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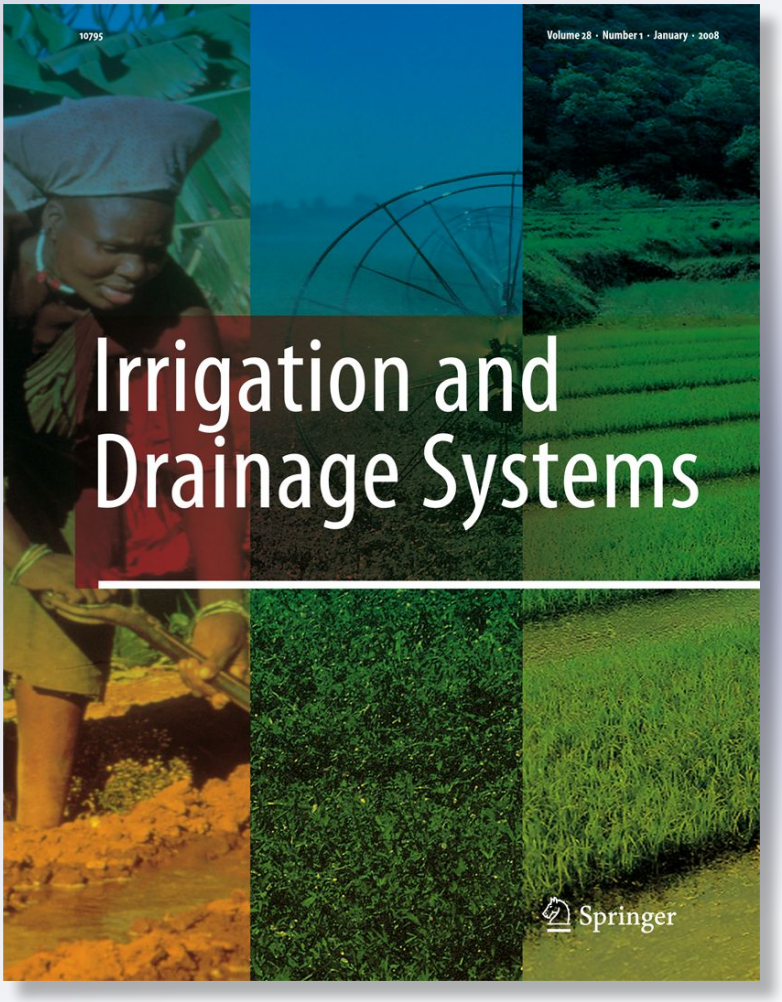

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Traditional techniques for increasing the discharge from qanats in Algeria

Boualem Remini · Bachir Achour · Rabah Kechad

Abstract This paper discusses the evolution of the foggara in time and the methods adopted by farmers to increase the water parts of owners. Field works were conducted in 2007, 2008, 2009 and 2010 in the oases of Timimoun and Adrar. Over 100 foggaras were visited. Surveys and interviews with the populations and the owners were conducted. Two ancestral methods are used by the farmers to increase the discharge of the foggara. This is an extension of part of the drainage gallery and the addition of one or more branch in the main gallery. Over time, the foggara to a single gallery evolves towards a foggara to several galleries in the form a ramified network of galleries.

Keywords Foggara · Gallery · Discharge · Prolongation · Groundwater · Maintenance

Introduction

The foggara is a hydraulic system of capture of groundwater. It consists of a gently sloping gallery, which drains the aquifer to the gardens. This ingenious system of Iranian origin it doubles with 35 centuries (Goblot 1963; Goblot 1979; Hussain et al. 2008; Kazemi 2004) has been developed in over 35 countries (Hofman 2007). Unlike

B. Remini (✉)
Department of Water Sciences, University of Blida, Blida 9000, Algeria
e-mail: reminib@yahoo.fr

B. Achour
Department of Hydraulic, Larhyss Laboratory, University of Biskra, Biskra 7000, Algeria
e-mail: bachir.achour@larhyss.net

R. Kechad
Department of Sociology, University of Blida, Blida 9000, Algeria
e-mail: rkechad@yahoo.fr

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the qanats of Marocco, which discharge renewable groundwater, the qanats in Algeria discharge water from the intercalary continental aquifer. Because this aquifer is not recharged, the discharge from the qanats decreases over time following the decrease of the groundwater level. The technical and environmental problems that contribute to reducing the discharge of the foggara. On the other part, two situations require the increased discharge of the foggara. This is the increasing number of owners and the extension of the palm.

This paper provides the solutions and the methods used by the farmers of Touat and Gourara to increase throughput foggaras.

Study sites and data used

Four Field works were conducted in the regions of Touat and Gourara in 2007, 2008, 2009 and 2010 to visit more than 100 foggaras in service. These qanats irrigate the gardens of more than 14 oases. The region of qanats is located more than 1000 km to the southwest of Algiers (Fig. 1). Interviews and investigations were conducted with the local population to understand the methods to improve the discharge practiced for ten centuries of operation. In addition to the work of prospecting on the sites, we used the data: discharge and length of foggaras of the region of the last survey conducted by the NAHR (National Agency of Hydraulic Resources) between 1998 and 2001.

These data were obtained by techniques for volumetric discharge measurement. Coordinates and dimensions were obtained using GPS. The displacements in the remote areas were carried out by vehicle type 4x4. For this type of work, a guide is indispensable.

Results and discussion

Operating principle

In its upper part (which is the party of draining situated between the points O and B), the gallery is sinking into the saturated zone of the aquifer (the gallery is located in the water) and drains water from the aquifer (Fig. 2). The flow in this case is a charge flow. The downstream part of the gallery (located between the points O and A) represents the non-draining part. It conveys water to the surface canal which distributes water between the gardens. The flow is gravity. The point O which is the meeting point between the line of saturation and the gallery. It represents the indicator of "health" of the foggara. In effect, the drainage operated by the gallery provokes a lowering of the water and the point O has a tendency to move towards the point B. When the drained flow is equal to the affluent flow, there is established a permanent flow and the point O is stable at a given position: we can say that the foggara is good "health". By cons, if the point O continues to move in time to point B, it will follow a longer of channel (party OA) where seepage reduces the discharge from the qanat. These losses were estimated between 10% and 20% of the total flow drained (Hassani 1982). In this case, the drying of the foggara is imminent. In this part, the flow is free surface.

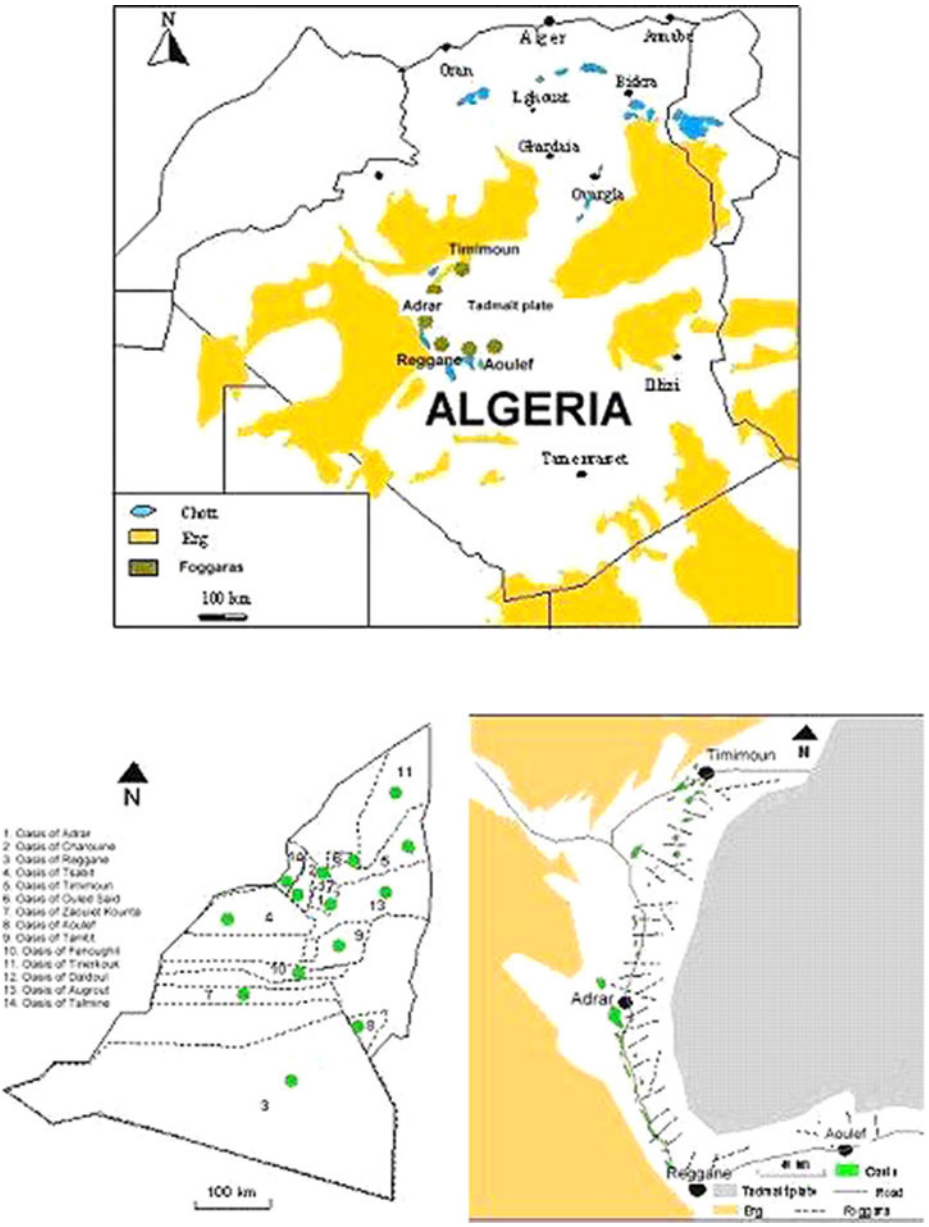


Fig. 1 Study sites

On leaving of the foggara, the water arrives until the main kasria which divided the water between the owners (Fig. 3). The water is divided and channeled through a series of channels to the clay to irrigate palm groves (Fig. 4). At different levels the palm grove; the water is again divided by other combs. The water will then be transported to the gardens with

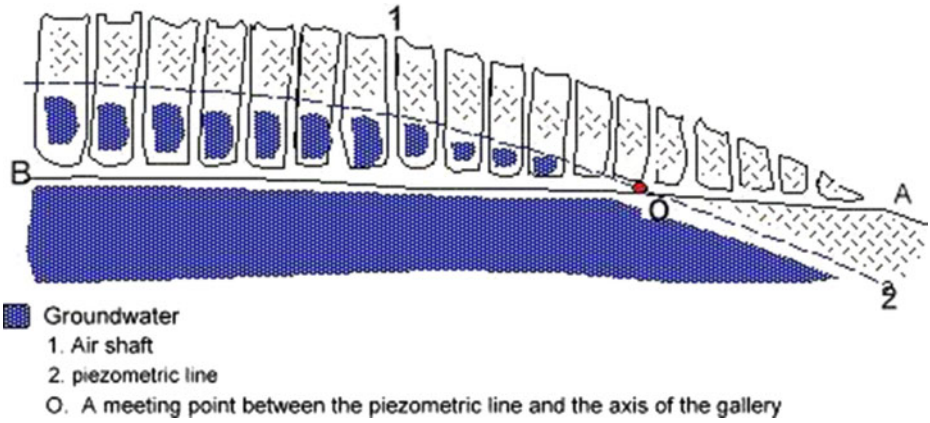


Fig. 2 Schematic synoptic of the operation of foggara

Fig. 3 Main kasria of the El Meghier foggara (Timimoun)

Fig. 4 Seguia in an oasis of Timimoun

Fig. 5 Madjen in an oasis of Adrar

small channels running through a dense distribution network whose ramifications terminate in a collecting basin called "madjen" (Fig. 5). The collection reservoir is used to regulate the water coming in thin liquid which is distributed in sufficient quantity for irrigation.

The operating principle of a foggara is based on the principle of draining.

The gallery of foggara is divided into two parts; an upstream part located within the aquifer. It is destined for the water capture (drainage length). A downstream part outside the aquifer. It is intended to transport water to the soil surface (transport length). In the case of a lowering of the water, draining the length decreases and the discharge decreases as well. The extension of the gallery drainage upstream, increases the discharge of foggara. It is from this principle that farmers have adopted various methods to increase of discharge of foggaras.

Methods to increase discharge

On the assumption of increase of the draining length, two methods have been adopted:

- The upstream extension of gallery
- The lateral galleries.

The upstream extension of gallery has been applied mainly for the foggaras of Timimoun oases. The lateral gallery is heavily used for the foggaras of Adrar oases (Fig. 6).

The method of the lateral galleries

Adding a lateral gallery is a technique adopted by farmers to increase the discharge of the foggara. When the discharge decreases with time, or increasing the number of owners, the farmers carry out the addition of one or more branches in the initial gallery (Fig. 7). The kraa is dug in a direction 30 to 45° to the main gallery.

The method of upstream extension

This method is defined as an extension of the main gallery to upstream (Fig. 8). The extension of a draining gallery increases the length of the gallery and therefore increases the discharge of foggara. This technique has been applied in the oases of Timimoun.

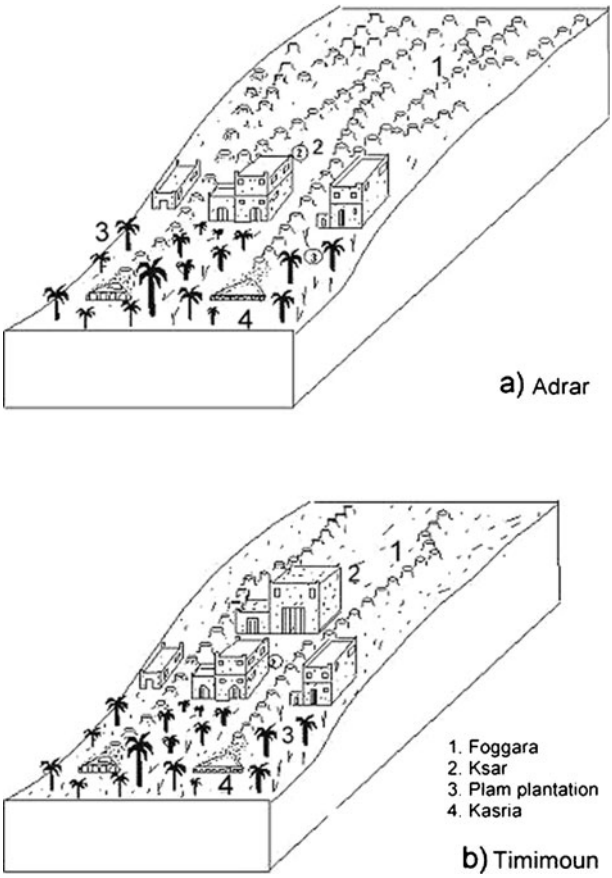


Fig. 6 Models of foggaras

The extension of the gallery for years carried on an ongoing basis. Whenever the discharge decreases, villagers add a number of wells until they found the initial rate. The operation is repeated each time the discharge decreases. Often found that the length of the extended portion of the gallery exceeds 5 times the length of the gallery mother. About 250 foggaras have suffered this technique during their operation.

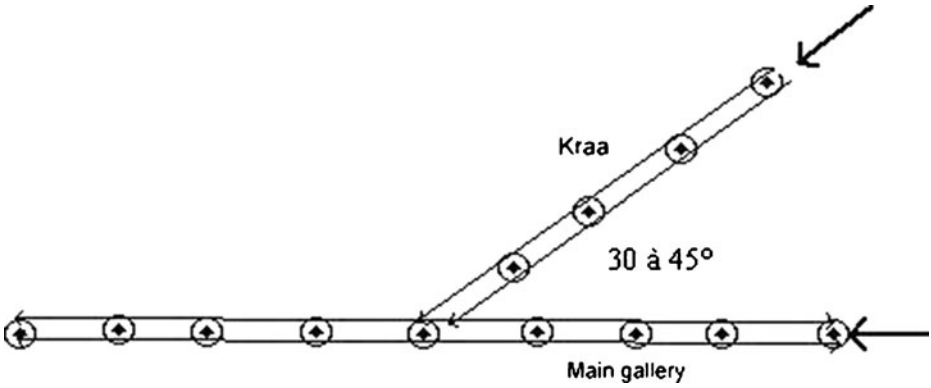


Fig. 7 Diagram of a kraa

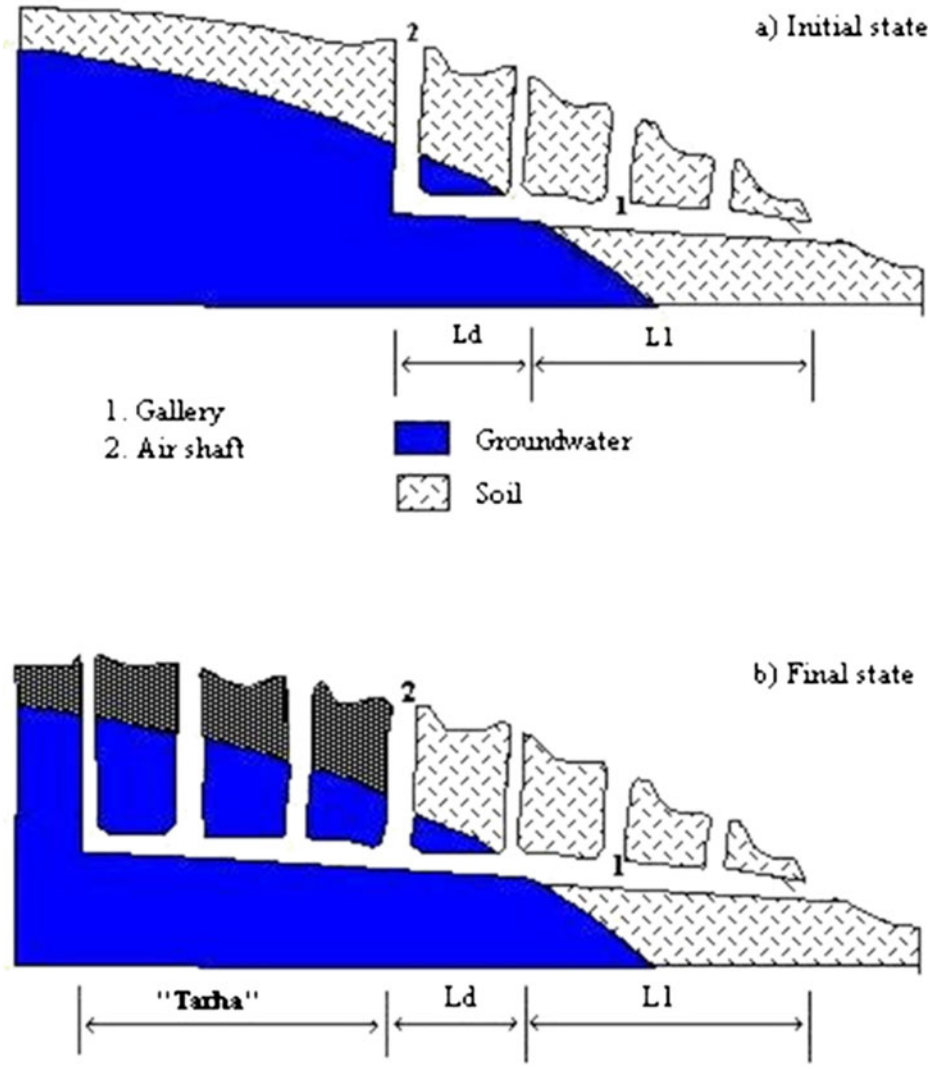


Fig. 8 Schematic of a tarha

Some examples

To illustrate these two techniques, we treated some foggaras in service. El Kebira foggara (Adrar) with a length of 7 km has undergone two operations of kraa during the period 1960–2010 (Fig. 9a). The foggara of Telgha (Adrar) whose main gallery has suffered a Kraa to face the lowering of the groundwater (Fig. 9b).

With adherence of many owners in a foggara, branch kraa increase to meet demand for water. The foggara a gallery pass a linear network of galleries. The Sidi Salem foggara (Adrar) has 4 Kraa (Fig. 10a), while the foggara of Karet Massini has a network of 17 Kraa (Fig. 10b).

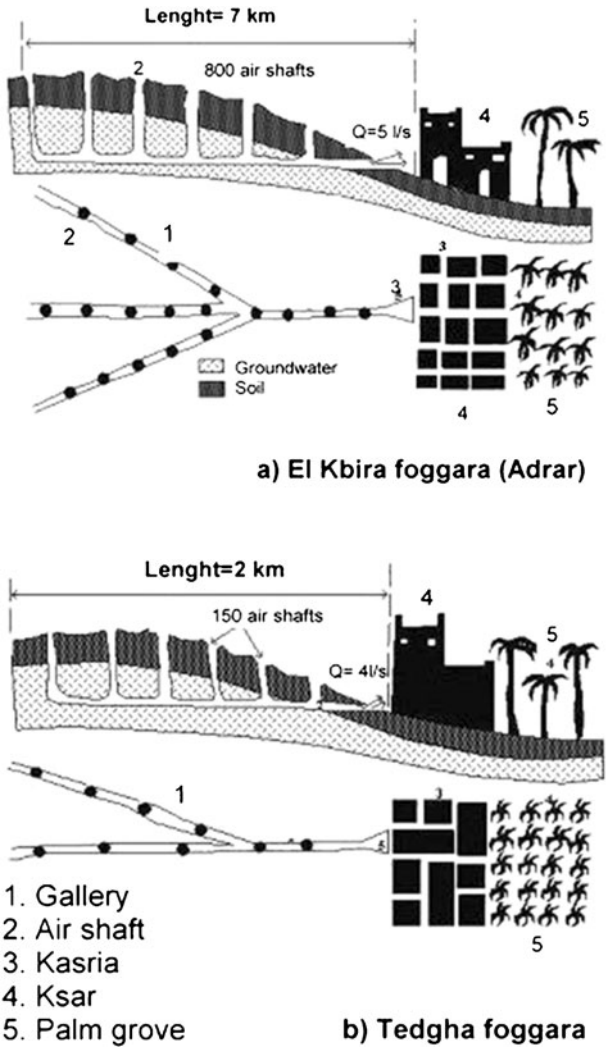
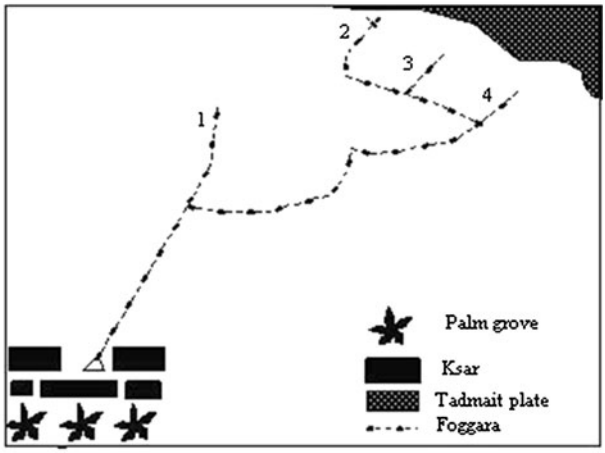


Fig. 9 Schematic of foggaras having undergone an operation of kraa

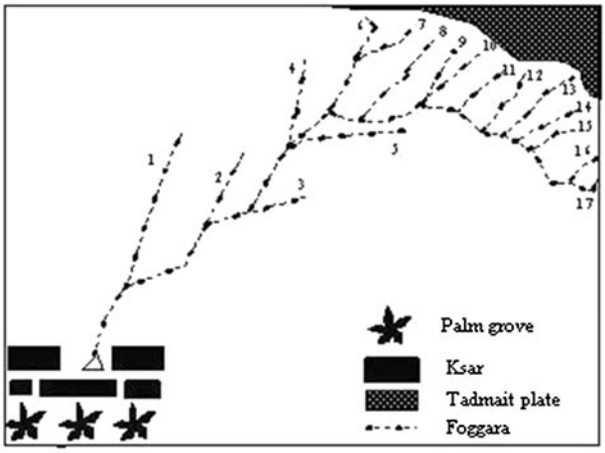
In the oasis of Regane, the gallery of the Aharda foggara has been extended since the beginning of its functioning until today with a length of 6.5 km. Initially, the foggara had a gallery of 1.5 km in length. Today, the gallery has reached a length of 8 km. The number of ventilation shafts has increased from 100 to 800 and the flow of the foggara increased from 5 l/s to 25 l/s. This extension resulted the extracting of quantity of 5500 t of soil (Fig. 11a).

In the oasis of Zaouit El Kaunta, the foggara of El Berda has a gallery of initial length equal to 2 km, equipped with 120 wells. During its operation, the foggara was subjected several extensions (tarha). Today, the gallery has reached 5 km of length and 170 air shafts. The discharge of the foggara reached 11.5 l/s. The excavation of this foggara has caused of extractions of 6500 t of soil (Fig. 11b). To increase its discharge of 8 l/s to 9.5 l/s, the farmers have prolonged the gallery of the Adrar foggara of tarha of 6 km. The gallery increased from 6.5 km to 12.5 km in length. The number of air shafts passed from 500 to 950. A quantity of 8000 t of earth was excavated by the farmers (Fig. 11c).

Fig. 10 Foggaras a several kraa



a) Sidi Salem foggara of 7 km of lenght (Adrar)



b) Karet Massini foggara of 7 km of lenght (Adrar)

Evolution of foggaras

Knowing that the Tadmait plate is the real water tower of foggaras of Touat, Gourara and Tidikelt. The Intercalary Continental aquifer rises to the periphery of the Tadmait plate. The digging a foggara is done in downstream to upstream in the opposite direction of the flow from the Ksar Tadmait plate.

The operation stops when the gallery plunged into the groundwater and the flow is judged satisfactory by the owners. Generally, one or two families begin by digging a small foggara a gallery of no more than 2 km with twenty of air shafts. As soon as the number of share-holders increases or there is an extension of the palm and even in the case of a reduction of the groundwater, the increased flow is required. In a first phase, we extend the gallery length L1 so it is again in the groundwater and is called the "tarha".

In a second phase and if the condition mentioned above is repeated, then we extend the gallery a second tarha of length L2, then a third tarha of length L3 to obtain a high discharge

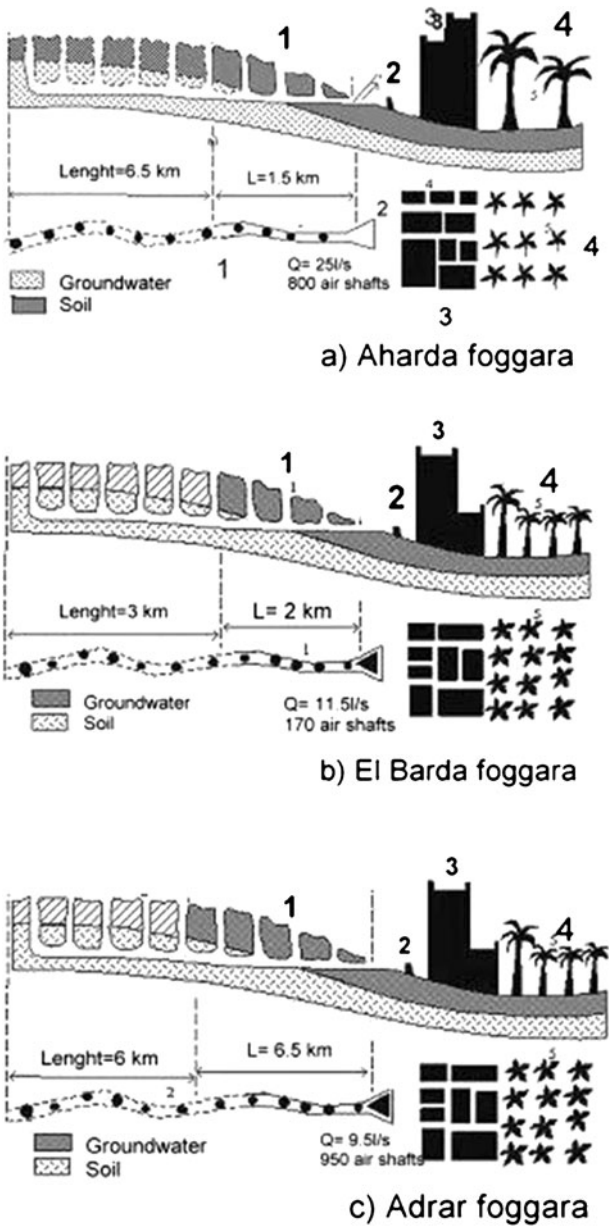


Fig. 11 Foggaras having undergone at least one of tarha

(Fig. 12). As soon as the discharge decreases, we proceed in a first phase to adding a gallery auxiliary (Kraa) and so on until one obtains a ramified network of galleries on the periphery of Tadmait plate to drain a much of water as possible.

This configuration of the ramified network is a characteristic of foggaras of oases of Adrar. In the oases of Timimoun, it is especially the tarha that is adopted by farmers. For foggaras whose gallery comes from the Greatest Western Erg, no method has been practiced following the difficulties of access amongst the vast dunes of Erg.

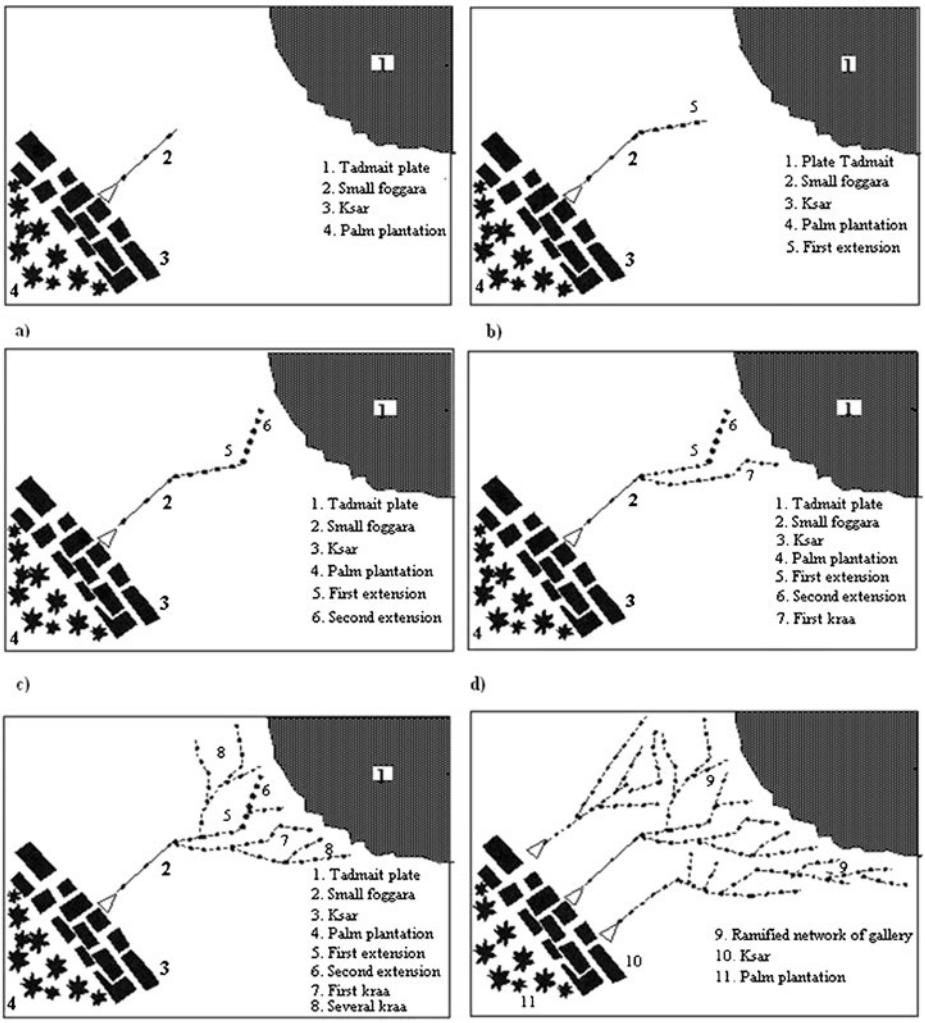


Fig. 12 Evolution of network capture of foggaras

Relationship between the Length of the gallery and the discharge of the foggara

The two techniques used by the villagers are mainly based on the extension of the gallery. So we thought it useful to examine the influence of the length of the gallery on the evolution of the discharge of the foggara. We used the inventory data from 1932 and the data from the last survey conducted between 1998 and 2001 by the National Agency of Hydraulic Resources (NAHR).

Figure 13 (a to r) represents the discharge of foggaras according to the length of the gallery for foggaras of Tmimoun and Adrar. A good correlation exists between the two parameters for the old data. This may be explained before the 30's the villagers maintain their foggaras periodically. Currently, in addition to very poor condition and poorly maintained of foggaras, the contribution of pumps and drilling has greatly influenced the discharge of the foggara.

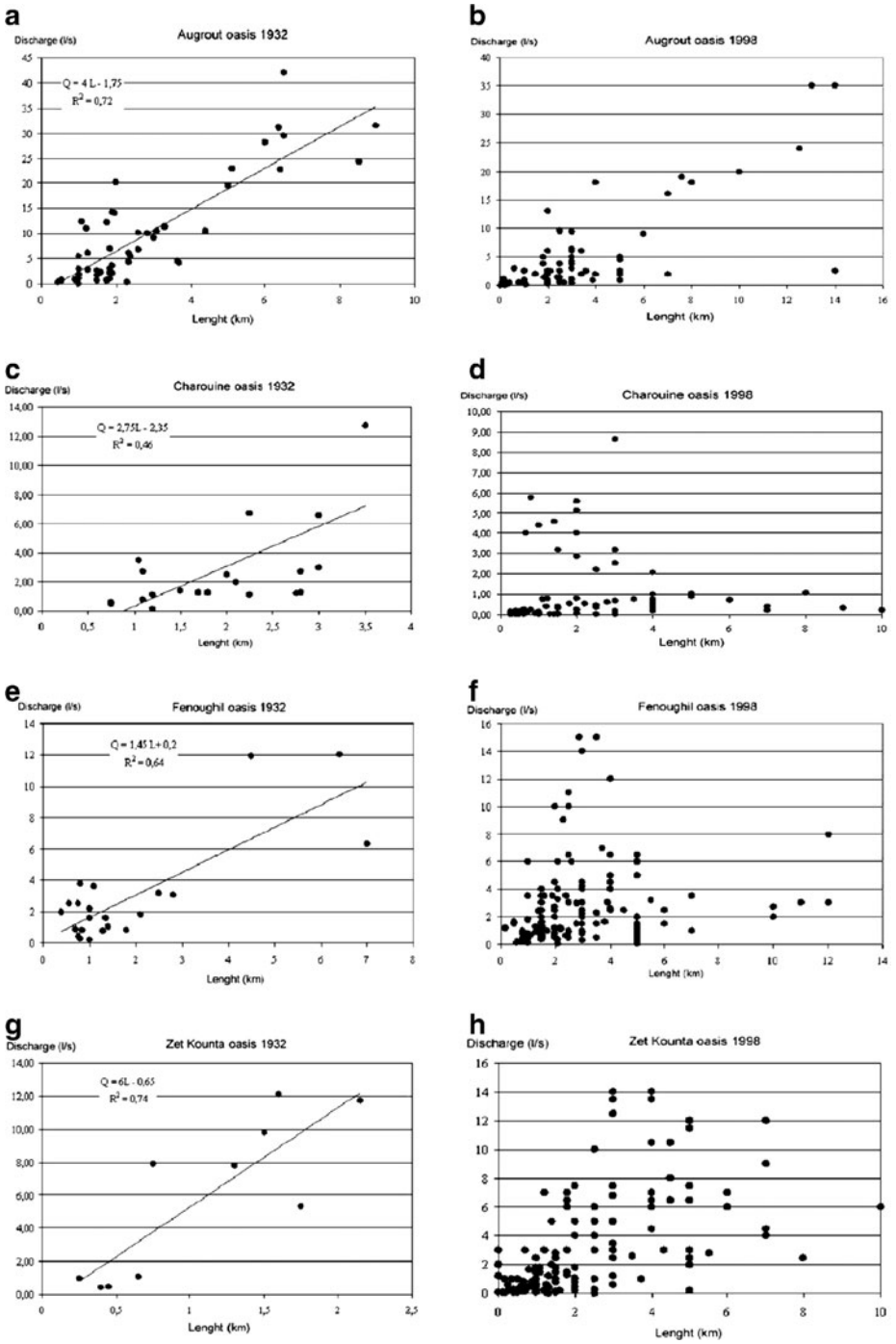


Fig. 13 Related: Discharge—length of the gallery of the foggara

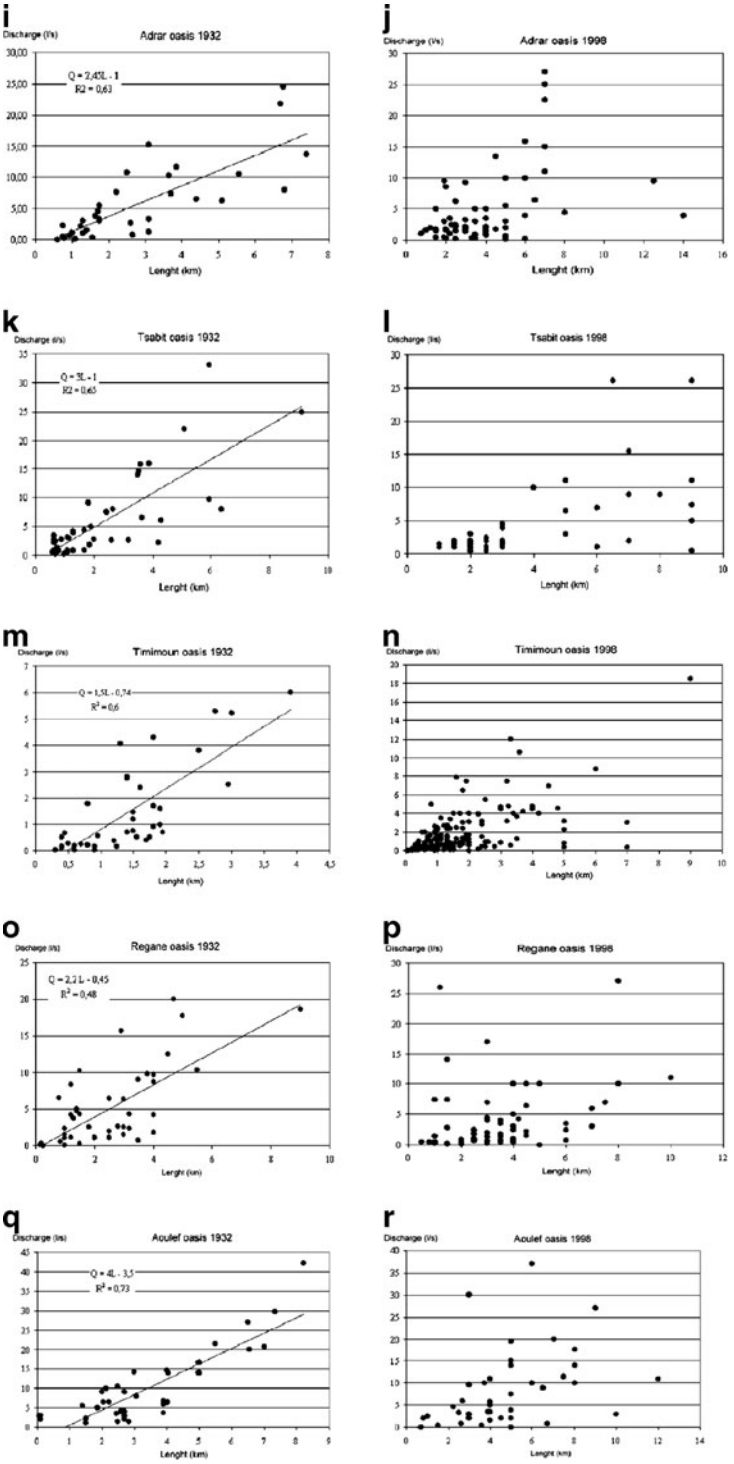


Fig. 13 (continued)

Conclusion

It appears from this study that the villagers of oases of Timimoun and Adrar were able obtain the water through the foggaras they have developed over 10 centuries. They have learned to manage water and its equitable distribution among the population during the difficult periods. For various problems (technical, environmental and social) of the foggara, the discharge decreases over time. The villagers have adopted two methods to increase the discharge: the extension and the addition of new galleries at the initial drain. The foggara develops continuously over time. It evolves from one gallery to a ramified network of galleries.

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