Traditional water supply systems at lack of water regions and their modern situation (cases of M’zab Valley, Algeria and Miyakojima Island, Japan)

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Abstract. The historical development of water supply systems for portable and irrigation water gathering is traditional for lack of water regions of the world. The diversity of such systems can be observed at Middle East and Asiatic cultures. Some of them are still in use or partly in use now. The study cases of the work are traditional distribution systems of rainwater in the deserted M’zab Valley, Algeria and tropical Miyakojima Island, Japan. The research is aiming to precise the modern situation of traditional water supply systems estimating the possible ways of theirs sustainable development and revitalization. The research conducted on the case grounds mainly with field studies and interview methods. The water supply system of M’zab has been implemented more than eight centuries ago and is still in use. It is a complex hydraulic system based on the principle of total utilization of torrent water and on the equitable division of this water over the entire oasis. Local people now beginning to understand its cultural significance aiming to popularise it. Miyakojima Island medieval water supply underground system consist of the network of cave sources integrated with architecture. Now it is in decay not using like a source of potable water but still preserving some sacral significance with not pointing on popularization. For the sustainability and revitalization of the traditional water supply systems now it is not enough to preserve their initial function but also need to develop the potency of tourist attraction with reservation as cultural property.

1. Introduction

The historical water supply systems is an interesting scientific topic connecting architectural, engineering, ecological, sustainable development, revitalization and other aspects. Mostly they shaped in lack of water regions of the world, including well-known medieval irrigation water systems of Middle East deserted regions (the foggara in Algeria, the Qanat in Iran, Khettara in Morocco, Falj in Oman and so) as well as city potable water supply underground systems of Middle East. We can observe medieval water supply systems also in other regions of the world, including some tropical regions of Okinawa, Japan. The significant amount of such ancient water ways are used until now, some of them are already out of use but currently obtained touristic and educational attraction. There also the cases of preserving both direct water supply and touristic options. Several of such system are designated as UNESCO cultural property.
In our work we tried to concentrate mostly to the topic of modern situation of provincial ancient water supply systems located in small historical settlements in connection with the current proses of theirs preserving and popularization aiming to estimate the possible ways of theirs sustainable development and revitalization. The study cases are traditional distribution system (foggara) of rainwater based on horizontal drainage galleries in the deserted M’zab Valley, Algeria and ancient network of cave sources and wells (uriga) for underground water gathering at tropical Miyakojima Island, Japan.

The research is based on the own authors field studies of M’zab Valley foggara (Algeria) and Okinawa Miyakojima Island uriga (Japan) concerning observation, photo fixation and interview methods of the investigation of foggara and uriga sites including municipal government and local people’s attitude to the point. The part of the work at Miyakojima Island was conducted within Kyoto University (Japan) and supported by Grant of Hakuho Foundation Japanese Research Fellowship program 13th (2018-2019).

2. M’zab case

The city of Ghardaïa, like all Saharan areas feels a lack of water due to low level of precipitation and high temperature and evaporation. Since the Mozabite people settled in the region, they have suffered from the scarcity of water, they have used water wells to irrigate their crops and for daily domestic use. After enormous damage caused by the unexpected floods of the valleys, the Mozabite sages put in place a system of defense against floods and use its running water in periods of drought. This efficient and undoubtedly the most sophisticated system has been designed to capture and distribute water and has resistance to the effect of time. From here was born the traditional system of sharing and collection of water, and it has been established for seven centuries and a half. The water sharing and collection system has been classified as a World heritage site in 1982, it works until today thanks to the people who made it, and also to the regular maintenance work that succeeded kept it in good condition.

2.1. Historical overview on the traditional water supply system in M’zab

Due to the location of the M’zab Valley in a dry, desert region, the Mozabite thought deeply in an efficient way that enables them to use the available water sagely. Initially, they dug wells to exploit the groundwater until it numbered more than a thousand, they did not stop there but rather they searched for methods to exploit the torrential water that used to pass through the valley from time to time, leaving behind some damages without actually benefitting from it.

The precursor Bahmed Abu Sahaba, who died in 1273, was the first who established all the bases of the traditional system.

Then it was improved and renewed by Hamou Oulhadj after a great flood in 1306. He opted for the construction of the bouchene dam which receives the surplus of waters of the bouchemdjene channel and which also replenishes the groundwater table and the surplus is directed again to the course of the M’zab Valley. This important achievement took years to complete, which indicates ingenuity despite the lack of means at the time.

Later, a commission called the trustees Al’umana was formed to monitor and divide the torrents and maintain their facilities in view of the fact that water is rare, and the difficulty of obtaining it in the M’zab area [1–3].

2.2. The functioning of the traditional water supply system

The system of dividing the water in the M’zab Valley is based on the principle of Total and optimum utilization of rainwater and on equitable division for this water on the total oasis. Here we can set two types of irrigation system in the oasis of Ghardaïa:

In ordinary days: the irrigation is done through wells khottara excavated along the M’zab Valley, in the oasis, and inside the settlement, so called ksar, to extract ground water from
varying depths between 10m and 80m approximately. The water is extracted using a bucket held by two cords and pulled by animals. Its capacity is between 40 and 50 liters. Then the water is stored in basins that precede the well, it contains a slot in one of its corners that allows the passage of water to the second basin which is larger in size. Then the extracted water is distributed by streams flow seguia towards the palm orchard. The main function of these basins is to store water, reduce its momentum, and maintain the constant flow of water in the streams during the process of irrigation. Their number varies according to the number of owners. The ownership of each well is from five to ten people. The exploitation of the well’s water is divided between them in the periods of time where each one takes his share of time according to his contribution to the process of drilling and preparing the well [4–6] (figure 1, figure 2, figure 3).

Figure 1. The functional diagram of the wells during the irrigation process in ordinary time (by author).
The flood is divided into 3 parts depending on the priority: irrigation, recharge of the water table, and the evacuation of excess water to the valley.

The floodwater is directed from the valleys towards the distribution point tissembath, it has openings that help to regulate and reduce the flow of floodwater before entering the underground galleries (tunnels). Each gallery (drain) is sized according to the flow to be conveyed for the irrigation of the oasis (depending on the number of palms needed to irrigate), it contains also a metal flat valve for closing or opening the slot, its dimensions are from 85cm to 40cm on the surface (figure 4).

There are 5 underground galleries along 170 m equipped with ventilation shafts with a diameter of about 90cm, and length varied according to the distance between the wells and the tissembath, the main role of these shafts is the aeration, control, and maintenance of underground galleries. The water reaches the oases through the underground galleries and then through the channels that are serving lake paths for human circulation in ordinary time and became water transporters during the flood days.

The water infiltrates the palm orchids through koua, which is a small opening located on the wall of the orchid, each orchid has a single koua, and its thickness varies from one palm grove to another, according to several parameters: the surface of the orchid, the number of palm trees and the distance between the underground canal and the orchids.

Inside the palm grove, the distribution of the water is promoted by an earthen network of seguia of variant dimensions (figure 4, figure 5, figure 6, figure 7, figure 8). When the palms are flooded, the surplus water flows through openings in the walls then directed automatically to the various dams, which in turn feed the layer of groundwater for later use by irrigation wells scattered in an oasis, and the excess of that water is automatically directed into the stream of the valley [1, 2, 6–8].
Figure 4. The functional diagrams of M’zab foggara in the flood time: vertical and horizontal projections (by author).
Figure 5. Tissembath and ventilation shafts.

Figure 6. Channel during the Flood.

Figure 7. Channel during ordinary time.

Figure 8. Koua.

Figure 9. Seguia.

Source:
http://www.atmzab.net/index.php?option=com_content&view=article&id=1265&It
2.3. The modern situation of the traditional water supply system of M’zab Valley

To date, the system of distribution of floodwaters has worked perfectly for 7 centuries. It has been renewed several times. The last repairs were carried out after the great flood of 2008 at tissembath level, and also the underground tunnels.

The credit goes to the people who created it, their traditional customs, and to the committee of Al’umana who set a regular maintenance work that has kept it in shape, and its good performance, such as:

- Covering the canals with plaster.
- Cleaning the system by removing waste before the arrival of irrigation water.
- Verification of the state of the wells and canals regularly.
- The permanent cleaning of the orifices, to avoid damage caused by the ascent water level.
- Usage of pumps in traditional wells, to promote easy and immediate irrigation and provides water all the time without the need for workers. However, this has disadvantages also such as making changes to the traditional system by replacing the bucket with the pump and exposing it to the risk of rising water levels over time, which may cause degradation and disturbance in its function.

As for now, the traditional water supply system considering also a tourist attraction due to its unique and genius structure. The local people volunteer organize tours inside the ksar settlement and the oasis for the visitors in all the seasons, and the traditional water system has a share from these tours [2,9].

2.4. General regulations in the traditional customs about the water supply system

The precursors in the M’zab Valley set customary rules and regulations, so called “customs”, inspired by the Islamic religion that contributed to preserve the Mozabite architecture over centuries.

The supply water traditional system has a share of general rules in the traditional customs can be set in the following:

- Respecting all water streams, valleys, reefs, wells, and others.
- Respecting the width of M’zab Valley, where it must be 20 meters and 10 meters on both sides and it is not permissible to construct any building there.
- In order to preserve the canals, it is forbidden to build any natural or artificial barriers over them, such as the road, building, trees, or to plow them.
- Not to make any change to the water transporting system because it will expose people to water danger.
- No one is allowed to open the barriers of dams or canals, whether during torrential rains or otherwise, except for the trustees Al’umana.
- The dividing of the torrent water between partners should be according to the number of palms, without counting other trees.
- The process of clearing the torrent water from dust inside the oasis is the responsibility and at the expense of all the partners as well as the restoration, but must be under the supervision of Al’umana and technicians.
- It is prohibited for any citizen to interfere in the maintenance of dams, waterways, and all stream channels, except under the supervision of those concerned, since it requires careful study of the supply system [2,3,5,10].
3. Miyakojima case
Miyakojima is a small coral reefs archipelago in a group of Okinawa Islands, Japan. Now it is widely known in Japan as a popular sea resort.

3.1. Geological and historical overview of Miyakojima water supply
Miyakojima archipelago is a very interesting example of historical water supply methodic starting to develop from 13th c. Natural water supply circumstances of Miyakojima Island are quite unusual: there is almost no sources of surface water. Nevertheless of rich tropical green forests covering the islands of Miyakojima, it has only one quite short (just for about 3 km long) Sakida-ga, river and is suffering of potable water shortage, depending mostly of underground water sources. The annual rainfall amount of Miyakojima is about 2,250 mm although nearly a half of rainwater quickly penetrates underground, and the rest is evaporating by subtropical sunshine leaving on the surface almost nothing [11]. The reason is a special geological structure of Miyakojima Islands where under the soil locates the layer of porous Ryukyu limestone that easily allows the rainwater to penetrate in. Beneath the limestone is lying a bedrock of impermeable mudstone. Tectonic forces of the archipelago created underground valleys with groundwater flows, where penetrated rainwater easily moves into the ocean [12]. Although there is abundant groundwater at Miyakojima, getting it is not an easy task. From ancient times, the people of Miyakojima either dug wells in hard limestone or obtained domestic water from naturally created caves called uriga in local language. These caves were up to 20 m deep places accessing with long down steps. The sources usually located in the bottom of the caves and it was the duty for the women and teenagers to get the water from them. From the 19th c., the population of Miyakojima increases and water selling business arose. At the beginning of 20th c. people started to collect rainwater in reservoirs and in 1924, there was the first case of manpowered circled treadmill water-for-cell lifting from a deep well.

From the middle of 20th c. there were several series of water supply aqueducts constructions leading the water pumped from the wells to the different places of the island finally covering almost all territory of Miyakojima [12]. In 1973, Miyakojima suffered from a big drought that leads to looking for new water distribution possibilities including creating huge underground water reservoirs as well as Fukuzato and Sunagawa underground dams’ construction completed in 1998 [11]. This point finally led to the completely stop of natural cave sources using for daily life water supply.

3.2. Uriga cave sources and wells of Miyakojima: current situation, preserving and revitalization efforts
According to 18th c. document “Yosei-Kyuki”, there were for about 60 wells and natural cave sources at Miyakojima Island [12]. Not all of them survived until now. According to the cultural and historical sites list of Miyakojima, currently are preserved for about 20 ones [13]. Although a very attentive attitude to historical waterways’ of agricultural, industrial and potable water supply [14, 15] preserving and revitalization in Japan, there are not much information about Miyakojima’s uriga cave sources in touristic internet resources or booklets as well as in the scientific field. Nearly single extensive notice of the Miyakojima cave sources could be find on the desk map installed in the center of Miyakojima city (figure 10) as well in the list of Miyakojima local historical property designated sites [13].

We investigated four of survived historic sources situated at the site of old Hirara city (now Miyakojima city) area. As a result, it became evident that they are currently in different situation and their level of preserving is not equal.

The first and the second of them: Yamatoga and Butoraga sources are situated nearly in the northeastern part of old Hirara city and both designated as National important cultural property [16].
Butoraga (figure 11) is a typical popular place of cave water source used by common people to get the water accumulated in the limestone of natural cave bottom with narrow entrance that now is hiding under the banyan tree branches. The villagers carved the stairs in the ground to make water lifting easier. Although this cave source is not actually used in daily life, the groundwater still collects at the bottom of the basin deep inside the cave. The atmosphere of the place is simple and solemn, making the little image of abundance.

Figure 10. The desk map with uriga cave source marking installed in the centre of Miyakojima city (by author).

Figure 11. The desk map with uriga cave source marking installed in the centre of Miyakojima city (by author).
Yamatoga (figure 12) is a deep well spring believed to have been excavated around 1720 as it comes from the contents described in “Yosei-Kyuki” ancient historical document (1727) [16]. According to local folklore, this source was limited only for official service people belonging to Shuri royal government (the capital of Ryukyu kingdom) and Satsuma domain, and was not open to the public. The spring is surrounded with the mixture of large and small curved stones erected with splendor high-level masonry technology of the time. The massive stone steps are leading down to a flat stone paved rectangular place with source water basin. There used to be two gates leading up to the source, and it is said that there was also a water guard. There are various theories as to why the name “Yamato” is given to this source, whether because the artisan involved in its construction was a person from central part of Japan (Yamato region), or because it was used by officials dispatched from the Shuri royal government that associated with central political power of Yamato lands. Currently, Yamatoga well is evidently the most known and good maintained source of Miyakojima, but even with this, it attracting only random tourists.

![Figure 12. The desk map with uriga cave source marking installed in the centre of Miyakojima city (by author).](image)

An interesting example of natural cave spring is Muikaga (figure 13). This is the largest and deepest historical cave source of the island having 103 stone steps leading down to the water source. The archeology of the nearest shell and porcelain mound witness that in ancient times there was large settlement around the source, but now Muikaga cave is surrounded with abandoned jungle spot locating at the western suburb of Miyakojima (Hirara) city and has a small local sanctuary (so called utaki) near the entrance. Muikaga historical cave source is designated as a Municipal Historic Site but seems to be visited very seldom [17].

Also in the northwestern part of Miyakojima city, we can find an interesting and rare ground water source called Upuka that was used before mostly for farm animal (cows and horses) drinking water (figure 14). The date of its discovering is not clear, but as it is described in “Yosei-Kyuki” historical document (1727), the repair work of the source was conducted in 1717, so it can be said that Upuka spring already existed at the beginning of the 18th c. After the Second World War, due to the spread of water supply and the decrease of cattle and horse breeding, the source was no longer used and was buried with the earth and sand. But it was re-excavated in 2004 as a cultural development project, enabling people to view Upuka spring for the first time in 50 years. Now it is designated as a Municipal Historic Site [18].

Generalizing, it can be noticed quite low engagement of Miyakojima historical water sources in the touristic attraction infrastructure of the Island. Although Miyakojima Archipelago is a
popular sea resort of Japan with developed transportation, housing and excursion network, the
touristic and educational function of local historical cave sources’ is not fully developed. At the
same time, the cave springs also are not in use any more as resources of potable water. One of the
reasons is bad natural quality of local hard water polluted with metallic mixtures. This problem
now resolving by softening the water in centralized water supply system of Miyakojima so the
cave sources became inconvenient for use as drinking water. Nevertheless, in some cases the cave
water is still used now for local rituals preserving at Miyakojima theirs own iniquity [19]. Judging
from the interview with local people, the image of uriga cave sources is closely associated here
with small homeland warm feelings and “childhood” local life traditions. All historical sources
of Miyakojima have appropriate marking and nearby desk information that also witnessing the
interest of local authorities to this topic (figure 11, figure 12, figure 13, figure 14).
4. M’zab and Miyakojima cases: comparing discussion

We tried to compare the foggara water supply system of M’zab and Miyakojima uriga cave sources network in two main parameters: basic historical features and current situation of functioning, preserving and revitalization.

The both operating with underground water resources water supply systems are products of local geographic situation, climate and culture. Foggara of M’zab is similar with other desert Middle East irrigation systems formed at the same circumstances, but it has original distinguishing points capturing only floodwaters and not using other water resources [7]. Uriga of Miyakojima is an original cultural phenomenon resulting from Miyakojima coral island non-ordinary geology and connected with local beliefs and rituals [19].

The initial function of foggara is irrigation water supply and preventing floods, uriga has a function of potable water supply also often serving as utaki – integrated in the nature sacral place of local deities worshiping.

The age of the both systems is nearly the same. Miyakojima’s uriga sources and wells are in use mostly from 13th c., M’zab Valley’s irrigation history also starts from 13th c. M’zab Valley foggara system is much more complicated and elaborated than Miyakojima uriga, but some uriga sources are integrated in interesting stonework architecture. The way of water extraction from foggara and uriga wells are different. While in M’zab is practicing mechanic water lifting from vertical wells, at Miyakojima the wells and cave sources are the places of people visiting for hand lifting of the water. The underground sources are often provided with elaborated inner space additionally used for water deities worship.

Nevertheless, it can be argued that uriga is similar to the initial stage of foggara development. In some meaning, uriga system started to follow the same as foggara way of development at the end of 19th – the beginning of 20th cc., when human powered mechanisms of water extraction from the wells appeared at Miyakojima. From the middle of 20th c., this system was replaced by pumped water lift up from the wells starting centralised water distribution at some parts of the island. Finally, this way of development was replaced by more progressive and original water supply system of underground dam and pre-oceanic cat-off walls system elaborated there at the end of 20th c. [11].

The current situation of M’zab foggara and Miyakojima uriga systems also is quite different. Foggara is still fully used in traditional way (just animal force of water lifting from the wells is replaced with the pumps) and professionally maintained by strong local community. There no modern water supply systems to replace or duplicate it. The touristic and educational function of foggara are complimenting and now are in developing stage. As a result – the preserving of historical water system in M’zab is excellent in all meanings.

Miyakojima’s uriga completely lost its initial function as a source of potable water due to the developing of a new modern water supply system and partly preserving only its ancient sacral function. Touristic and educational functions are aiming to develop in the frame of some revitalization efforts of municipal authorities (designating as historical sites and placing nearby the information desks marking uriga touristic sites, realization of some small projects of sources renovation and preserving) but seems not to meet enough enthusiasm from local community and business.

This effect may be directly connected with natural environment, local customs and traditional way of living preserving situation of the researched cases. While in M’zab Valley all three aspects (the natural environment, local customs and traditional way of living) are fully preserved, in Miyakojima Island only the aspect of natural environment is preserved, the local customs are preserved only party and the local community traditional way of living is in the study of decay due to modernisation and globalization (figure 15).
5. Conclusion

The situation with preserving and revitalization of historic water supply systems at some area supposed to be directly connected with the surviving of local natural environment, customs and traditional way of living of the area. In this point, the natural environment and traditional way of living preserving leads to the preservation of the needs in historical water supply system functioning as it is clearly seen in the case of M’zab. It also important to preserve the possibilities (experience and ancient techniques) to operate and maintain such water system that is provided by preserving of local culture customs transmitting the experience of centuries to the new generations. The loss of some of the aspects named above usually causes the interrupting of historic water supply system operating that in most cases leads to its decay as we can clearly see at the case of Miyakojima. In other words, only in the case of all three these aspects presence, the historical water system may currently remain in use that create a best condition to its sustainable development.

It is also evident that the best way to preserve ancient water supply systems are joint efforts of local authorities and community. At the same time for the sustainable development and revitalization of the traditional water supply systems now it is not enough only to preserve their initial function but also needs to develop theirs potency as tourist attractions and educational hubs as well as to popularize and designate these extremely interesting objects of human civilization history as cultural property cites.

Figure 15. The desk map with uriga cave source marking installed in the centre of Miyakojima city (by author).
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