of

earth caused by the collapse. This phenomenon occurs in two processes:

- Slow Process

A slow process in which water flow erodes continuously to the bed and walls of the gallery dug in sandy

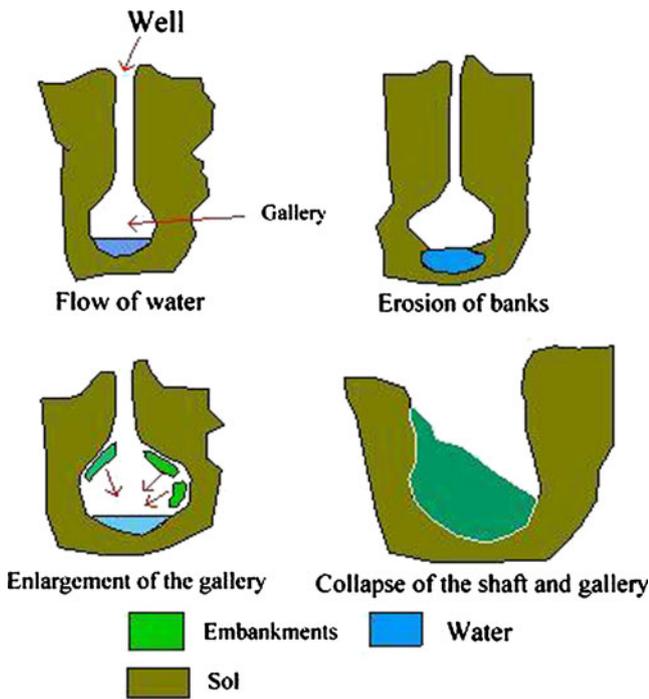


Fig. 5 Simplified collapse of foggara (slow) (Remini 2004)

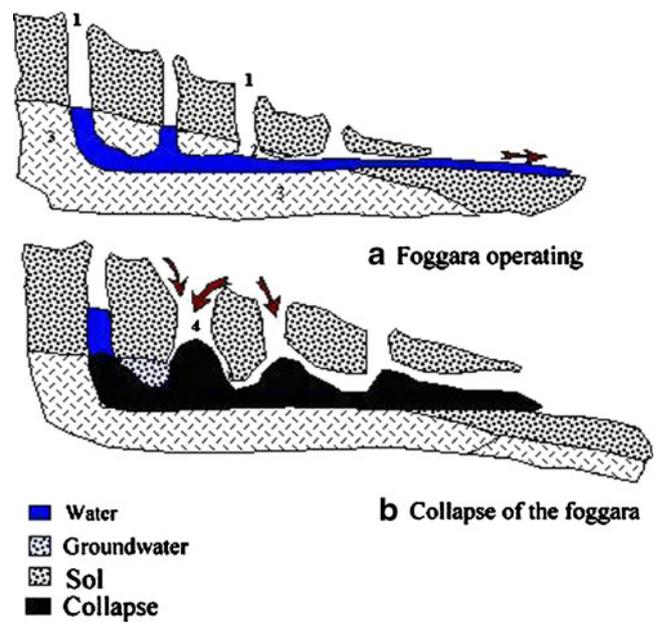


Fig. 7 Simplified collapse of a foggara (Fast)

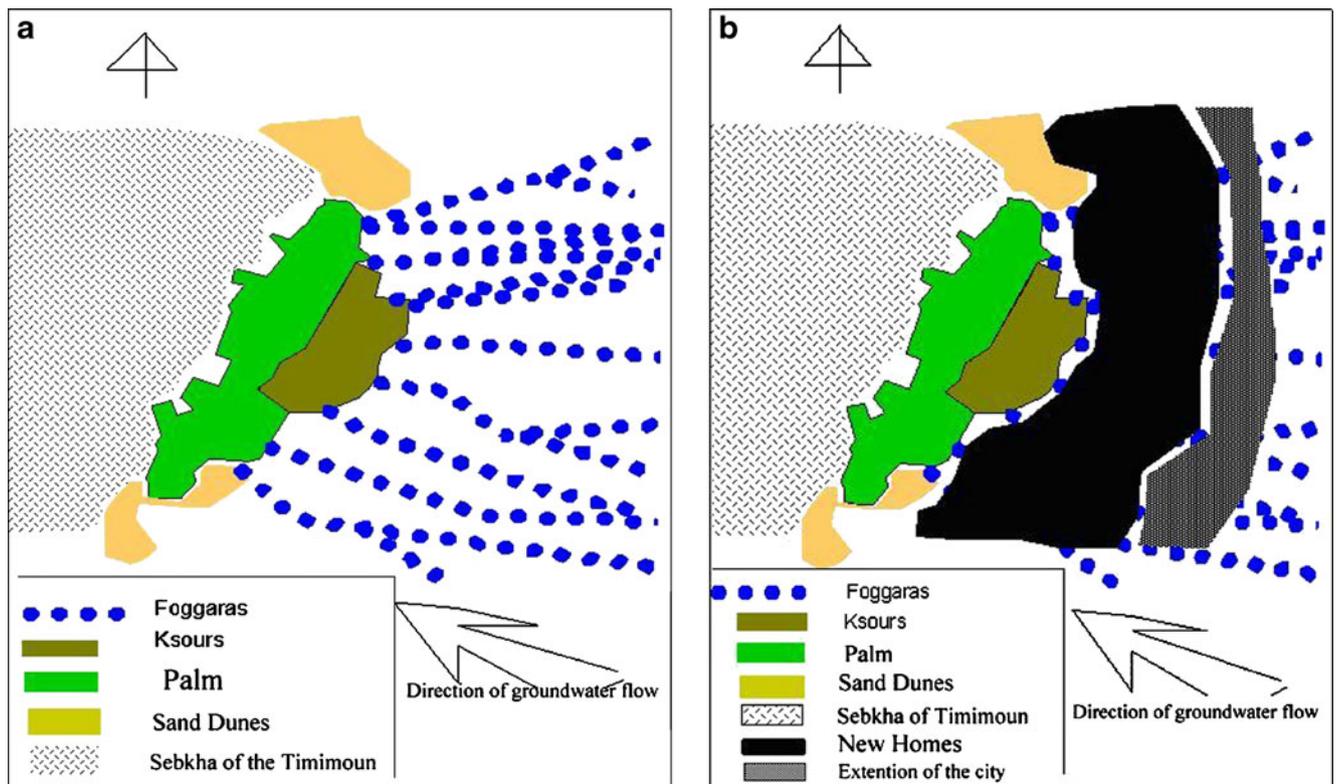


Fig. 6 Simplified diagram of the evolution of urban planning in the region of Timimoun

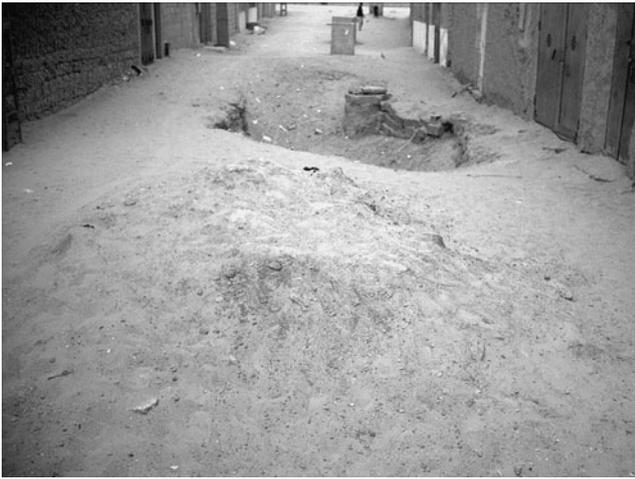


Fig. 8 Collapse of a section of the gallery of the foggara Amokrane (Timimoun) during the flood of 2003 (photography Remini 2007)

soil (Fig. 5). This process causes, over time, a larger section of the gallery to collapse, then the collapse of the foggara.

This case occurs often in foggaras crossing towns and roads (Fig. 6(a and b)). The vibrations caused by the movement of vehicles and facilities operated by the population are the main causes of collapse of foggaras. Generally, landslides and falling rocks inside the gallery caused a rapid decrease in flow in the foggara. According to the owners of El foggara Meghier (Timimoun), reducing its speed (in addition to the effect of drilling), is due to deposits of soil in the gallery of some sections caused by landslides during the last 10 years. Several sections of gallery foggaras in the region Timimoun collapsed over time.

- Quick Process

A rapid process leading to the almost instantaneous collapse of the gallery caused by the passage of floods that are usually sudden and high intensity (Fig. 7). By draining a significant amount of sediment, runoff water reaches the gallery through the air shaft causing the collapse of the foggara. For example, in the city of Timimoun, three foggaras collapsed following the floods of 2003. The foggara Amokrane was abandoned following the collapse of part of the gallery. Several sections of the gallery collapsed resulting in the restoration of flow (Fig. 8). Table 1 summarizes the different types of collapse caused a few foggaras.

To maintain the steady flow, the foggara requires periodic and continuous maintenance. The first owners encourage investment and make use of other shareholders. The new owners, as the former have every right to sell or lease the number of shares owned. Gradually, as the number of owners increased by purchase or investment,

Table 1 Types of collapse

Foggara names	Types of collapse	Observations	Debit
Amokrane	Quick	The flood of 2003 caused the collapse of several sections of gallery	No flow
Meghier	Slow	Introduced in the gallery following the erosion of some sections	Functional foggara's with a low flow

foggara eventually become a business subject to strict and rigorous rules.

To maintain the flow foggaras stationary, the cleaning of mud and sand deposit in the gallery is large scale and highly complex which requires skilled labor. The repetition of the cleaning operation causes the deepening of the gallery (Fig. 9). Currently, it is difficult to proceed at the construction of new foggaras because of lack of skilled labor and the cost price of the transaction. Currently, maintenance operations are rare in the region of Timimoun.

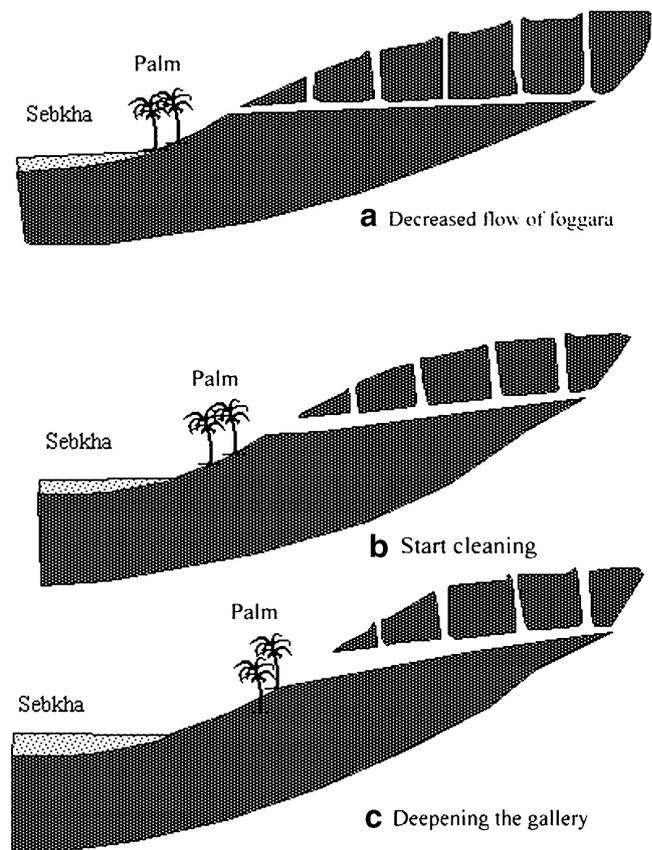
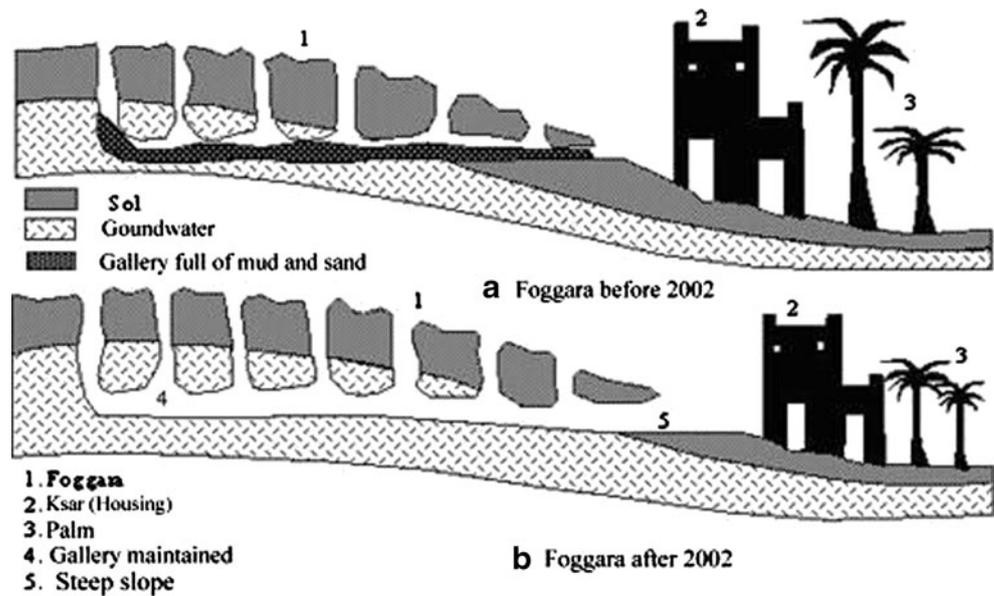


Fig. 9 Simplified process of flushing

Fig. 10 Simplified diagram of the foggara Iflan bara before and after 2002



The population of the Ksar Kali (Timimoun) is an example for others to ksars. The population rehabilitated the foggara of IfanBara in 2002 (Fig. 10). It has even rehabilitated the foggara of Ksar Aghlad in 2004 (Table 2).

Depletion of foggaras

The field collection of holes drilled around the foggaras is the main cause of dwindling foggaras. Because of the high water demand, forges have proliferated in the early 1980s resulting in lowering of the water; piezop metric in the level of groundwater decreased to remain below the gallery. The draining part of the foggara (which is the backbone of the foggara) dries and becomes inactive, causing the depletion of the foggara (Fig. 11). The exploitation of groundwater by pumping foggara resulted in heavy drawdown since the 1960s, the period of installation of the first deep drilling in the region. Timimoun region has not escaped this phenomenon. Currently, the flow of drilling throughout the region of Timimoun is well over 800 l/s. However, one of foggaras in Timimoun is around 350 l/s. Since the radius of influence

of drilling on foggaras was estimated at 1.7 km from the water services of Timimoun, the value is judged likely to cause a lowering of the water (Fig. 12). If we take only the holes that are placed in a 1-km radius, there are approximately 120 wells throughout the wilaya of Adrar. It turns out that 13% of wells are located within a radius of 50 m,

Table 2 Some rehabilitated foggaras

Foggara	Year
Foggara of ksar Kali	Foggara abandoned in 1966 and rehabilitated by the population during the 90s.
A foggara of Ksar Aghlad	Foggara rehabilitated by the population in 2004.
Iflanbara	Foggara rehabilitated by the population in 2002.

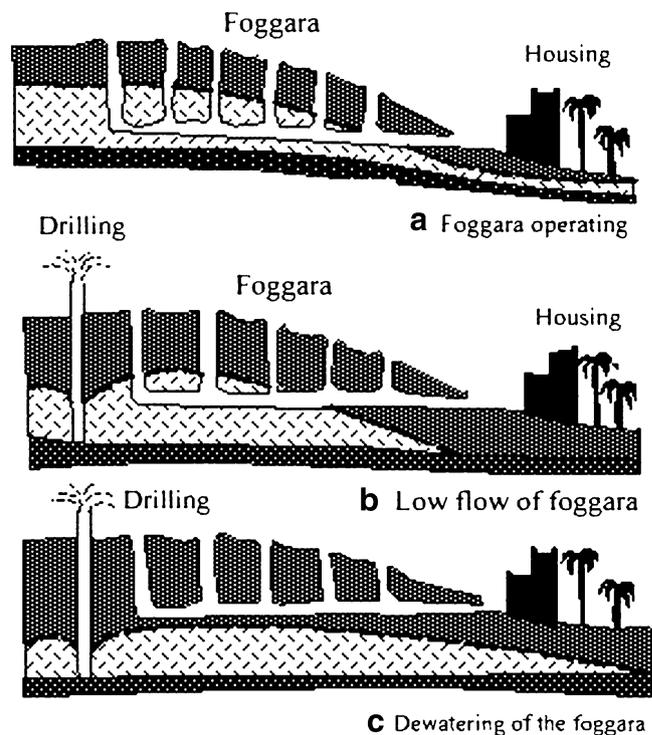


Fig. 11 Simplified diagram of a drying foggara

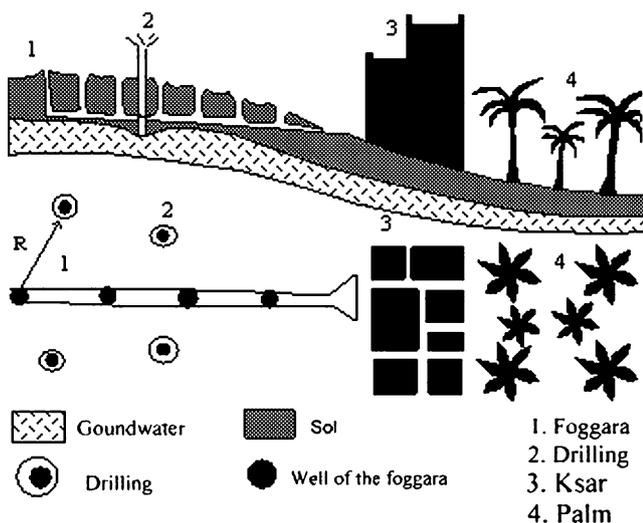


Fig. 12 Schematic overview of the state near the drilling foggara

giving this case the foggara is certainly influenced by the pumping of the drilling (Table 3).

Reduction to the sheet's level

In the early 1960s, when the appearance of deep drilling, the groundwater level of the Continental Intercalar (water Albian) decreases, causing the disappearance of artesian wells, the lowering of the water Albian and the decreased flow foggaras. This water belongs to the aquifer system of the Sahara septentrional (SASS), which designates the superposition of two major deep aquifers: the water of the Intercalar Continental (which is the broadest and deepest) and the Terminal Complex (Fig. 13). The SASS covers an area of over 1 million km², 700,000 km² are in Algeria, 80,000 km² in Tunisia, and 250,000 km² in Libya (Larbes 2003, Abdous et al. 2005).

Today, the SASS is used by nearly 8,800 water points, drilling, foggaras sources and distributed among three countries (Algeria 6,600, Tunisia 1,200, and Libya 11,000). Either a total volume of timber throughput equal to 2.2 billion m³/year: 1.33 billion m³/year in Algeria, 0.55 billion m³/year in Tunisia, and 0.33 billion m³/year in Libya (Abdous et al. 2005; Remini and Achour 2008). This high water consumption by three countries caused a

significant reduction of the water and therefore lower rates of foggaras time.

Meghier's foggara is regarded as the greatest foggara in the Timimoun, with a total length of 11 km, 600 wells equipped with ventilation, reached a speed of 50 l/s during the 1970s (Fig. 14). More than 200 families lived on this foggara. In 2007, the Meghier's foggara is in disrepair: its speed dropped to less than 3 l/s, several tertiary kasrias are destroyed (Fig. 15), over 50% of network completely degraded the seguias (Fig. 16).

Environmental problems

The silting and clogging of the galleries by plant's roots "Terza" are the main environmental problems that particularly affect the foggaras of Erg.

Silting of foggaras

Over 120 functional foggaras in the region of Timimoun are exposed to the phenomenon of silting. About ten foggara oases of Aghlad and Badou are lost in the middle of Erg. In these oases, silting remains a thorny problem, because every wind of sand, kasriates the souaguiss and the galleries are filled with sand. Several sections are completely stuck. For example, in the oasis Aghlad, 14 ksours which were powered by nine foggaras, were powered with a single foggara in 2008. Inhabited by three families of 80 people, Ksar is powered by a single foggara because of silting which has invaded other foggaras.

In addition to cleaning and periodic cleaning, covering seguiss and kasriates by rocks and clay has become an essential operation (Figs. 17 and 18).

This practice has yielded results for the foggara of Badou. It is an effective solution, but it still takes time. In case of rain, the clay is diluted in water and the material is carried by runoff. The next sandstorms accentuate the sand deposit in seguiss and galleries. The ventilation shafts exit from sand (Fig. 19).

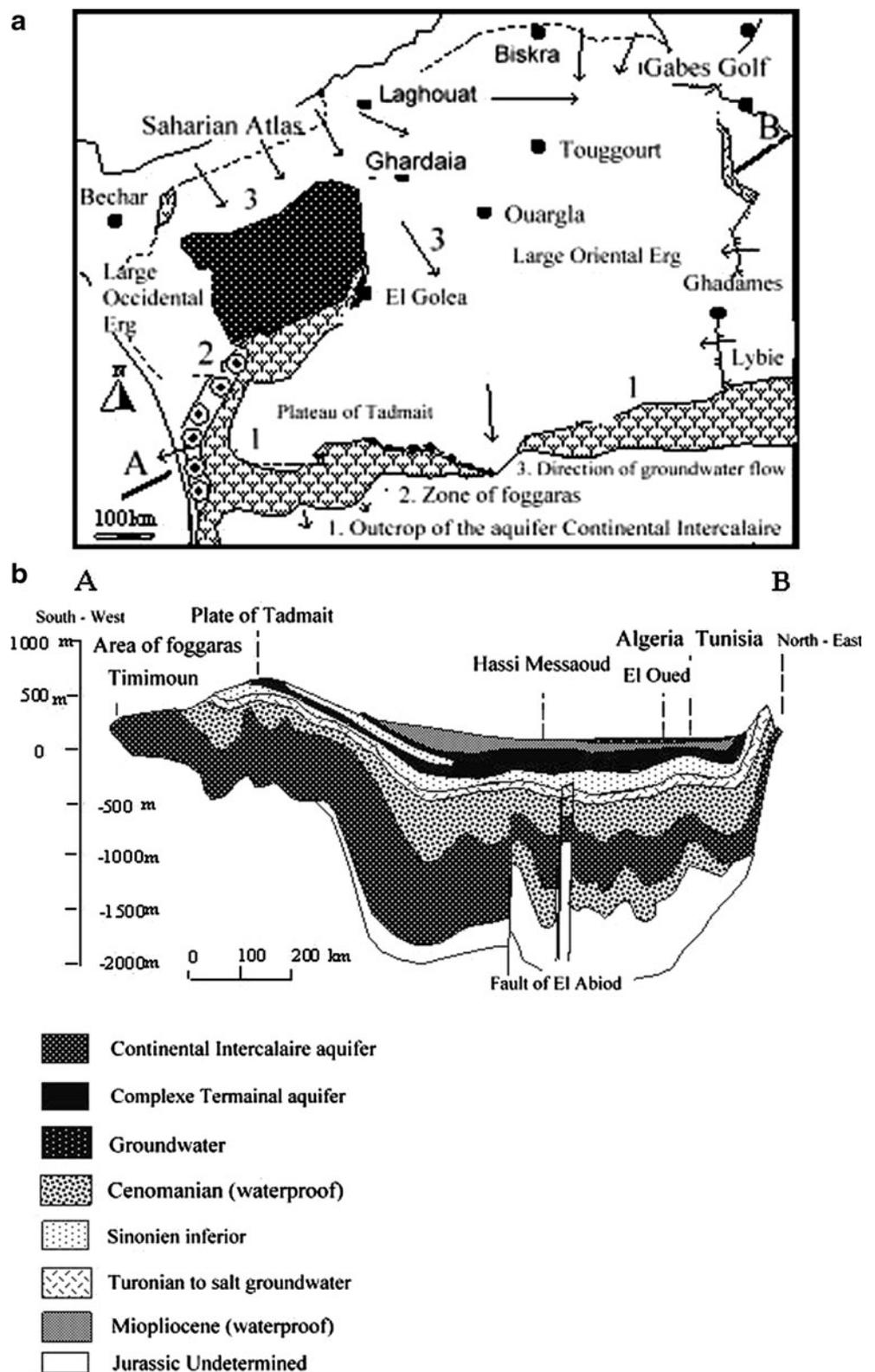
The plant, which closes the foggara

This problem affects particularly the foggaras of Erg. A wild plant locally called "Terza" grows in Erg (Fig. 20). It

Table 3 Percentage of wells located near foggaras

Distance between drilling and foggara	Percentage of holes drilled (%)
$R \leq 50$ m	13
$50 \text{ m} < R \leq 100$ m	13
$100 < R \leq 500$ m	66
$500 < R \leq 1,000$ m	8

Fig. 13 **a** Continental Intercalaire aquifer: the supply of foggara (UNESCO 1972). **b** Continental Intercalaire aquifer; sections A–B (UNESCO 1972)



represents the oasis, an indicator of the presence of sheet of surface water within a radius of 10 m. With exceptional speed, it easily invades the galleries and Segui. Several meters long, the roots of “Terza” spread smoothly to the

bottom of the sand to the galleries of the foggara. They form a true stopper in the galleries of a foggara. This causes a rapid reduction of the wet section and the flow of the foggara. Its maintenance requires the displacement of

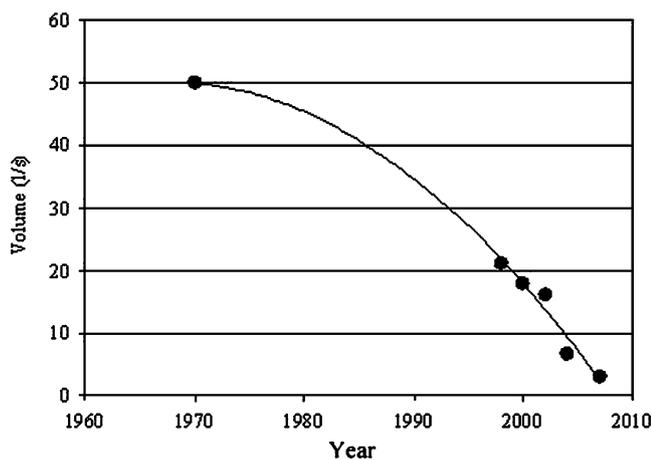


Fig. 14 El Meghier's Foggara flow evolution in time (Remini and Achour 2008)



Fig. 17 A periodic cleaning of the foggara Kasria of Badou (photography Remini and Achour 2008)



Fig. 15 Kasria secondary to the degraded state (photography Remini and Achour 2008)



Fig. 16 A portion of the network of the foggara seguia El Méghier abandoned (photography Remini and Achour 2008)



Fig. 18 Coverage of seguia by flat slabs of rock, a way to fight against sand (photography Remini 2007)

several kilometers in the middle of the huge dunes of the large Occidental Erg. Burning the plant is the only solution practiced by the oasis. A temporary solution, since a few days, the plant pushes again and again invade the gallery.

Conclusion

At Timimoun, the foggaras gradually disappear because of technical, socioeconomic, and environmental problems (Fig. 21). Unlike socio-economic problems that are common to the both types of foggaras (Erg and Albian), environmental problems are the main causes of the disappearance of foggaras of Erg. Technical problems are mainly the causes of degradation to the foggaras of Albian.

Fig. 19 Schematic of the silting of a foggara

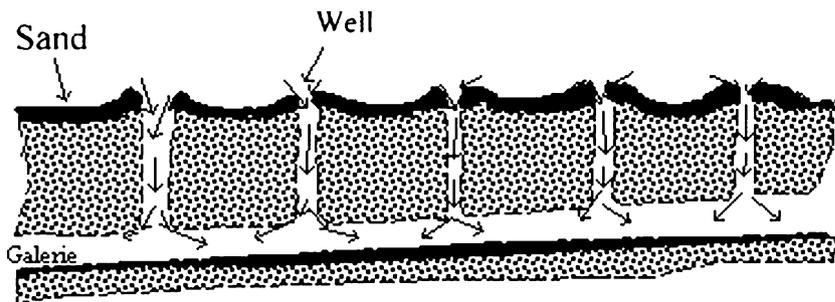
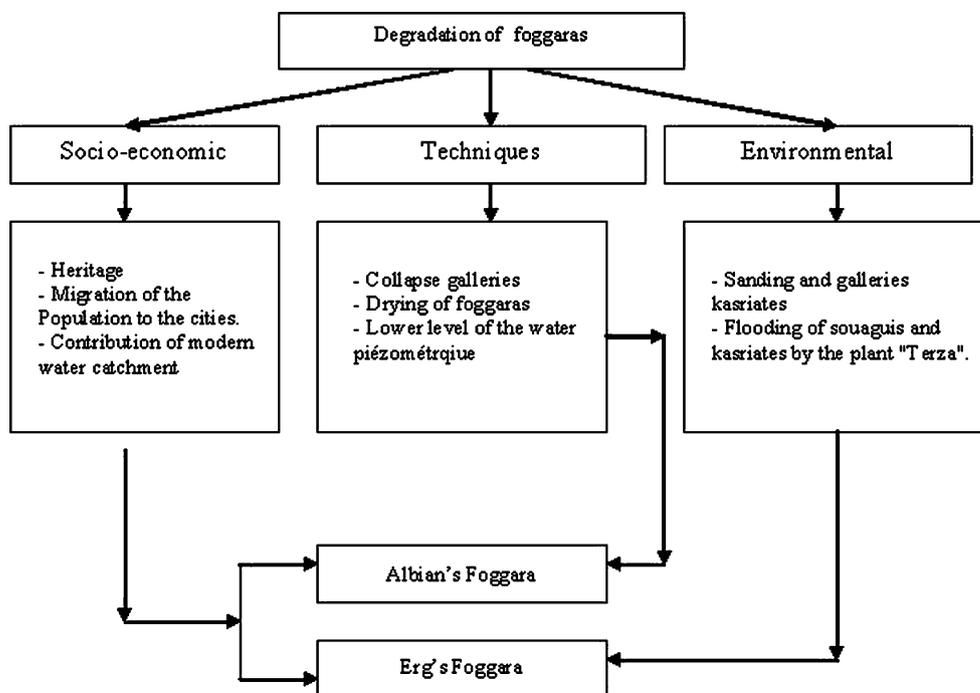


Fig. 20 Flooding of the plant “Tazra” on the length of the seguia (photography Remini and Achour 2008)

Thus eight foggaras to the oasis of Aghlad are lost below the dunes. The collapse of some sections of the gallery and the lowering of the water caused the collapse of the flow foggara El Meghier, the most foggara of Timimoun. The flood of 2003 caused the collapse of sections of the gallery of the foggara of Amokane.

Hydraulics services and agriculture have made enormous efforts for the development and reconstruction of the abandoned foggaras. This is a temporary solution since the foggara, a more technical work, is a social nature system. With the abundance and ease of acquisition of ground water, the oasis is increasingly attracted to modern techniques of water catchment, gradually leaving the traditional system. So, seeking for solutions is a social aspect.

Fig. 21 Degradation of Timimoun foggaras



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