The Qanat as a Crucial Antique Water Acquisition System Common to Arid Zones’ Communities: Two case Studies, Foggara in Tunisia and Falaj in Oman

Dipl. Arch. Feirouz Megdiche,
Senior Lecturer, Department of Design, College of Applied Sciences - Nizwa
611Nizwa- Oman
PhD student, Research Unit «Horticulture, Landscape, Environment»
UR13AGR06. ISA-IRESA-University of Sousse, 4042 Sousse- Tunisia

&

Dr. Mohamed Moussa
Associate Professor, Global Desert Technology (GDT) Expert, Institute of Arid Regions, 4100 Medenine - Tunisia

Abstract

Water, the first mirror of the man who reasons, was considered at the dawn of the Greek philosophy as the origin of all things. Across the times of the landscape, societies have attempted to control this material necessary for their existence and proliferation. In its quest for water, man has built the most spectacular of systems: the qanat. This system represents one of the rare ancient procedures of water acquisition succeeding to overcome the rainfall's rhythm in arid zones. This key attribute elucidates the considerable expansion of the technique in the Near and the Middle East and its exportation to North Africa which assured the survival of generations in harsh climatic conditions. This paper highlights the existence and use of this antique system of water acquisition in Tunisia and in Oman in the light of new challenges including climate, environmental and social changes. In fact, the two countries share, to different degrees, a main ground and surface water supply technique: the qanat; known as foggara in Tunisia and falaj in Oman. This paper explores the present situation of the system in both countries besides its near future and the ways considered for its preservation as important cultural heritage.

Keywords: Water, heritage Infrastructure, qanat

INTRODUCTION

From the prehistoric period to the recent centuries, societies have been trying to control and manage water throughout diverse processes which are the fruit of man's genius in dealing with his geographical context. On the Nile River, at Kosheisk, was built the earliest recorded dam about 2900 BC to supply water to King Menes’ capital at Memphis. Dams were also edified by the Assyrians, Babylonians and Persians between 700 and 250 BC ("Ancient Dams," 2005: 358). In the South-West of the Arabic peninsula, hundreds of dams were found including the very famous and most gigantic of all: the dam of Ma’rib (Costa, 1983: 274). The Greeks constructed aqueducts in the mid 2000 BC. The Romans in their turn edified a series of aqueducts in Tunisia, 13 are still existent. They also made cisterns that became part of the water supply and irrigation solutions first found in situ then adopted by the Arabs when they conquered North Africa (Mazot, 2007: 136). Inspired by the Roman and Byzantine period, the Arab engineers constructed in the 9th century and under the rule of the Aghlabids impressive works of hydraulic engineering including circular pools in the city of kairouan: the fasqiya. (Mazot, 2007: 137).

Besides, on earth water is distributed unequally: rain is insufficient on about half the earth's land which includes most of Asia and North Africa, Central Australia and the Middle East ("The water Supply Problems," 1991: 122). In such arid zones, man had developed the most spectacular procedures of water acquisition to overcome the rainfall's rhythm and assure his survival: the qanat which used to be the main water resource for people specifically in rural communities.

GENERALITIES ABOUT QANAT
Its diverse appellations according some world regions

“The Arabic word qanat meaning “lance” or “conduit” is used in Iran, the Persian term kariz is used in Afghanistan, while in Syria, Palestine, and North Africa Fuqara is the most common term” (English, 1968: 170). Also in North Africa, the system is known as Mkayel or Mkoula (Moussa M., 2005) and Khettara in Morocco (S.Yazdi & L.Khaneiki, 2010: 177). In Madrid (Spain), it is called “viajes de agua”; In Italy they use the term “ingruttato” and in Oman falaj, plural aflaj, which means the small river (S.Yazdi & L.Khaneiki, 2010).

Description and Mechanism

Qanat is described by Beaumont as “a method for developing and supplying groundwater and consists of a gently sloping tunnel (...) which leads water by gravity flow from beneath the water table at its upper end to a ground surface outlet and irrigation canal at its lower end” (Beaumont, 1971: 39). The cross section of the underground tunnel presents generally an elliptical shape with approximately 1.2 metres height and 0.8 metres width (Beaumont, 1971: 40). To insure ventilation for diggers while excavating these tunnels and to facilitate the spoil’s removal, a series of vertical shafts are elaborated along the tunnels’ course. The shafts are spaced every 50 to 150 metres (English, 1968: 170). The tops of the shafts (0.7 to 1.0 metres in diameter) are elevated upon the ground surface and strengthened by mud lining (Beaumont, 1971: 40). Smith also describes the qanat’s shafts in Iran, he writes: “At the top of each shaft a mound is formed which gives the land above a qanat its characteristic appearance. These shafts are also used when repair work or removal of silt is being carried out (...) As there are shafts along the length of the qanat and as the water eventually flows out of its lower end, the depth of the shafts lessen towards the exit” (Smith, 1953: 57).

Plate 1: Illustration showing the qanat system (falaj) and its use (Source: Oman Geologic Heritage)

History of qanat: its origin and spread

“Subterranean tunnel-wells (qanats) are extremely important in the history of irrigation and human settlement in the arid lands of the Old World” (English, 1968: 170). In fact, Costa states that “settled life in South-West Arabia could not have existed without the terraced fields which now cover most of the highlands of Asir and North Yemen” (Costa, 1983: 275). About the origin of the qanat, English writes that “qanat technology apparently originated in the highlands of western Iran, northern Iraq, and eastern Turkey some 2,500 years ago (...) Later Assyrian cities, particularly those on the Tigris River, relied on qanats for their drinking water” (English, 1968: 175). This theory was largely debated by
Costa who asserted that “Assyrians and Babylonians built a network of surface canals taking water from the Euphrates, the Tigris and its tributaries. Though possessing an advanced technology they never developed anything like the qanat simply because, in that terrain, an underground channel would never have reached the surface” (Costa, 1983: 275). Costa based his hypothesis on the fact that the adoption of a particular water exploitation method is dictated by the hydro-geological environment; the latter being in the plains of Mesopotamia non suitable for the use of systems like the qanat. According to Costa (1983: 275) many scholars identify Persia as the region where the first qanats were built because of their amazement by the great development of irrigation under the powerful Achaemenian rule. Nevertheless, both English (1968: 175) and Costa (1983: 275) agreed that underground water-channels were constructed by The Assyrian king Sennacherib (705-681 BC) to supply the town of Arbil. Costa explained that the town’s location, near the mountains of Kurdistan, presented a more suitable hydro-geological environment for the construction of a qanat. Following his ideas and thoughts about the origin of the qanat, we notice that Costa was trying to turn the attention toward Arabia and specifically Oman: “(…) recently acquired is knowledge of copper mining and smelting in mid-3rd millennium BC Oman (Weisgerber 1981 quoted in Costa, 1983). “It is largely recognized that mining techniques are the same as those used in the exploitation of underground water (Forbes 1964: 157; J. C. Wilkinson 1977: 76). It is also true that in Oman there could hardly be settlement without a falaj. So far there is limited evidence of 3rd-2nd millennia BC settlements in Oman, but their existence is indirectly indicated by the hundreds of thousands of tombs of that date which dot much of the northern part of the country”(Costa, 1983: 275).

Also, in Omani folk culture, some tales say that the prophet Suleiman Ibn Daoud settled in Slout of Oman for 10 days, and because he found the region an arid desert he ordered the Jinn to slit in the underground 100 qanats per day. This explains the locals’ designation of the qanat bringing water from the water table as Daoudi falaj (MRMW, 2009: 13).

English explains how the technique of qanat reached Spain: “the Arabs carried qanat across North Africa into Spain and Cyprus” (English, 1968: 170). The technique was also adopted by populations in the Extreme East region: central Asia and Western China. Similar procedures of water acquisition were found in dry regions of Latin America (English, 1968: 170).

FOGARAS IN TUNISIA

About Tunisia

Tunisia is located in North Africa, between the Mediterranean Sea and the Sahara desert, and between Algeria and Libya. It covers a total surface of 164,418 km² of which about 40% (in the South) is desert; the remainder consists of fertile lands.

The country offers a landscape that varies from mountains in the North to arid Sahara in the South, thus the climate is temperate, with mild, rainy winters and hot, dry summers. In the Southern part of the country, there are many oases (especially around the city of Gabes) where flourish 400,000 date palms (source: MEDOMED.com). In actual Tunisia and according to the National institute of Statistics (INS), the population is estimated to 10.8865 millions.

Water resources in actual Tunisia

For water supply, Tunisian communities relay mostly on natural resources (ground and surface water) more than unconventional resources. Ground and surface water are disponible as follows:

Total ground and surface water disponible resources: 4.88 m³ per year.
Total ground and surface water that can be used: 4.66 m³ per year.
- The used surface water (56%): 2.7 m³ per year
  o 81% from the North’s bassins
  o 13.7% from the central part of the country
  o 5.2% from the South
The ground water supply (44%): \(2.18 \text{m}^3\) per year
- from the superficial watertable: \(740 \text{ m}^3\) per year
- from the deep watertable: \(1440 \text{ m}^3\) per year
(BelKhadi, 2013; Attia, Moussa & Rejeb, 2013)

For a better administration of these resources, Tunisia have constructed dams above its rivers (Oued Madjerda being the largest one in the country) that are managed by The Direction Générale des Barrages et des Grands Travaux Hydrauliques (DGBGTH) (Attia, Moussa & Rejeb, 2013).

The actual excessive use of water resources is leading to an increasing shortage in water. Also water’s quality degrades mainly due to climate changes.

### Foggaras of the Tunisian South

Besides foggara, the system of qanat is known in Tunisia as mkayel or mkula. It has been developed through generations specifically in the Southern part of the country where the climate is hot and dry. In the region of Gafsa, 29 fugaras have been located: 2 in Lortos and 27 in El Guettar. Water was distributed to the communities of users through a traditional system of sharing based on a measurement using extension or shrinkage of the shadow with a "human step": "foot" the day and by night regarding prayer times (2 hours correspond roughly to 6 steps shade during the day) (Moussa M., 2005).

![Plate 2: Foggara Project Tunisia - Arid Regions Institute Medenine Tunisia (Moussa M, 2005)](image-url)
in the south). Indeed, its geography and geology make it favorable to the existence of potentially exploitable groundwater.

Regarding the evolution of foggaras from 1949 to 2000, photo-interpretations besides field observations reveal the following findings and changes (Moussa M., 2005):

Spacing between the wells of the foggaras of Lortos and El Guettar varies between 15 and 20 m, their depth varies between 21 and 25 m;

- Foggaras Boussoufa has a length of approximately 1000m and counts 40 wells;
- Nowadays, no foggara is functional; the latest is Ain Bousoufa that functioned till 1969. This is because of the lowering of the piezometric level of the water due to the creation of many shallow wells and boreholes with pumps;
- Much of the foggaras of Lortos and El Guettar are now under constructions in the village and the city. They are either filled or used as dry wells;
- Some fugaras’ wells are planted by fig, pomegranate, almond and olive trees;
- Entire sections of some fugaras are completely filled and have disappeared from the landscape; and some have served as a shelter during the war;
- Traditional oasis, formerly irrigated by foggaras, continues to be operated using water boreholes and wells. This allowed the extension of the oasis area on the upstream side by the creation of irrigated olive groves with a low floor consisting of vegetable and forage crops where palm trees are very rare;
- Due to the emergence of shallow wells and boreholes, the water distribution system is no longer managed as before.
- Currently, management is provided by AIC (Association of Collective Interest); traditional seguias are replaced by concrete channels or pipes.

Plate 3: Photo-interpretation based on an aerial photograph of 1948-49 (Moussa M., 2005)
Plate 4: Photo-interpretation based on an aerial photograph of 2000 (Moussa M., 2005)

Plate 5 (right side): Photo showing concrete channels replacing the traditional ones (Moussa M., 2005)
Plate 6 (left side): Extension of the oasis area on the upstream side (Moussa M., 2005)

AFLAJ IN OMAN

About Oman

Oman is located in the extreme southeast of the Arabian Peninsula. It has a total area of approximately 309,500 km², and opens onto the Gulf of Oman and the Arabian Sea with a coastline that reaches 1700 km (Hawley, 2005: 70). The land of Oman has a geomorphologic diversity that varies from mountains reaching 3000 meters (The Jabal Shams of Al-Hajar chain), to coastal plains descending almost to sea level, passing through the plains of the central part of the country that are at an altitude of 100 to 300 meters. To the west of the country, lies the largest sandy plain of Oman which is a part of the Ar Rub 'al-Khali basin (El-Baz, 2002). The country is known for its abundant presence of wadis that shape and sculpt its topography. It has an arid climate characterized by clear skies during the whole year, light winds, moderate winter temperatures and remarkably hot dry summers. Rainfall is highly variable from year to year, and also changes considerably across the country, ranging from under 50mm in central Oman to over 300 mm in the northern mountains (El-Baz, 2002).
Water resources in actual Oman

Ground water is the main source for meeting Omani population water needs. It provides 78% of the water supply in the Sultanate of Oman. Besides ground water, conventional or natural water resources relay on surface water (rainfall) and water springs. Unconventional resources represent only 16%; these resources include seawater desalination and treated wastewater (MRMWR website). Omani societies, specifically in rural regions, have access to the ground water mainly by means of aflaj but also through dug wells and boreholes.

Aflaj classification and administration

Aflaj are commonly defined as tunnels which bring water from where it concentrates in the ground and lead it to the surface (Al-Marshudi, 2007: 34). According to the National Aflaj Inventory Project conducted by the Ministry of Regional Municipalities, Environment and Water in the period from 1997 to 1999, there are 4112 aflaj distributed throughout the regions of Oman; from which 3017 are still operational (MRMWR website). In terms of their physical structure, these aflaj are classified into three different types: Ghaili, Dawoodi, and Aini (Al-Marshudi, 2007: 34). Indeed, they are classified according to their different methods of water extraction: “channeling surface flow, tapping springs, and draining water-soaked” (Costa, 1983: 275).

Omani aflaj administration relies mainly on a director (wakil), chosen from the village citizens by the owners of land and water, and his assistants (arifs), besides other responsible acting under the direction of the wakil and which number depends on the size of the falaj system (Al-Ghafri in S.Yazdi and L.Khaneiki [Ed], 2010: 198). They distribute the falaj water to communities of users regarding many factors such as: the flaj flow rate and fluctuations, the type of the soil and overall the number of owners and their proportional contribution in building the system. This distribution is based on an irrigation rotation (dawaran) or cycle that varies from 4 to 21 days; the dawaran itself is divided into many time’s subdivisions: athar being the base unit of water share (Al-Ghafri in S.Yazdi and L.Khaneiki [Ed], 2010: 213).

Five Omani aflaj inscribed in the World Heritage List

In July 2006, during its 30th session held in the Republic of Lithuania, the World Heritage Committee, under UNESCO, adopted the inscription of five Omani aflaj in the World Heritage List: falaj Daris and falaj Al-Khatmeen in Willayat Nizwa, falaj Al-Malki in Willayat Izki, falaj Al-Muyassar in Willayat Al-Rustaq and falaj Al-Jeela in Willayat Sur. This inscription is not only restricted to the falaj channel, but also includes its location and surrounding environment: ancient monuments, buildings, farms, industries, and other on-site activities (MRMWR website).

Falaj Daris

Falaj Daris, in Willayat Nizwa, was built under the rule of the Imam Sultan Ben Saif Al-Yaarabi about 400 years ago. The Wakil of falaj Daris Sheik Nasser Al-Kharousi asserts that the falaj was named Daris (From Arabic Darasa which means to step on) because its construction led to the extinction of many other Aflaj such as: falaj Al-Muhaidith, falaj Al-Maara, falaj Al-Dausmed..etc.
Table 1
Physical Data of Falaj Daris (Nizwa)

<table>
<thead>
<tr>
<th>The flow</th>
<th>Exceeding the 2000 liters/second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality</td>
<td>Electric Conductivity</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>pH</td>
</tr>
<tr>
<td></td>
<td>477 microsimens/cm</td>
</tr>
<tr>
<td></td>
<td>29 degrees centigrade</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
</tr>
<tr>
<td>Branches</td>
<td>Large branch</td>
</tr>
<tr>
<td></td>
<td>1700 m long, 17.5 m source’s depth</td>
</tr>
<tr>
<td></td>
<td>Small branch</td>
</tr>
<tr>
<td></td>
<td>1900 m long, 16 m source’s depth</td>
</tr>
<tr>
<td>Total falaj length</td>
<td>7990 m</td>
</tr>
<tr>
<td>Total demand area</td>
<td>2382642 m²</td>
</tr>
<tr>
<td>Irrigation area</td>
<td>1715502 m²</td>
</tr>
</tbody>
</table>

(Adapted from MRMWR website)

Plate 7: Aerial view of falaj Daris showing a chain of vertical shafts connecting to the underground tunnel (Source: Google earth Geoeye 22° 59’ N 57° 32’ E- Eye alt 2839 ft; imagery date 5/24/2009)

The carried water by falaj Daris serves not only the agricultural area, but also the domestic needs of the inhabitants of Al-Alaya. Indeed, before it irrigates the diverse plantations, it passes first between houses to be a chronic within people’s everyday life and habits. In the early morning, the users of the falaj bring their drinking water from the Shariaa, the first opening after which the canal appears under the sunlight. Few steps in their houses’ outdoor spaces, people can access the channel. On the way, following the falaj between the tight lanes intra the housing area of Al-Alaya, we can cross some kids swimming in the channel, women washing dishes and clothes, a couple of men cleaning the channel from dirt and mud, others cleaning their cars…etc.
Aflaj present situation and issues
In spite of the overall stable present situation of aflaj in Oman, they are going to vanish in case they are not adapted to the new present and future challenges. Already, more than 24% of the inventoried Omani aflaj are declared dead (MRMWR website). Several hydro-physical and socio-economic factors are behind the dryness of these systems; among these the lack of regular maintenance due to local workers shifting from agriculture sector to oil industry and governmental organizations that offer higher incomes (Al-Ghafri in S.Yazdi and L.Khaneiki [Ed], 2010: 209). Also the passive attitude of farmers toward aflaj noticed during the previous decades menaces the survival and transmission of the technical knowledge about these systems to the future generations (Al-Ghafri in S.Yazdi and L.Khaneiki [Ed], 2010: 210).

CONCLUSION
The climate of the Tunisian south is close to Oman’s climate; hot and dry. This explains the proliferation of qanat in both countries. But unlike Oman where this system is still operating with 3017 aflaj, no foggara is still functioning in Tunisia and the local authorities envisage the system’s valorization as important heritage by its integration into touristic projects. Regarding that, Oman has already done a step further with its National Aflaj Inventory Project that enumerated 4112 aflaj distributed throughout its regions. Besides, the concerned authorities succeeded in joining five of its systems to the World Heritage List since 2006. In general, qanat is a very important heritage that testifies human glory and potential to adapt nature to his needs. This system removed boundaries and traveled, starting from the Middle East, throughout times to flow not only water but also culture from the Extreme West to the Extreme East.

References

BelKhadi, M.S. (2013). Workshop to exchange experiences and planning of a regional program on the valuation of non-conventional waters (FAO & Institute of Arid Regions, Tunisia), 10 to 12 December 2013 -Djerba, Tunisia.


The Ministry of Regional Municipalities and Water Resources website provides a wide range of information on water resources in Oman and delivers annual reports implemented with statistics (http://www.mrmwr.gov.om/en/)


