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Traditional Techniques of Underground Water Catchment in the Algerian Sahara

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NM and MIH designed the study and wrote the first draft of manuscript. Authors NM and MD managed the literature searches. Author NM wrote the final version of the manuscript. All authors read and approved the final.

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ABSTRACT

In desert regions, the water constitutes an indispensable supply to every human, animal or vegetable life. In the Algerian Sahara, where underground waters are the main exploitable hydric resources, saharian agriculturists make use of several traditional catchment processes.
The first process corresponds to the "Ghout" technique. It is spread in the sandy dune region (erg) of El Oued. Agriculturists create their palm groves at the center of large concentric basins, dug so that the artificial topographic elevation is brought to one meter or less above the water table.
The most usual means to get the water up is still the traditional well (hassi), dug by hand. Its construction and its exploitation do not lead to particular problems, nevertheless, these ordinary wells are badly adapted to reach confined aquifers, especially artesian aquifers. However, well-diggers of Oued Righ took up the challenge, by digging real artesian wells with rudimentary tools.
Another original process of underground water catchments that has been well developed in the Sahara is the digging of "foggaras". This method takes advantage of natural topographic declivity of the ground and the piezometric surface in order to bring the aquifer waters to the surface. The water flows by simple gravity through sub-horizontal draining galleries that lower upper part crests of underground water tables. The water exploitation

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by these different techniques is a good example of mastery and rational use of natural resources. Today, in strong competition with modern drillings within great pumping discharges, these techniques are fast disappearing. Nevertheless, through new know-how contribution and by adapting modern techniques, these patterns of catchments can make an important contribution to ensure the durable use of water in these arid regions.

Keywords: Sahara; groundwater exploitation; ghout; artesian well; foggara.

1. INTRODUCTION

For centuries, agriculturists of the Algerian Sahara have redoubled ingenuity and technical expertise to find solutions more adapted to underground water-catchment. For this purpose, they have been inspired by the observation of their natural habitat. They used the site and the topography to their own advantage without damaging the environment.

According to hydrogeological contexts, different techniques of water-catchment coexist in the Algerian Sahara (Fig. 1) ; the most important are : "ghouts", artesian wells and "foggaras".

To reach the contiguity in space between the underground water and plant roots extremities, two traditional processes are possible: The first process consists in getting the roots down in order to bring them closer to the water table, the second consists in getting the water up by drawing it [1].

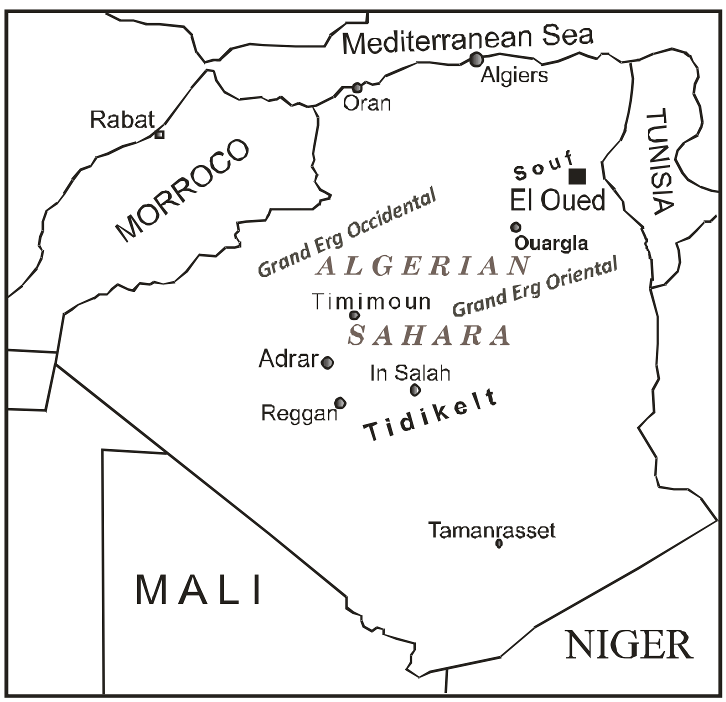

Fig. 1. Algerian Sahara location

In all cases, saharian populations have drawn a lesson from the observation of their natural environment and have thus applied what they learnt by imitating the nature and sometimes by improving on it. By persistent and long hard work, they have been able to fertilize an arid environment, which is scarcely propitious to an agricultural ecosystem development. They did not practise excessive irrigation because these water resources were limited. They caused neither erosion nor salinization of cultivated soils. Without this know-how of local populations and without balanced management of their natural environment, the Sahara would have probably remained at the neolithic stage.

In this work, the principles of functioning of these various ancestral catchment systems, perfectly adapted to the Saharan region, are given. The main objective of this study is to highlight the advantages of each of these exploitation techniques in the water use and management and the importance to protect them.

2. THE "GHOUTS" TECHNIQUE

The Ghout technique is a process of "dry culture" that does not require irrigation. Palm trees are directly planted above the aquifer, putting in direct contact the roots with the water-table level. This process is well represented in the region of El Oued (also called Oued Souf) (Plate 1), and North of the Oriental Erg, close to the Tunisian border (Fig.1).

The Souf (El Oued region) is constituted in surface of great sandy dunes of the Oriental Erg. It counts more than 9000 ghouts among which approximately 900 were destroyed because of the rise in water levels [2]. The buried palm groves are scattered in groups of 20 to 100 palm trees in the center of large concentric basins dug by man, reaching 10 meters of difference in level, in such a way that the artificial topographic elevation, has been brought to one meter or less above the ground water table. The soil is progressively dug so that the palm trees have constantly their roots in water, and therefore do not need irrigation (Fig. 2).

Plate 1. A Ghout View in El Oued [3]

When the agriculturist creates his palm grove, he first surrounds it by an artificial dune fixed by stones of gypsum and palisades in djerid (dry palms). As he digs, shovelfuls of sand will form a protecting wall surmounted by another hedge of dry palm leaves. Once the big works are finished, he have to carry the sand from the bottom to the top of the crater in a permanent way, covering a distance of 80 to 200 meters, and to block the sand flux by several dams of palm leaves.

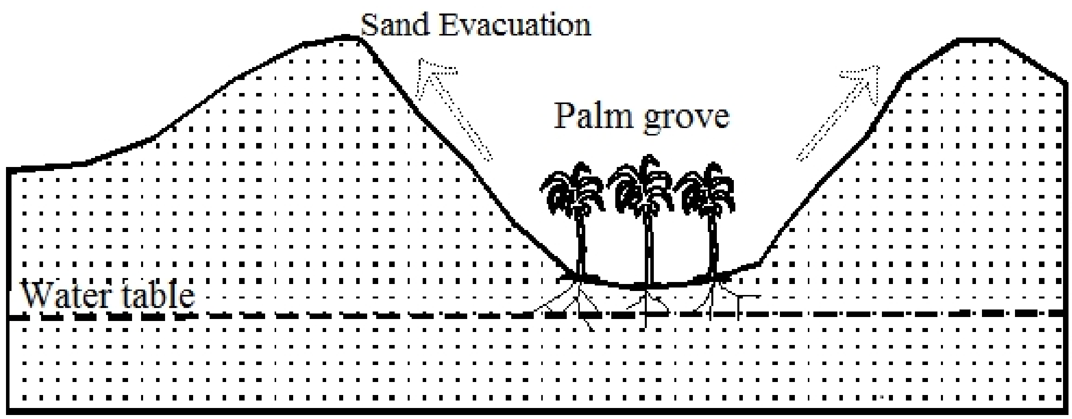

Fig. 2. The Ghout Principle

The principle of the "ghouts" is simple and has the advantage of reducing the evaporation but it requires important earthworks for a really very reduced cultivated surface and a permanent upkeep, otherwise, it is the death of the small palm grove through sanding up.

In 2006, the Food and Agricultultural Organization (FAO), decided to classify "ghouts" of the region of Oued Souf as a universal heritage.

3. WATER-CATCHMENTS BY WELLS

The usual means to get the water up is the traditional well (localy called ″hassi″ or ″bir″) (Fig. 3). Its depth can be very variable, from some meters up to several tens of meters. The ordinary wells, dug by hand, have been used for thousands of years. They are easy to construct and both their construction and their upkeep can be assured by little specialized labourer. They constitute a source and a reservoir of water at a same time.

Currently, the ordinary wells are more and more replaced by modern drillings, more costly, but they can reach bigger depths. In fact, the ordinary wells are often more adapted and used, for example, in the case of shallow groundwater with a weak output, and for inaccessible regions where the drillings material transport is a problem.

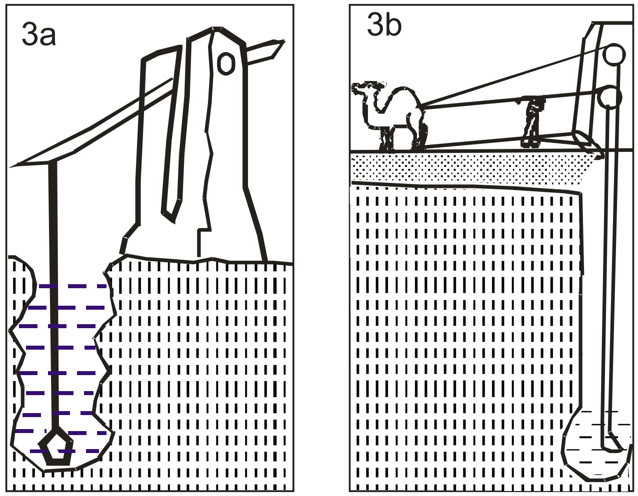

Fig. 3. Water catchment by traditional wells
3a:beam well used for shallow water-table3b : well used for deeper water table

The ordinary wells include, nevertheless, some drawbacks

The drilling technique is known, but the well coating art is in regression. The coating protects against collapse and prevents polluted surface water from penetrating in wells.
These wells are badly adapted to reach confined aquifers, especially, artesian ones (Fig. 4). These groundwaters are contained in aquifers, stored between impervious geological layers, disposed in such a way that the pressure pushes out the water as soon as the well reaches the groundwater [4].

All ordinary wells drawbacks have been remarkably overcome by the corporation of the well-diggers of Oued Righ (valley located to the Southwest of El Oued). They have made real artesian wells with rudimentary tools. This drilling technique seems to date back to the tenth century [5].

Probably inspired by the view of shooting springs, the local well-diggers dug wells that could reach a depth of 80 meters. The necessary installation for the digging operation consists in the setting up, in a firststep, of two vertical wooden uprights on the site where they intend to dig the well.

These uprights are joined in their superior part by two crosspieces with a fixed wood wheel between them.

A cable plaited with the woody fibers of the superior part of the palm coils up on the wheel. It is used to bring workers up and down and to extract matters and to exhaust water.

Only one worker works at the bottom of the well, crouching down.

The height he occupies in this position serves as a term of comparison to appreciate the depth of works; this unit called "kama" is equivalent to a cubit and quarter or 1,625 meters.
To dig the wells, a kind of hoe with a very short and tilted handle is used [6].

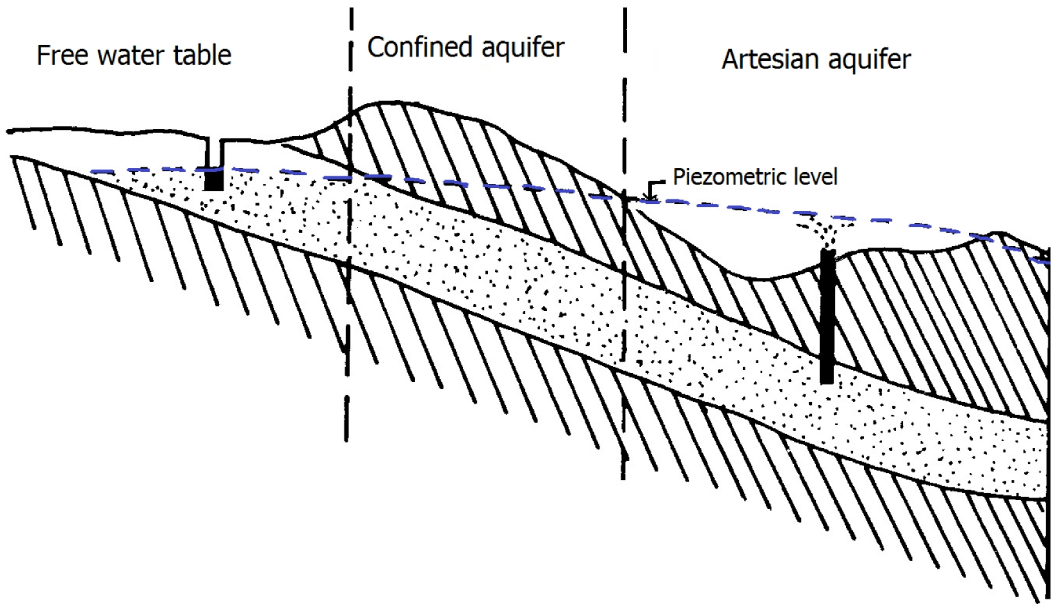

Fig. 4. Different kinds of aquifers [4]

According to local populations, "to reach the water table, they go through five varieties of rocks called:

"Es–Sbah", earthy gypsum that forms vicinities of Touggourt;
"Et–Tin" or "Et-trab", reddish yellow marly rock, coating gypsum crystals;
"Et-Tizaouin", mixture of siliceous sand, plaster and clay with arenaceous structure;
"El-Hadjer", gypseous rock, reddish and compact;
"El-Mazoul", a greenish white rock, very compact and very greasy, surmonting the sandy aquifer".

It is at the superior part of Et-Tizaouin that well-diggers meet two briny and fetid water tables. Sometimes, they are so abundant that workers stop digging; but they usually cross them by placing behind timber frameworks, a trimming axe formed by clay and dung mixed in suitable proportion and then, the digging operation continues without obstacle until they reach the aquifer.

Wells are timbered as far as El-Hadjer layer, usually reached between 30 and 40 meters, further down. The boxing is done by specialized workers. They split wood and put the framework down in the well. It consists of a series of wooden palm trees frameworks, joined in six. Nine to ten frameworks are put down to one meter. These boxings, carefully established, go down until they reach the gypseous bank beyond which they can continue without timbering [5,6].

In order to be able to work, the well-digger of Oued Righ must remain attached to the cable and blocks his ears with goat grease. While the water springs up, the labourer makes asignal and he is immediatly brought up to the soil surface. Sometimes, the water gushes out with such force, that it does not allow to pull the worker out of the well and he is asphyxiated. For this purpose, this final work is often reserved to the most senior of the corporation who, sometimes, lose his life.

But the water often arrives slowly, carrying an important proportion of clayey sand that obstructs the bottom of the well, covering a hight of about 4.5 to 6 meters. Il was necessary for divers to go in the dark and with apnoea under the pressure of several tens of meters water column, in order to clean the well basis by clearing this sand away with buckets as rapidly as possible.

In spite of modern well drillings techniques, this digging way continued until the beginning of the seventies.

4. WATER CATCHMENTS BY DRAINING GALLERIES OR "FOGGARAS"

Another original and remarkable process, for bringing up water to the surface, made great strides in the Algerian Sahara : It is the digging of "Foggaras". To avoid laborious work of drawing water, Saharian people sometimes dug, when the relief allowed it, underground catchments' galleries that conduct water to their oases.

Three thousand years ago, Perses already mastered the technique of draining galleries "quanats" (Semitic word from which the word "canal" derived) to bring the water from mountains to arid plains [7-9]. This system of draining galleries is found in a geographical area going from Pakistan to Morocco. They are also signalled in Spain and in the south of France. They have different names: Khirras in Pakistan and in Afghanistan, Falaj in Arabic Emirates, Ngoula or Friga in the south of Tunisia, Khettaras in the south of Morocco, Chegga in some regions of the southeast Algeria etc. [10] (Fig. 5).

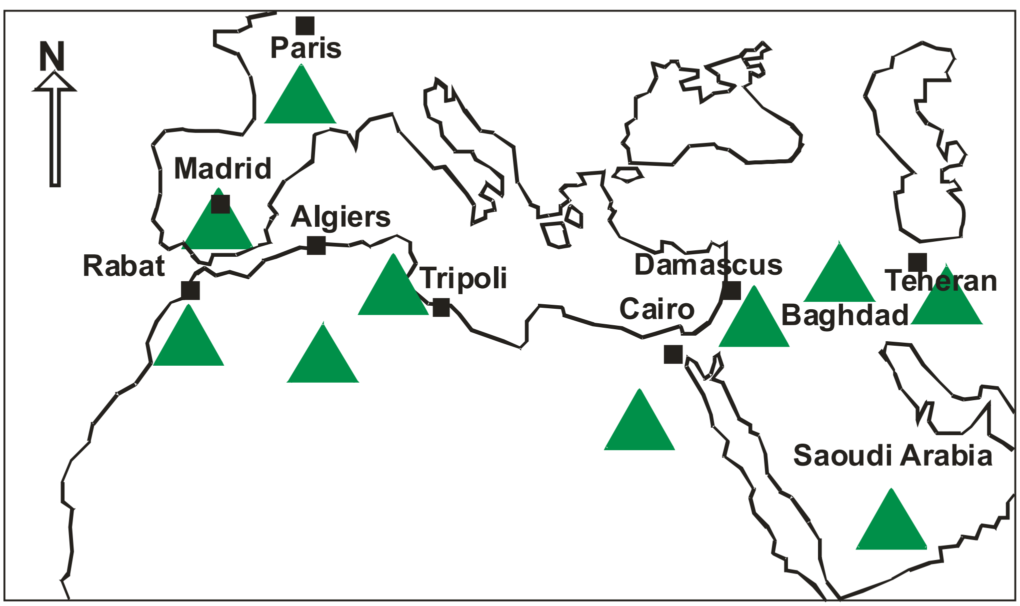

Fig. 5. Map location of draining galleries system

"Quanats" (Iran) ; "Khirras" (Pakistan & Afghanistan) ; "Falaj" (Arabic Emirates) ;
"Ngoula" or "Friga" (Tunisia) ; "Khettaras"(Morroco) ; "Viajes" (Spain)

Etymologically, the word "foggara" would come from the arabic verb "Fajjara" that means "to make gush" the water.

In the Algerian Sahara, foggaras are spread in the North Central and Occidental Sahara Oases. In the "Touat" (region of Adrar), the "Gourara" (region of Timimoun) and the "Tidikelt" (region of Reggan, In Salah) (see Fig.1 above for the location of the quoted regions), oases almost exclusively fed by foggaras that served the several palm groves.

The foggara functioning was perfectly understood by the past [11]. The foggaras' antiquity reputation is justified by their downstream side: Local populations affirm that at the beginning, the foggara was only an open trench: We often find traces of this trench stowed on a ceiling made of sandstone tiles: Towards the upstream side, the trench depth increasing, it became more advantageous to work in galleries. For this purpose, the technique of the local population has not changed for four centuries: At about 10 m upstream of the gallery's head, a well is dug down up to the water table aquifer is reached; then, two workers work, one prolonging the gallery upstream, the other starting from the new well and meeting the first one downstream: Passageways sinuosities, sometimes enormous, show the topographic mistakes of drillers [12].

The foggara principle is simple and audacious at the same time. According to the hydrogeological context, the presence of a relief provokes an inflection of free-water table piezometric profile of local aquifers whose exsurgences go towards depressed areas (Fig. 6). Taking advantage of the natural topographic declivity of the land, some sub-horizontal galleries are going to drain water by gravity, from the aquifer zone situated under reliefs, upstream, to the driest grounds, situated downstream, towards the palm grove.

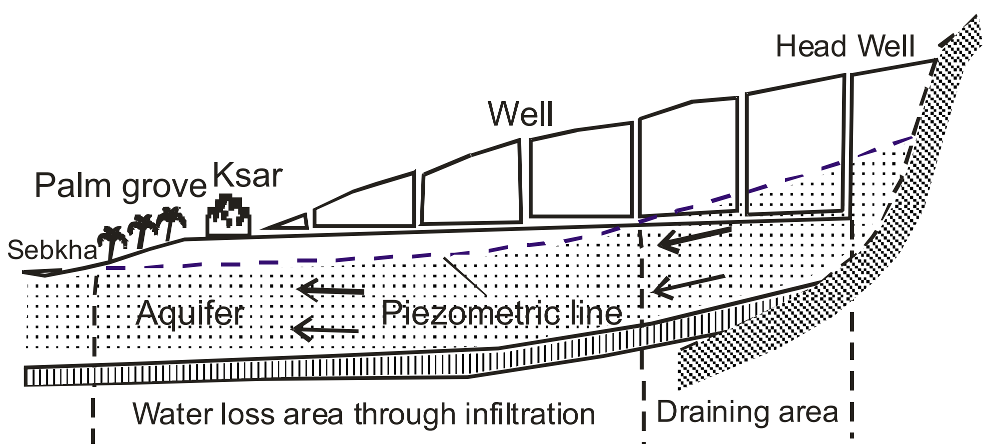

Fig. 6. Diagram of a foggara working

The foggara digging is possible only if the water table roof coast is higher than the one of the zone to irrigate. The length of galleries varies considerably according to the depth of the water table and the land slope.It varies from hundreds of meters to 40 kilometers sometimes and must have a weak and constant slope (0,3% in mean). From downstream to upstreamn, foggaras were constructed from wells at wide intervals of about a maximum of twenty meters (Plate 2).

Plate 2. Foggaras wells at the town center of Adrar [13]

Well-diggers went down the first two wells and made an underground junction and so on with the other wells until they reached the aquifer layer. There, began the draining part of the foggara and it continued until the discharge was sufficient or that the growing depth of wells did not permit to go further technically. When the foggara was finished, wells were not filled up and served as they always do to ventilation and upkeep [11]. Indeed, it is necessary to constantly clear away the drain by hand and to bring up the various remains, otherwise, the foggara chokes and dries up (Fig. 7). If, in spite of the upkeep, the discharge decreases by normal lowering of ground water level, three processes can be considered :

Whether to lower the gallery level, which entails a displacement of gardens downward the depression.
Or to dig, when it is still possible, new wells upstream and to lengthen the foggara.
Or to dig confluent annex galleries so as to feed the main conduct.

The underground water catchment method by foggara has several advantages [13]:

* It insures a modest but regular discharge.
* Water does not evaporate.
* The chore of drawing water is suppressed.

The foggaras solve a problem of water quantity and quality, because in addition to mobilize an important discharge that would have decreased in the loss area through infiltration, they also allow the catchment of a less saline water. Indeed, in arid and semi-arid regions, free-water tables are increasingly mineralized, from upstream to downstream. In depressed areas, the free-water table is less deep or outcroping (sebkha); its evaporation is then very important. This entails a notable increase of the water mineralization [14].

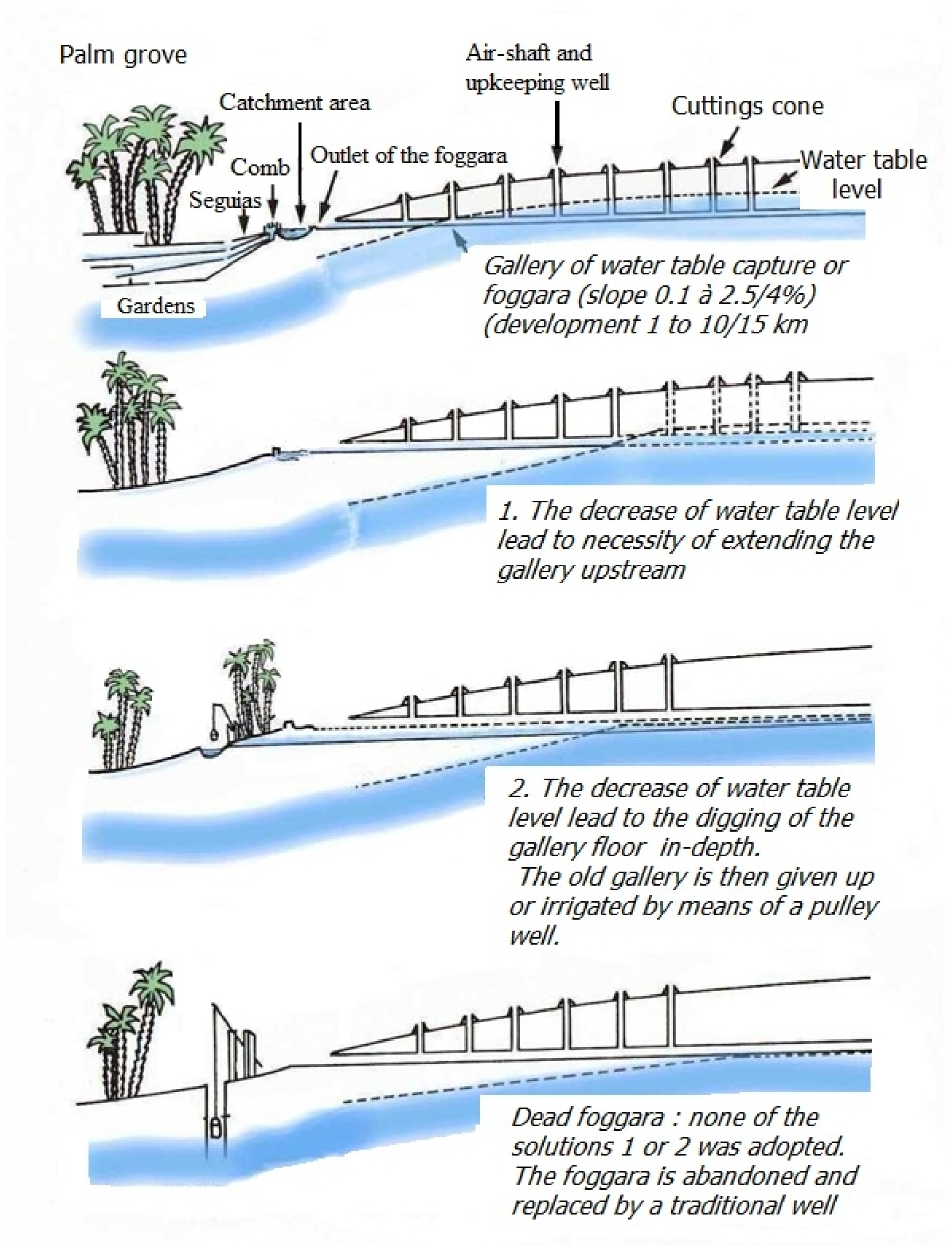

Fig. 7. A foggara evolution steps [15]

The foggaras have nevertheless some disadvantages:

a. The investment in work is colossal : To dig a foggara of 4 kilometers with an average depth of 12 meters requires approximately 4800 working days/ man. The working conditions of minors were very hard : They worked groping their way down, folded in two in these narrow trenches, drilling with shovel and pickax, ascending the sand in baskets. In addition to that, accidents caused by slides were very frequent.

b. They transport water all the year long, without stopping. Thereby, water that is not used is lost. The maximum discharge is during the rain season, when the water requirements for irrigation are minimum, while during the main irrigation period (The Summer), foggaras can give no water during the years of drought.
c. Instead of watering upstream lands, the foggaras serve downstream lands, where soils are often more poor and saline.
d. Foggaras' upkeep and cleaning require constant, difficult and tedious care. In 1960, 500 working days by kilometer of gallery were necessary to insure this upkeep.

The foggara's water quality is often less good than wells water, dug further up.

Today, no new foggara is dug but the local population continues to upkeep, and sometimes to prolong the existing ones. Nevertheless, as the standard of living improves, it is more and more difficult to find workers for such ungrateful and dangerous work of digging and upkeep. Also, a number of galleries are sometimes abandoned, fallen down or obstructed, allowing only a thin runnel of water [15].

We can notice that this decrease of discharge is only partially due to the lack of upkeep. It is the important water pumpings, done by modern drilling wells established upstream the foggaras that dragged this meaningful decrease of discharge. These drilling wells on which is based the modern saharian agriculture cause a big waste of water resources and often a deterioration of the soil quality by salinisation [14].

5. CONCLUSION

Secular methods of underground water catchments in the Sahara constitute a good example of mastery and a very rational utilization of natural resources. The ingenuity of local populations in the perfecting and the development of these water catchment techniques has allowed to restore the life to one of the most arid regions of the globe, in an area where all the elements are against it: almost nonexistent rain, excessive temperatures, violence of winds and invasion by sand.

Currently, witness depreciation of local know-how that seems to be little effective on a technical plan can be noticed. Nevertheless, they ensure quite good solutions to delicate problems.

Hydraulic practices adapted to temperate climates and developed countries cannot have the same success in arid regions and developing countries for technical, economical, ecological and cultural reasons. For this purpose, innovative techniques in water technology domain must be developed for arid and developping countries. These techniques should be inspired from traditional methods that had been well-tried for centuries, by improving them:

a. By combining for example, directional and horizontal drilling terchnology with water exploitation by foggaras, using tight and resistant water pipes in the galleries to avoid the crushing and earth slide, as well as constant upkeep.
b. By the construction of subterranean small dams, where possible, which reduce water-table undertow evaporation which is very important in arid regions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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