Proposal for a candidate site of
Globally Important Ingenious Agricultural System (GIAHS)

Qanat Irrigation Systems:
An ancient water distribution system allowing specialised and diverse cropping in desert regions of Iran

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کاشت نشا تنباکو در دشت قاضي(قنات قاضي)

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1. Summary

The technology related to the construction and use of Qanats is a method that has from long time ago been adhered to in Iran so as to take advantage of the underground water resources in arid regions. In this manner water resources were brought to the surface with the help of non-mechanical efforts, as the phenomena relied upon gravity alone. As water flowed to the lowest levels, the 'art' of constructing Qanats was a tremendous success and then water was transferred to areas where it was most needed, especially for the development of agriculture. The techniques or invention of Qanats construction took a strong hold in Iran such that this aspect was later related to science of *hydrology* (Mahdavi, 1977).

Qanats are still counted as one of the main ways of procuring water for irrigation and agricultural development not only in the internal plateau of Iran but also in other countries such as China and Afghanistan. In most cases however, Qanats are more than just a way of using groundwater. They represent a unique and integrative system illustrating use of indigenous knowledge and wisdom in sustainable management of land, water, and agricultural biodiversity.

At present, many factors threaten the Qanat systems in Iran as well as worldwide. Climate change and increasing risks of desertification, over-consumption of freshwater resources, and introduction of new technologies, as well as inadequate policies have all contributed towards the degradation of ingenious system of Qanat construction and maintenance. There is thus an urgent need for the protection and revival of the existing network of Qanat systems to further sustain water resources and related agricultural biodiversity in arid regions of the world.

In here Qanat systems have been described (structure and function) and Kashan area has been proposed for further investigation of Qanats as **globally important ingenious agricultural heritage sites**. The reasons for proposing Qanats as GIAHS have been illustrated and can be summarized as follows:

- Qanats sustain food and livelihood security
- Qanats contribute to CBD, CCD and other international treaties
- Qanats support both biophysical and social/cultural diversity
- Qanats are efficient systems which minimize water consumption and improve water and crop quality
- Qanats maximize benefits (economic, social, global environmental, livelihood)
- Qanat systems are resilient and adaptive (using indigenous knowledge and wisdom in identifying solutions to critical environmental constraints)
- Qanat system of management is cohesive and creates solidarity and a sense of belonging at local levels
- Qanat systems are historically unique and may be considered as global heritage sites (intrinsic global benefit)
- Qanats have a demonstration effect
- Qanat management systems enhance decentralized decision making and participatory processes

2. Importance of Qanats as an Agricultural Heritage Site

2.1 Ancient history of Qanats

Some historical records contribute the existence of Qanats to the pre-Islamic period in Iran. The history of Qanats in the plateau of Iran relates more to the Aryans and many Qanats especially in the eastern part of Iran can be correlated to the ancient times[1] (at least 1200 years ago). According to other studies, in northwestern Iran, the presence of Qanats goes back as far as 800 BC. It is also estimated that in about 525 BC, Qanats existed in the coastal borders of the Persian Gulf.

In fact, there are records that the ancient Iranians had come to recognize and utilize Qanats from the time of the Achaemenian period and taught the Egyptians this technique. In the Parthian period, Qanats were present, as according to historical records, the ruler of the time (205–212 BC) brought about damage to these canals to make Romans suffer and drawback in the war. *Tabbari* also discloses some facts about Qanats in the times of the Sassanides, though the actual location has not been mentioned. In the year 828, the Abbasid Caliph built a garden near Baghdad which was irrigated by Qanats. *Karaji* emphasized on the principles of the earth's gravity and flow of surface waters nearly a thousand years ago which shows that at that time Iranians had knowledge on underground waters. The use of horizontal wells rather than vertical ones was gradually introduced and thus the incline that brought these waters to the surface.

There are records that this technique later spread from Iran to other regions of the world such as North Africa, Spain, Cyprus, Sicily, etc. In 500 BC presence of Qanats were recorded in Egypt, in 750 in Madrid, in 850 in south of Algeria, in year 1520 in Los Angeles, in 1540 in Chile, in 1780 to Turkmenistan and from 120 BC to 1475 Qanats prevailed in China.

Thus, even though Qanats have been used from Chili to Japan but the core region where Qanats have been used as the main source of water has been in the Iranian plateau, especially in the desert regions. The geographical regions around the Central Desert of Iran, including cities of Yazd[2], Kerman, Bam, Birjand, Ghabel, Ferdows, Gonabad, Tabass, Kashmar, Sabzevar, Semnan, Damghan, Garmsar, Kashan, and the old Tehran, for thousands of years have been using the technology of Qanat **(Map 1).**

1- For example, the Qanat of Jupar (Kerman) is linked to the period of the worshippers of the goddess of Rain "Anahita".

2- Some of the archaic and reputed Qanats of Iran are in Yazd, having a length of 120 km or the depth of the mother wells being up to 400 meters (*Kinmur, Gonabar* and *Bidaft).* The ancient Qanat of *Gababeesh* dating back to 1200 years ago in Sanabad (Mashhad) is another example.

Qanats and their importance are usually reflected in arid regions with an annual rainfall that does not exceed 150 mm. In these regions Qanats were relied upon as the only means of water resource. To date this feature maintains its importance, but also the socio-economical and cultural aspects and the way Qanats have contributed to forming civilizations in these harsh climatic conditions. As a result, these regions have developed quite a distinct culture and civilization which can be called **the Qanat civilization** sharing a unique cultural, socio-economic and political characteristic that would distinguish this region from others **(Map 1)**.

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2.2 Multiple functions of Qanats

The southern, eastern and central parts of Iran are in general rural and short in water. Shortage of water in these rural areas is the main barrier for development of agriculture. The role of water in agriculture is essential and the livelihoods of the local people depend on it. As a result most villages have been built in areas where there is a Qanat or other source of water. The quality and quantity of the harvest also depends on water availability. In other words, productivity of land and the type of crops are in direct relationship with water quality and quantity.

On the other hand, until about 40 years ago, part or most of the water in larger cities was also provided by Qanats. Thus, Qanats are not uniquely a rural phenomenon but they have also had a significant role in formation of cities[3] such as Yazd, Kazeroon, Esfadan, Tabriz, Shiraz, Ghazvin, Zanjan, and Kashan. Traditional water reservoirs (or *ab-anbars*) were one of the infrastructures that were used in cities along the desert to store and provide drinking water to citizens. Considering that Qanat water was available all year long, and it was somewhat difficult to control its flow and prevent water going wasted, in winter and fall (non-agriculture seasons), people used to store the extra water in water pools, wetlands and ab-anbars to make good use of it as needed.

Even nowadays in regions where industries exist, Qanat water is used for industrial purposes in some areas. In some other regions of Iran where slope of the main trunks of Qanats were built step-wise, mills were installed along the way to make use of the water power.

One way to make use of Qanat and rain water was also to store water in large natural and semi-natural water pools called ab-bandan. This water was used in a timely manner for agricultural purposes.

Thus, various functions of Qanats can be mentioned as follows:

To secure water for irrigation
In many regions of Iran, due to insufficient rainfall, agriculture has depended on irrigation. On the other hand due to aridity, surface waters cannot be relied upon, as this is scarce too. Therefore, Qanats from the long past have been the main providers of water for agricultural purposes, and are still considered as one of the vital means to provide water for irrigation.

Securing water for rural and urban areas
In the past, not only was water required for cultivation, but urban and rural areas were also dependant on water for dwelling purposes. Like-wise majority of the larger and ancient cities of Iran like *Yazd, Kerman, Rey, Toos, Mashad, Neshabur, Sabzevar* and *Tabas* have also revealed their reliance on Qanats.

3- *Hamdollah Mostofi*, the author of the *Nezhalgholoob* in explaining the geography and history of regions of Iran has specifically mentioned the name of the cities which used Qanats as sources of water.


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Utilization of water currents

In many regions of Iran, not only were Qanats utilized as security measures for water requirements, but the energy produced was also taken advantage of. Prominent examples are the water mills on the routes of the Qanats, and in some places several mills were present on the route of one Qanat. An example is the Qanat of *Fin-e-Kashan* where there were 7 water mills some of which are still working. In Najaf Abad (Esfahan), 17 water mills were present on the main Qanat, whereas on the Bashruyieh Qanat in Khorassan 7 water mills are present.

Social functions of Qanats

Large parts of the social system in areas that rely on Qanats were directly or indirectly related to this phenomenon. In such regions the importance and value of people were judged according to their 'ownership rights to the amount of 'water'. No matter how small a share was in this aspect, the person was held in high esteem. In cities too this was held as social hieárachy, as the vicinity of a persons premises (that is whether it was upstream or downstream in relation to the Qanat) was a factor to be considered.
Reliance on the Qanat has brought about social cooperation in many fields. This order is noticed in the agricultural sphere, such as the method of water distribution.

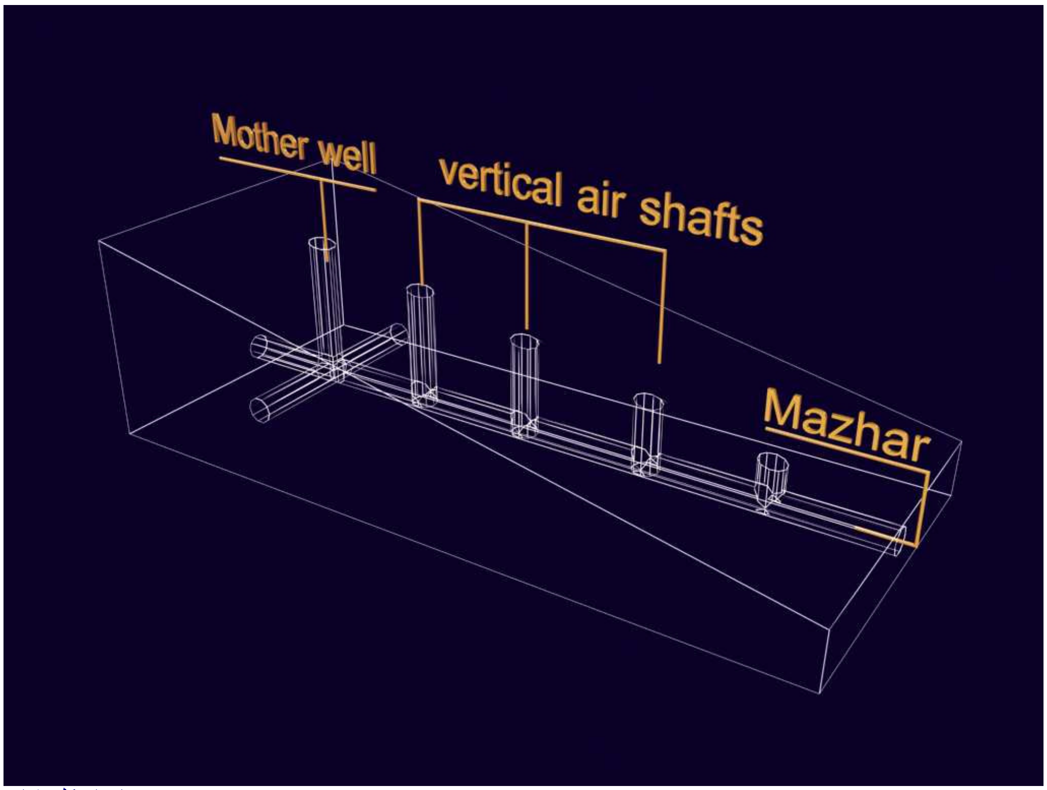
Legacy of Qanats

A legacy of this kind was always held as a religious belief as well as a tradition that fortified religious beliefs. At times such beliefs stood for the protection and care of Qanats. Whereas, sometimes the total water output of a Qanat or Qanats was left as a legacy for various purposes like securing water for religious activities as well as other functions.

2.3 Various types of Qanats

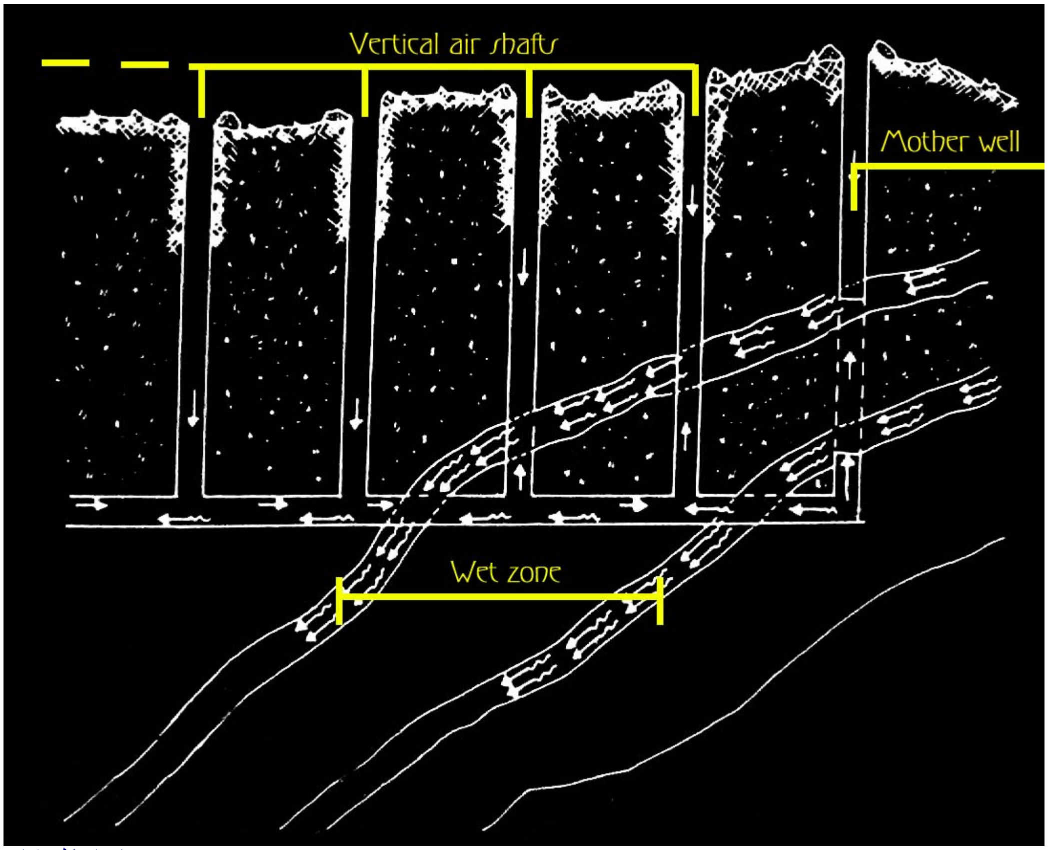
The Qanat structure is on the whole simple. It consists of a tunnel running throughout on an incline with many vertical wells (*Millehs*) that form air passages allowing for required operations such as excavation and dredging (**Diagram 1**). This forms the basic pattern of Qanats, but from a structural point of view Qanats can be divided into two main types:

- Mountain type: These are simple Qanats that use water resources from mountainous regions;
- Plain type: These Qanats branch out from rivers.



ساختار كلي قنات

On the other hand, Qanats are synchronized with the climatic conditions of the region such that if annual rainfall is heavy, the length of the Qanats is shorter and the depth of the 'mother wells' (*Madaar-chah*) is like-wise not deep. Whereas, in cases when rainfall is not heavy, the opposite occurs. The lengths of Qanats increase and the depth of the mother wells do equally so (Pazunon, 1980). In general, the depth of the mother well and the length of Qanats in mountain regions are lower than those in plain regions. The amount of water they provide is also variable and depends on rainfall levels.



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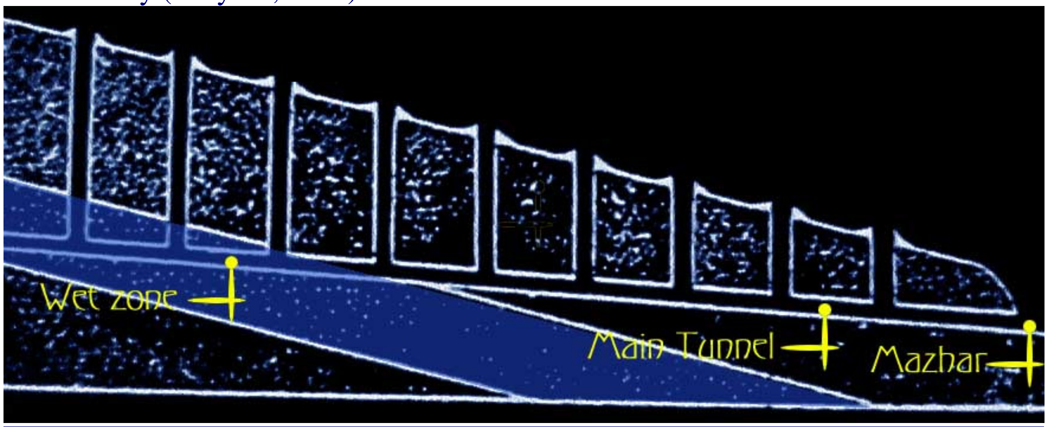
Various types of Qanats are categorized according to the flow, depth of the mother well, type of construction, geographical environment, etc. There are Qanats in the plains and those from springs (mountains), those that run parallel or those that run successively (Ghiyoor, 1991).



2.4 Indigenous knowledge and wisdom

Techniques involved in construction of Qanats is a complex matter and strongly requires expertise and a detailed division of work concerned.

2.4.1 Identification of underground water sources:

When surface water present is not sufficient, Qanats that are excavated for the purpose of exploiting underground waters comprise of two types: those in the mountainous regions and in plains. Before the basic procedures for excavation take place, the course in which the Qanat must run and underground water resources have to be studied carefully. These studies are in general conducted as follows:

1) *Determining underground waters in accordance to the region*: And more specifically based on existence of layers with evidence of water in shallow depths (such as springs or stagnant water) located in higher elevations in comparison to the source of the Qanat, or the least evidence of water.

2) The recognition of underground waters in accordance to the vegetative cover, the presence of certain animal life and insects: In particular, regions that are not under cultivation but have immense herbal coverage reveal the presence of water in shallow depths, especially if dew is sighted on this coverage at dawn (*Karaji*, ………). In addition, other kinds of herbs (in uncultivated pastures) such as cowslip, nettles, artichoke, teasel, Persian turpentine besides rushes and moss might reveal the presence of water.

The presence of frogs, snails and certain insects in regions that are devoid of springs, rivers or swamps, can also be a sign of presence of underground waters in that region.

3) The recognition of underground waters according to the color and form of the land[4]*:* The evidence of blackish hue in mountains, moisture along with muddy boulders can determine water presence. Whereas, according to ancient theories, next come mountains with a greenish tinge, then such colors as yellow and red in respect to the diminishing water content.

Needless to state that in such excavations unpredictable problems may arise increasing the cost and the manpower required to continue such operations. These problems might include:
- Limited air and presence of toxic gases
- Extremely loose or hard earth
- Land morphology such as presence of rivers, valleys, etc.
- Change in water direction

2.4.2 Excavation of Qanats:

[4] *It is worth mentioning in here that the presence of underground waters nowadays can also be determined with the help of latest technologies such as aerial and satellite pictures.*

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The excavation of Qanats resembles to tunnel construction to a certain degree. It varies in that the process is more complicated and requires a thorough study of water flow underground. However, the traditional methods involved in Qanat construction have not altered considerably to date (**Annex I**). Tools and apparatus utilized for planning and excavation of Qanats have not differed much from the early 14th century and that used in the earlier periods. But from the beginning of this century slight changes have come to be noticed in the said instruments.

2.4.3 Dredging for renovation

As an example, for the *Ghazi* Qanat of Kashan which is located in the desert areas in the middle of sandy dunes, due to the type of earth and the constant degradation of the Qanat canal, dredging is required on a regular basis. For dredging every month, 3 or 4 *Moghanees* and the owner would clean up the obstacles that have been formed to prevent water circulation. They would enter from the mother well and exit from *Mazhar* (exit). In addition, few days every year people would work on the renovation (*nokani*) of the Qanat to control and enhance the water flow.

2.5 A valuable community management system

In general, traditional systems of resource management like *Boneh*, *Sahra* and *Harasseh* have been formed since historical times in Iran, especially in regions where there is shortage of rainfall and rural people have to combat difficulties due to natural conditions and to satisfy their needs. As result, unique collective systems of management have been formed. One of these systems is related to the management of Qanats and more specifically related to agriculture (the *Boneh* system). The *Boneh* system consists of a collective management system to develop agricultural lands in rural areas of Iran and is described briefly in this section.

As mentioned previously, provision of water through Qanats was a unique methodology to irrigate arid and semi-arid regions of most of the Iranian Plateau. This methodology today, despite new ways of making use of underground waters, still has its own special advantages. Qanat waters have always been in the ownership of local people and because of this sense of ownership water has been used cautiously. As a result, the traditional irrigation systems which were based on Qanats gave rise to valuable systems of ownership and management that are unique to each region. Even the socio-economic status of people has been very much dependent on ownership over water resources. As a result, water distribution at local levels required a very tedious system of benefit sharing and management.

Even though the **construction of Qanats** may seem simple, but the procedure requires skillful workers and a carefully designed community management system. In order to begin construction, 3–5 persons are required to the minimum to form a team (or *Charkh Kargar*). Each team member is specialized in one area and is responsible for a very specific task related to the excavation of the Qanat (**Annex I**).

It is said that in the old times the person in charge of a Qanat (*Moghanee*) was selected from the most popular tribes which was in return considered as an honor to that tribe. *Kolangdaran* (or diggers) were also experienced workers who had the responsibility to dig canals and wells. As a result, they were better paid compared to other workers and were well respected in the society. In fact, they ranked highest in the social hierarchy of Qanat business and came the other categories (**Annex I**).

Similarly, another team is involved in the **renovation and maintenance of Qanats** (**Annex I**):

1. *Moghanee* = He is the "digger" who comes under the observation of the head of the irrigation and the required contract or agreement relative to the repair and dredging of the Qanat is made between them. *Moghanee* is responsible for digging and determining the direction and the size of the wells as well as the underground canal;
2. *Guelband* = He collects the mud and soil that has been accumulated due to digging and puts it into a bucket;
3. *Deloaviz* = He receives the bucket and transports it from the canal to the nearest opening (*Milleh),* connecting it to a hook and returning the bucket;
4. *Charkhkesh* = He stands in the opening of the well beside the *Charkh-chah* and will pull up the filled bucket and pull down an empty one.
5. *Deloguir* = Once the filled bucket reaches the ground, he will collect the filled bucket and empty it by connecting it to the hook again to send back to the well.

So in addition to a collective management system for Qanat construction and renovation, fair **distribution of Qanat water** also required a well designed community management system. This management organization has always been cohesive and people-oriented with private and small ownerships. However, the exact organizational structure differed based on the type of ownership and number of shareholders.

In general, to distribute water a certain rotation period was defined (called "*madar-ab*") over which time water was distributed (10-14 days). This period was variable depending on the number of owners and their need for water. *Madar-ab* consisted of several nights and days and sub-divided into local time units called "*Serjeh*". Use of water during the day was determined randomly and the time of use switched between day and night at regular intervals for each user. The exact time when water would be made available was determined under supervision of a designated and well trusted person. In this type of management system that was unique to Qanats, "*Sartaghs*" were responsible for daily distribution of water between the owners. One of the main responsibilities of "*Sartaghs*" was to supervise water distribution and to coordinate with "*Mirrabs*" (in charge of water distribution) in case more water was needed. "*Mirrabs*" were a group of people selected by "*Sartaghs*" of every "*Tagh-ab*" for that same "*Tagh-ab*". In general, *Mirrabs* were selected from people who did not have water shares but were well trusted by the community. The *Mirrab* along with a few people supervised the water distribution affairs..

The responsibility of "*Peykan*" was to guard water on a daily basis, especially the area where water went into sub-streams (*Karts*), to avoid any wasting or any stealing of water. In general he would be also responsible to announce whose turn is next. In those times when there was no clock, "*tassnaareh-zan*" was in charge of announcing the time by climbing up the closest tower and shouting the time to the person who was at the water reservoir waiting to change the water direction.

2.6 Natural heritage value

Qanats collect water from different layers of earth, that is why building Qanats in the desert regions are key to water conservation and continuity of life. In other words, Qanats keep the underground water level at reasonable balance and prevent depletion of underground water resources even at worst drought situations. Qanats play the role of a drainage system at local, regional and national levels. Drainage through Qanats during centuries has been beneficial and have prevented rising of groundwater levels.
In addition, Qanats play an important role in balancing the salinity of water and protecting the agricultural lands downstream. For example, in the *Ghazi* Qanat of Kashan, the water has become less salty in 30 years period.

2.7 Cultural heritage value

One phenomena in the cultural aspect relative to Qanats in Iran are the beliefs that people had and the traditions that revolved around such beliefs. For instance it was a notion that Qanats were either 'male' or 'female'. Majority of the Qanats were known to be the former, whereas a minority the latter. These Qanats were coupled or paired off, in such that marriage ceremonies were performed as a ritual, in addition to sacrifices made. All these Qanats were held as being sacred.

Furthermore, in parts of Iran, gushing and the spurting nature of the water of the Qanats was believed to be from that of a 'male' gender, whereas, if the nature was found to be the opposite, that is gentle, subtle and soundless, it was taken to be a 'female'. For example, in the villages of *Yazd* when a Qanat dried up, people collect and select a courageous youngster as the 'bridegroom' that is if the 'mother well' had dried up, for the latter was considered the 'bride'. In order to perform the wedding ceremony a widow or a young girl was chosen and her consent was gained. After which people young and old take part in the festivities such as dancing and singing. This ritual resembled that of an actual wedding ceremony. These rituals are still being followed to some degree in areas like *Kamrah* in the province of *Khomein, Imamzadeh Buhal* Village, *Meymey* Village (province of Esfahan), *Bonbaksh* Village (province of *Chahar-Mahal Bakhtiari*), and the pastoral lands and villages around *Shahr Abadeh.*

2.8 Economic value

The expenditure involved for the construction of a Qanat may be eight or nine times more than that of a deep well, but the former is more economical in long-term even by standards of today.

In general, there is a council gathering annually in the month of June to discuss matters relative to regional irrigation systems. It is in this meeting that approximate expenditure relating to Qanats is determined. Thus, each agriculture worker (farmer) has to duly pay in respect to the amount of water that is utilized by him. This payment is known as '*nafagheh*'. Payment that is due in relation to dredging or the excavation of Qanats differs from the former.

2.9 Legal framework

Qanats are placed such that they are next to each other but this arrangement avoids the infiltration of water from one Qanat system to another. The distance between Qanats pertains to the relative legal and customary laws and regulations. If an owner finds another person encroaching on his rights where the Qanat is concerned, he has the authority to stop the progress as will bring forth problems of water output due to infiltration. Moreover, the distance between Qanats varies according to the regional layout. For example in well drained areas, the distance between Qanats should at the minimum be 500 meters, in dry areas the distance increases to 1500 meters and in the mountainous regions and valleys this distance has been determined to be 500 meters. In general, this distance should be between 1500–2000 meters.

2.10 Qanat-based Agricultural biodiversity

A Qanat-based cultivation system aims to make the best use of available water resources. The crops that are cultivated under this system are selected based on this principle. In general, these types of cultivation systems are dependent on Qanat water. Every farmer considering the amount of water he disposes may modify the area of land he is going to cultivate each year. There is a collective system of cultivation which needs to be followed by every farmer in order to avoid Qanat water from going to waste. In fact, the selected crops need to be diverse and complement each other in terms of their requirements for water.

2.10.1 Seasonality of crops

Seasonality of crops helps in making maximum use of available water resources throughout the year and thus sustaining the livelihoods of farmers all year long.

Spring cultivation: Crops that are cultivated in Spring include tomato, eggplant, cucumber, watermelon, melon, etc. These crops are cultivated in the beginning of Spring. For this purpose, first the land needs to be prepared and irrigated until it reaches a certain humidity. Seeds are soaked in water until they germinate and are then planted into the soil. After germination of seeds and their growth in soil, there is no irrigation for a while until the stem starts to turn yellow and stiff. The farmers believe this process makes the crops more resistant to future water shortage problems. This period may last from 2 to 5 days depending on weather conditions. Then, every 3 to 4 days the crops are irrigated. As mentioned previously, the "irrigation cycle" in dry seasons is reduced from 8 to 4 days and each farmer uses half of his share (or water rights) in the first 4 days and the other half in the second 4 days. Crops are irrigated in such a way that water is not accumulated at the root of the stem or otherwise the crops will get damaged. In fact, the irrigation regime for all seasonal crops are more or less the same. Farmers believe that red soil due to its organic content and high productivity for various crops is the best soil type for all kinds of seasonal crops.

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<u>Example:</u>

The amount of water that is needed for irrigation of Spring crops (eg. cucumber) may be calculated as below:

March/April: planting seeds but no irrigation
April/May: irrigation every other day
May/July-July/August: irrigation every three days.

The amount of water that is needed for irrigation of 625 sq.m. of cucumber cultivation (or one *jerib* of land) during a 7-day irrigation cycle, is such that crops are irrigated every day for one hour only.

In a 3-day irrigation cycle, this is reduced to half an hour a day:

April/May: Irrigation four times, every time for one hour (in total 4 hours)
May/June-July/August: Half an hour every 3 days (5 hours in total per month)

As a result, in total 16 hours of irrigation is needed for cultivation of 625 sq.m. of cucumber. The amount of water that is needed is calcualted as follows:
16 x 6 = 96 *serje*

Fall cultivation: Crops of this type include wheat and barley. These crops are planted in September/October and are not irrigated during winter but in the beginning of April up to beginning of June. Instead during winter these crops are irrigated with natural ice water which has indeed multiple benefits:

- prevents Qanat water from going to waste
- improves soil texture and quality
- destroys pests

2.10.2 The water distribution system:

Qanat water is used according to the share every farmer owns. In other words, one can only use as much water as he owns the right to do so. In general, the right to water varies from few minutes to few hours per year. The main point is that the cultivation system is very dependent on the water distribution system and thus, every farmer only cultivates the area of land that he is able to irrigate with his share of water. As a result, no crop is left without being adequately irrigated.

There has always been a balance between right of water and the land area that is being cultivated. With division of water shares from generation to generation, this balance has been preserved throughout years. Fairness of this water distribution system is due to the fact that every land owner depending on where his land is located (distance from the Qanat, quality of the land itself, etc.) will get his share of water. In fact this is the reason behind division of land into smaller pieces and their fair distribution (every farmer might get a mixture of good and bad quality lands).

2.10.3 Agrobiodiversity

Regarding the diversity of the agricultural system and species diversity, it has taken years of experience for farmers to find out which crops and seeds grow best in which type of land. This type of agricultural system is based on indigenous knowledge and in perfect harmony with environmental conditions.

For example, farmers do select the species they want to cultivate and perform seed improvements on selected species:

- Seed improvements: Every year the best crops are selected by farmers to extract the seeds. This activity is performed as soon as the crop is harvested (on farm). Farmers believe that if the crops are left or stored for more than two days, the seeds will loose their quality.
- In selection of seeds, various species are examined. The species are selected based on their requirements for water, cropping season, resistance to pests, etc. Selection of a diversity of species helps in reducing risks and enhances the sustainability of this traditional agricultural system.

2.10.4 The effect of Qanat water on crop quality:

Qanat water is freshwater that is also very light. Farmers believe that because Qanat water travels long distances, it loses a lot of its minerals. Crops that are being irrigated with Qanat water are usually of a better quality. They happen to be more resistant against drought. In addition, when using Qanat water, lower amounts of water are needed. For example, for cultivation of 625 sq.m. of hay, only 2 kg of seed is needed whereas if the same crop was to be irrigated using well water, 12 kg seed would be needed.

On the other hand, well water due to its higher salinity affects the quality and quantity of crops (especially those that are cultivated in Spring). For other crops that are more resistant (eg. hay), well water makes less difference in quantity of crops but the quality is still lower.

2.10.5 Orchard keeping and livestock breeding:

Orchard keeping: Traditional orchards have always been dependent on Qanat systems (especially those that were closer to Qanats or nearer to villages). In this relation, also diversification of tree species has proven to be important in maintaining the quality of Orchards.

Livestock breeding: Livestock breeding has always been considered as a complementary activity to agriculture in Iran. Livestock breeding in many ways has been dependent on agriculture due to the need for hay for livestock feeding. Vice versa, most fertilizers necessary for agriculture come from livestock. Animal fertilizers not only enrich the soil but also improve its texture (unlike chemical fertilizers). Farmers also believe that crops that are fertilized by animal fertilizers usually have lower water requirements due to adsorption of water to particles.

Both orchard keeping and livestock breeding are common in mountain plateaus of Iran and thus the importance of mountain type Qanats.

3. Case Study: Qanats of Kashan

3.1 Reasons for selecting Kashan as a study site

There are several reasons for selecting Kashan (Map 1) as a study site:

1) ***Historical importance:*** Due to geographical and climatic conditions, from long time ago human and social aspects of Kashan have depended on the groundwater resources and hereby Qanats.
2) ***Potential for revival:*** To date, approximately half of the water requirements relative to agricultural purposes or otherwise in this region are still secured from Qanats. Thus Qanats even today play a vital role in the urban and particularly rural areas of Kashan, as well as having a significant effect on the agricultural activities. Presently, throughout the region there are more than 500 Qanats in utilization.
3) ***Diversity:*** Geographical and topographical variations in this region have caused different types of Qanats to come into play which vary in respect to the techniques used in their construction and use.
4) ***Threats:*** The misuse of water resources due to negligence, unawareness or modern technologies (such as introduction of deep and semi-deep wells) have been leading to unsustainable use of underground waters which can result in diminishing water resources, or else turning the water saline.
5) ***Socio-cultural aspect:*** There are certain Qanats in the area that illustrate the social and cultural aspects of collective management of these resources.
6) ***Urgency:*** Qanats in this region have to be protected as some of these lie exposed to the accelerating sandy dunes of the area.
7) ***Accessibility:*** Kashan is only 3 hours away from the south of the capital (Teheran).

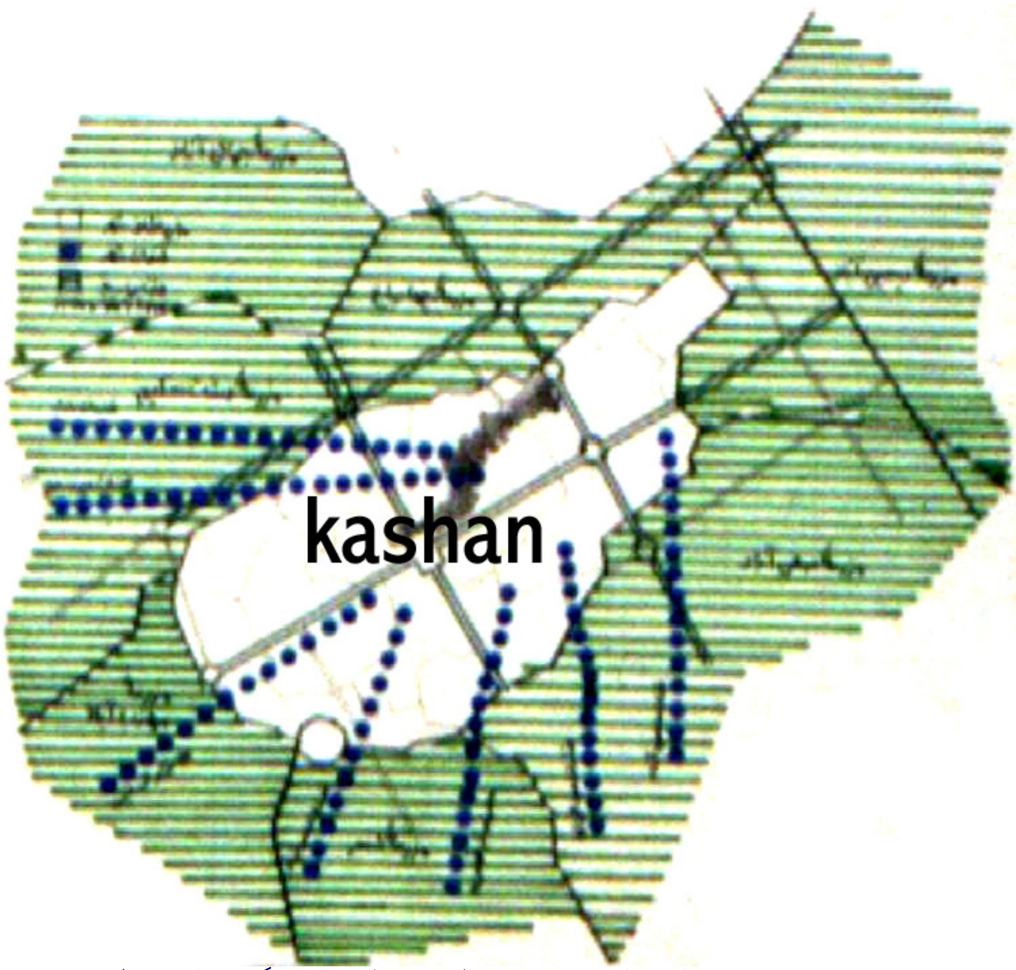
3.2 Geographical location of Kashan

Kashan lies within the latitude of 33.35° to 34.25° and the longitude of 50.54 to 7.52 respectively. According to the divisions of the country, it is part of the Esfahan Province (Iran) at a distance of 240 km south of the capital (Tehran). The west and southwestern parts of Kashan are mountainous, whereas, the east and northeastern parts are of desert type. Elevation ranges from 3251 meters in the southwest of Kashan to 800 meters in the Salt Lake (east of Kashan) such that Kashan lies at an average altitude of 945 meters from sea level. The annual rainfall is 153.1 mm and the annual rate of evaporation exceeds 2800 mm. Kashan has moderate winters, and dry and warm summers. The average minimum temperature is in the month of January (0.8° C) and the maximum temperature is in summer months (38.9° C). On average, the temperature difference within a year varies between 12.5° C and 25.7° C. The difference of day and night temperatures is distinctly high, and in the summer it is as much as 15° C. The annual rainfall within the period of 1962-92 has been registered as134.9 mm (ranging between 47.1 mm and 30.45 mm)[5]. Bearing a coefficient of 4.8 related to its dry climate, Therefore, Kashan is situated in a climatically **dry and arid region** and can be considered to have a desert type of climate.

From the historical point of view, Kashan lies in one of the archaic regions of Iran with a civilization dating back to 7000 years (the Sialk Civilization). In addition, the city of Kashan stands as an example of an Oriental Islamic city, enjoying from an architecture that reflects the intermingling of the Iranian civilization with a barren and dry region.

3.3 Qanats of Kashan

5- According to the meteorological center of Kashan



شهر كاشان و قناتهاي مربوط به ان و تاثير قنئات در گسترش شهر و تجلي مبارزه با بيابان

As mentioned previously, the region of Kashan in the desert part is partially mountainous, and lies between two extensive areas, pertaining to agriculture and traditional irrigation. The desert area of Kashan compromises of the northern and northwestern parts. In the mountainous region, which is to the southwest, water resources are usually from rivers, springs and Qanats. Due to high potentials in orchard keeping, this occupation tallies with agriculture or at times even supersedes it. Plains at the foothills between the two regions mentioned, dominate where population is concerned (both rural and urban). In this circuit it can be stated that suitable topographical conditions contribute towards the presence of Qanats and this in turn has contributed to the distribution of population in this area.

In Kashan because of the variation of the topography of the region different kinds of Qanats are present: mountainous Qanats, those in the plains, desert Qanats, short and lengthy Qanats, deep and semi-deep ones, those with a high output of water in comparison to the ones with a low output of water, and those from dams (the so-called *hava neggar* and *zamin neggar* types).

Qanats that have permanent beneficial values are again classified. The former are those that are lengthy, with vast and deepwater resources in comparison to the surface of the land and are usually in the plains.

Such examples can be found in the villages of *Fakhreh, Ali Abad, Mohammad Abad*, *Abu Zeid Abad, Kaqazi* and *Hossein Abad* of Kashan. Qanats that reveal variations or are seasonal are those that depend on rainfall or actually serve as dredgers for rivers or flood waters. Examples of these types are found in *Shahriyar, Reyjan, Amin Abad, Yazddelan* and *Ghaem Abad* villages of Kashan.

Deep Qanats in Kashan are those with a mother well ranging from a depth of 5 meters to over 45 meters which vary distinctly (**tables 4-7**). From this point of view, the region is a suitable one to be further studied.

The number of Qanats present in Kashan, Aran and Bidgol according to recent statistics is approximately 489 consisting of different types. Details of the Qanats in utilization are given in tables 4, 5, 6 and 7. Considering variety of Qanat types in Kashan and after conducting field surveys, a few of these Qanats, consisting of desert, plain, mountain types, have been selected for further in depth research. The Ghazi Qanat is only one example to illustrate the indigenous knowledge and management system that lie behind these ingenious structures that are part of the global, regional, and national agricultural heritage sites.

In Kashan, the division of water rests on a specific system. Usually Qanats are under the ownership of several persons and each has his share (**Table 4**). But all the owners abide the regulations entailed, and no problems arise.

In Kashan, the circuit of water circulation (rotation) is known by the term of '*zooregeh*'. This refers to the duration when the owners utilize their share of the water which varies between 6-12 days and nights. Each duration that is, night and day is divided into half, and each half is known as '*tagh*'. For each '*tagh*' a person is responsible for the division of water. Furthermore, each '*tagh*' is known by the name of the person (*sartagh*) who owns the same, and this is hereditary. The '*sartagh*' is held in high respect.

Each '*tagh*' is divided into two, that coincides with 36 degrees and each degree coincides with 9 minutes. Every 2 days and nights is called one block, at the apex of which is a person responsible and is selected usually for this purpose from one of the '*sartaghs*'.

Cooperation is not only within the confines of water usage or sharing between the people concerned in the region, but this cooperation is apparent in other areas such as agriculture and social activities. Thus, this grouping of '*taghs* and blocks' relative to irrigation further extends cooperation in the rural community at large.

3.4 An ingenious irrigation system: Example of Ghazi Qanat

The Ghazi Qanat is located 10 km northeast of Kashan in the desert parts. This Qanat irrigates a plain under the same name near the town of Bidgol. The characteristics of Ghazi Qanat are summarized below:

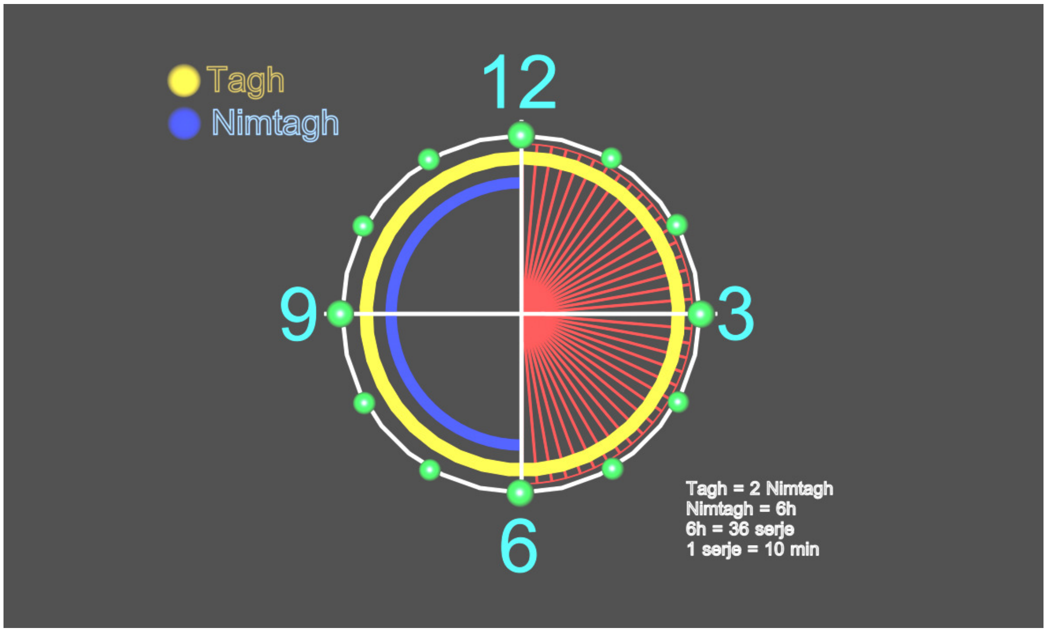
Characteristics of Ghazi Qanat
Length = 36 km
Depth of Mother Well = 22 m (in one branch)
Furnace characteristics = 1.5 m height, 40 cm width
Number of *Millehs* = 650 (with a distance of 40-50 cm between each)
Debis = 30 cm/s
Number of owners = 50 people

Water division is an important issue in the Ghazi Qanat. Water circulation or rotation in order to allow every shareholder/owner of the Qanat to use their water rights consists of a period of 8 full days (days and nights). In Fall and Winter when less

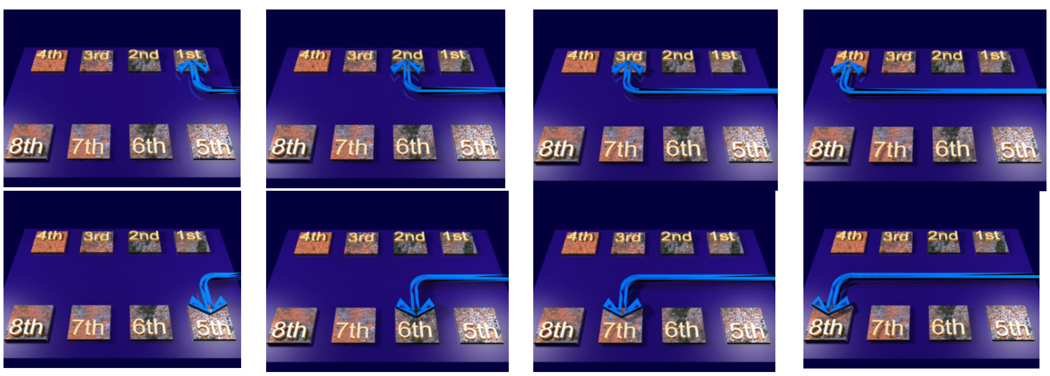
water is required, this period extends to 16 full days.

مظهر قنات قاضي

In Kashan area, a unit for water division is called "*serje*" which equals to 9.6 minutes. Every 12 hours is called a "*Tagh-ab*" and person responsible is called "*Sartagh*". *Sartagh* is in charge of distributing water between owners during the 12 hours of his supervision. This is a position that is inherited from father to son and in general *Sartagh*s are well respected by the farmer community.

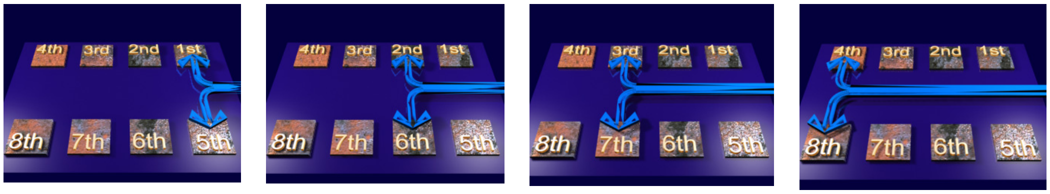


Within each *Tagh* the rights to water are equally divided such that the turn for irrigation at each rotation (or *Madaar*) will shift. For example, the owner who is first in the first rotation, will be second in the second rotation and third in the third rotation…This shift of turns also happens between two *tagh*s-*abs* (between night and day) such that in the first rotation water will be used during the day and in the second rotation during the night



Water Rotation during 8 days

Water rotation (*Madaar-ab*) in the warmer summer months (beginning of Spring and during summer) is reduced to a period of 8 full days and during Fall and Winter when water is more available it extends to 16 full days. This is because in Summer months weather is hot and dry, and crops need to be irrigated more frequently. Farmers even go as far as using only half of their water in each *tagh* and giving the other half to the *tagh* that is symmetric to them (which normally should get water in the next four days), and *vice versa*. In this way every 4 days farmers will have a right to water which helps in more regular irrigation of their crops.



Watter rotation in 4 days

Division of water rights and the water distribution system is a traditional method that involves team work and order. Such collaborative work can be observed not only in the irrigation system but also in other activities related to agriculture and rural societies. In general there are strong relationships between people of the same *tagh* which also affect their daily life together.

As mentioned previously, the unit for water division in the Ghazi Qanat is *serje* and 72 *serje* forms a *tagh*. Each *tagh* is a unit for irrigation that is supervised by a person called *Sartagh*. People of the same *tagh* usually help each other with the cultivation also on a rotation basis. Every two days and nights or every four *tagh*s is called a *Blook*. In the past there used to be a person in charge of each *Blook,* called *Sar-Blook* but now the unit for collective irrigation is *tagh* which consists of a system of *Boneh* between owners and farmers. The following table attempts to summarize this traditional system of division of water rights:

Comments	**Shares**	**Duration**	**Unit name**
Hot summer months	1200	8 full days	**Rotation period (*Madaar Gardesh*)**
Fall and Winter	1200	16 full days	**Rotation period (*Madaar Gardesh*)**
	150	2 *taghs*	**Full days (day + night)**

Therefore, the whole water rotation period and existing shares of the Qanat are divided into four *Blooks* (with a *sarblook* who is supervising each *Blook*). Each *Sar blook* is divided into four *taghs* which have one *Sartagh* supervising them. *Sartagh* himself belongs to the farmers community. He is in charge of dividing the water between all shareholders. Each *serje* for irrigation is 9.6 minutes and has a difference of 10 minutes with the official *serje* which becomes 6 minutes in one hour. In general 3 minutes goes to *Sar Blook* and 3 minutes to *Sartagh*. In addition, one day all members of the same *Blook* will help them (*Sar Blook and Sartagh)* with the harvest.

The task of water division in each *tagh* and its distribution between *tagh*s is the responsibility of *Sartagh*. In the meanwhile the farmers belonging to the same *tagh* will obey the *Sartagh* about what kind of crop to plant. *Sartagh* is also responsible to collect the money for cost of dredging and renovation of the Qanat in his *tagh*.

3.5 Role of Qanats in Agro-biodiversity

نهوه ابياري به دشت قاضي

3.5.1 Methods of agriculture and type of cultivation

From the long past in Kashan, Qanats were on the basis of ownership. Thereby, factors that caused a weakening or depreciation in agriculture and inheritance legislature restricted this system from gaining expansion. In that, the presence of superior (bigger) owners was ruled out. This aspect affected other spheres in this connection such as, the upkeep and protection of Qanats, division of water, or even where enjoying a share from cultivation is concerned. So each plot is usually irrigated and cultivated by those who own the land. This is performed in turns or with the help of each other.

Besides being divided into plots for agricultural purposes, the plots belonging to an owner may be scattered, but this too is dealt with as if it is one piece of land. In that one kind of crop is cultivated in plots near each other in alternate form. The '*mirrab'* or the person responsible for water distribution and thus irrigating the land defines the same. Moreover, in keeping with the type of land and the amount of water it contains, after one or two years of cultivation the land is left fallow. In every Qanat usually a part of the land is kept aside for orchard keeping purposes, these plots are adjacent and are cultivated alternately. Such as one crop is cultivated every one and the next year this varies. In areas where there is adequate supply of water, this may lead to the cultivation of two or three types of crops annually.

A pool at the source of the Qanat is known as '*salkh* 'in Kashan. It is at this juncture that the intensity of the water flow is controlled en route to the Qanat. Normally the division of water at this point takes place in the presence of the '*sartagh*' and '*mirrab*' or water distributor who is well trusted and respected by the community at large.

As mentioned previously the rights over water in the Ghazi Qanat is farmer-owner type. Each owner has one to several *serje* which is related to the amount of land he owns. Each *serje* is for 625 m2 of land (or one *jarib*). Each owner has one or several small pieces of land distributed in the plain. All the lands within the plain are irrigated with the Qanat water and are divided in three according to their distance from the Qanat. In each section land is divided according to type and quality. Each owner has one or several pieces of land. According to the cultivation system in place, every year one section of the plain (or one *jarib*) is allocate to the Fall cultivation and one jarib to Spring cultivation. One *jarib* will be left uncultivated (*Ayesh*). In the Fall, usually crops such as barley and wheat are cultivated. And the Spring cultivation includes other types of crops such as sugar beet. Each farmer has also usually a piece of land allocated for orchard keeping (i.e. growing pomegrenades). Although land is divided into small pieces but the fact that farmers consult with each other and also with *Sartagh*, there is some kind of harmony in the cultivation system. This collective system of working and using the Qanat also compensates for the disadvantages of having multiple but small and highly distributed pieces of land..

Third year	**Second year**	**First year**	**Name of the plain**
Ayesh (left uncultivated)	Spring cultivation	Fall cultivation	**Upper plain**
Fall cultivation	*Ayesh* (left uncultivated)	Spring cultivation	**Riguestan**
Spring cultivation	Fall cultivation	*Ayesh* (left uncultivated)	**Ghazi**

Part of the upper plain that is closer to the Qanat and *Mazhar* is allocated to orchard keeping. Fall cultivation starts from Oct.9th to May 5th each year and includes barely and wheat. Spring cultivation includes crops such as melon, onion, turnip, sugar beet, tobacco, cotton, and alfalfa.

Apart from the water division and distribution system, as farmers and *sartagh* are all aware of what is being cultivated and where, diversity is better protected. This is all part of the traditional knowledge of farmers: For example experience shows that the best tobacco grows in hard soil whereas loose soil will produce average quality tobacco. Or for example, in cultivation of watermelon and melon, each seed has its own characteristics (fast growing or slow growing).

3.5.2 Example: Planting watermelons in the desert

چاله سمبک براي كاشت هندوانه و خربوزه
مرز بندي هاي بين كرت ها براي حفاظت كرت از شنهاي روان ميباشد

The farmers of the Ghazi Qanat gradually have found out how to live with the desert. An example which illustrates this traditional knowledge is the technique of planting watermelon within sandy desert. In Kashan, they call this type of cultivation *sambak*. Rising the underground water levels in the desert (Sambak Plain of Ghazi area) up to 1 meter, farmers plant watermelon by digging holes that are 1 m deep and 30 cm wide and then cover them with different layers of soil in such a way that first they fill it with the top layer of soil (most heated by sun) and then add 10 cm of animal fertilizers, and finally cover it with the most humid layer that has been extracted the hole. They place the watermelon seeds inside the soil and prepare some kind of barrier against the moving sand and wind in the surroundings of the hole. As the seed grows the farmer irrigates it little by little. Once the root reaches the layer with fertilizer, there is no further need for irrigation.

كشت هندوانه در دل كوير در رملهاي مربوط به دشت قاضي كه سرچشمه قنات قاضي به شمار ميرود

In fact farmers use each watermelon species for a specific purpose. They carefully select the seeds and believe that watermelon seeds are best four days after harvest. This is how agriculture using Qanats has survived and adapted to the desert environment in Kashan area, also preventing desertification and establishing a sustainable system

4. Threats to Qanats:

4.1 Evolution of Qanats

Qanats have been perceived in different ways at different times. The following summarizes how this perception has evolved:

In the ancient past, traditional farmers had a critical role in the economy of the region and were supported by other sectors of the society. Most tradesmen, governors, etc. had some share in agriculture. Cities as well as rural areas were all dependent on agriculture and thus on Qanat systems.

In the years 1930–1960, vital factors regarding Qanats have not been brought into focus, but touch on subjects relating to underground waters and Qanats that have been in use in those years.

In the post 1960's till approximately 1970, due to an increase in population, industrialization, urbanization and migration, written matter in connection to Qanats have increased, mainly posing the questions on whether to choose a Qanat or a well. In 1957, the first wells were constructed in Kashan (especially during 1967-1977).

During the years 1970–78, namely the Iranian pre-revolutionary period, and in the last decade, a heated matter of discussion has been raised on the adversity between wells and Qanats. This proclaimed a serious threat of the drying up of Qanats and thus an equal threat to the diminishing aspects of the Iranian civilization in respect to the beneficial utilization of underground waters. In Kashan alone, from 1957, when the first wells were constructed up to 1977 when their number reached 170, ground water table levels dropped to 10-40 m. This increased up to 20-25 m and even reached 30-60m causing many Qanats to dry up.

After the 1978 Revolution in Iran, especially from 1978-1988, due to lack of clear policies and regulations the number of wells increased and Qanat systems became more and more endangered. Especially with the aim of increasing the area of the cultivated lands and reaching agricultural independence, more permits were issued in favor of wells and in 10 years time the number of wells doubled. As a result, the water table for underground waters dropped (reaching 50-80m). Most of the Qanats that were surrounded by wells went dry and the water quality also dropped as a result.
.
In the past few years, due to lowering of water table levels and increasing salinity, the Ministry of Agricultural Jihad has started to revive the Qanat systems. Although these efforts have been so organised, but they have proven to be relatively effective.

Another government organisation which has had an impact on the Qanat systems through its policies has been the Ministry of Energy (Water Affairs). For example, this Ministry has issued permits to landowners giving them the right to replace Qanats with wells (even in plain areas where construction of wells was forbidden previously).

Since the 1990s, some policies have been in place for revival and maintenance of the existing Qanats in addition to larger watershed management programmes undertaken by the Ministry of Agricultural Jihad. Several seminars and conferences were also held in Iran with the main concern of "Salvaging Qanats" all over Iran. However this issue was put up more seriously for discussion towards the end of the second millennium, when great efforts were made to organize an international gathering on Qanats in the city of Yazd (1999/2000).

4.2 Current Status

Regarding the number of Qanats present in Iran prior to the year 1954, diversity of opinions exist and a concrete estimation is difficult to obtain. The unofficial statistics stand at about 50000 Qanats at that time. But from 1973 onwards, various governmental authorities have taken records such that, in the year 1973 these official statistics disclosed a number of 15500 Qanats in Iran. In early 1976 an agricultural census took place by Iran Statistics Organization, and according to this census, there were approximately 5300 Qanats that were in circulation. Thereby, taking into account the number of those in circulation and otherwise could be approximated at 20800 Qanats. **Table 1** attempts to summarize these figures and give an overall picture of an increasing trend of decline in the number of Qanats in Iran.

Whereas the official statistics revealed a total of 18400 Qanats in 1978, according to the recent records in 1998, the total number of Qanats was 32164 (with an annual output of 9.823.000.000 cubic meters) approximately 77.7% of which lie in eastern Iran and the remaining 22.3% are in the western part of the country.

Annually about **9 billion cubic meters** of agricultural water in the country is provided by Qanats. Thus, restoration and maintenance of Qanats plays an important role in the level of productivity and eventually per capita income of the country.

4.3 Dilemma over wells and Qanats

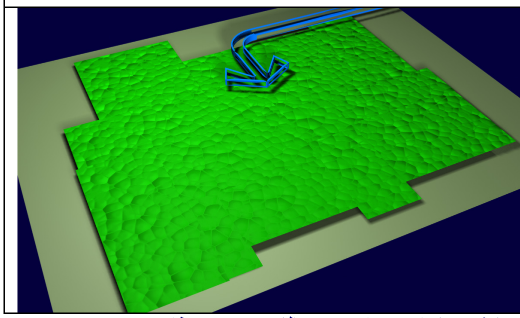
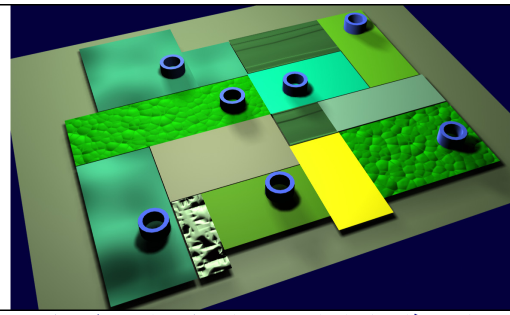
In areas where Qanats still exist, deep well can also be found but deep wells in some areas have completely destroyed Qanats. A comparison between a well and a Qanat can reflect the relative advantages of each. The level of income of a farmer from a well or a Qanat when having the same share in each can be described as follows, showing that a Qanat is more economical in long-term for agricultural purposes:

	Qanat (Cost in Rls.)	**Well (Cost in Rls.)**
Cost	20000 Rls./*serje*/ year 25x20000 = 500000	20000 Rls./hour/month Cost of fuel and engine service: 6 hours x 20000 = 120000/month Cost of fuel and engine service: 12000 x 8 = 96000/year Repairing costs = 540000 Rls.
Total	500000 / serje	1500000 for about 36 *serje*
Income	Tobacco = 4000000	Chicory (*kassni*) = 2900000
	Barley = 2400000	Carrot (*zardak*) = 280000
	Hay = 900000	Cotton = 900000
	Onion = 600000	Sugar beet = 1800000
	Turnip = 500000	Turnip = 250000
	Sugar beet = 2100000	
	Pomegrenade = 576000	
Total	11076000	8650000

While using a Qanat the level of income of a farmer is 1.3 times more than the amount he earns using a well. For lands irrigated by a Qanat for each *jarib* of land (625 sq.m.) for example to cultivate alfalfa 2 kilos of seeds are required, whereas using a well 12 kilos of the same is required. Considering these costs, the difference in income level of a farmer is relatively high, and thus the choice between a well and Qanat becomes a simple one. In fact. land related to a well is usually of a lower quality and less suitable for cultivation. As a result, some of these costs are incurred to the land and results in the need for expansion of agricultural land to increase income.

Some other advantages of a Qanat compared to a well are as follows:

Well	**Qanat**
Usage of groundwater sources more than the existing capacity	Usage of groundwater sources according to the existing capacity
Unsustainable use of water resources	Sustainable use of water sources
Worsening of water quality with respect	Protection of water quality and its

to salinity and hardness	amelioration in long-term
After a while agricultural lands are degraded and left unused	Improves agricultural lands and enhances cultivation in long-term
Worsening quality of land	Better quality of land
No cultivation system to follow	A cultivation system that works
Weak collaborative work	Strong collaborative work
Unsustainable agricultural communities	Sustainable agricultural communities
Enhances desertification	Prevents desertification
Unsuitable drinking water for rural and urban dwellers	Very suitable drinking water for urban and rural dwellers
	

در مقايسه نظام چاه با قنات متوجه اين نكته بارز ميشويم كه در قنات كشت يكپارچه با وجود مالكين متعدد نظام مديريتي منسجمي را داراست كه الگوي بومي تعاون به شمارميرود ولي در ابياري با چاه موتوجه خودسري در كاشت كه حاصل از بين رفتن نظام مديريتي و از بين رفتن انسجام است ميشويم.

4.4 Decline in the number of *Moghanees*

Finally, another major reason for the decline of the Qanats could be due to a decrease in the number of 'driller'. For the past three decades the number of 'drillers' in the country have decreased and this is said to be due to the following reason:

a) The necessary attention to be paid to these 'drillers' is not fulfilled by the government that is, in respect to their welfare and living conditions.
b) A change of employment by these workers who have for instance become miners.
c) The absence of an insurance scheme (relative to their work and area of expertise).
d) Insufficient wages in comparison to work entailed and also in respect to work in other fields in a similar category.
e) The absence of any kind of support or backup such as pension in old age or in case of a handicap related to work.

4.5 Changing system of ownerships

On the other hand, agriculture pertaining to lease and shares (*nezam-e-sahm bari, nezam-e-waghf*) comes under a particular managerial control which in the past was controlled by the owners of the Qanats and the cultivators of the land. Today, a part of the lease management is under government control and this has taken from the personal incentives in maintenance of Qanat systems. Traditionally, personal incentives and a fear of damage or loss were reasons to more sustainable use.

5. Sustainable development options

While the annual increase in water utilization in the country is 18 billion cubic meters, from an economic, environmental, social and cultural point of view, development and proper channeling of a part of the countries financial resources towards the protection and maintenance of Qanats will prove beneficial.

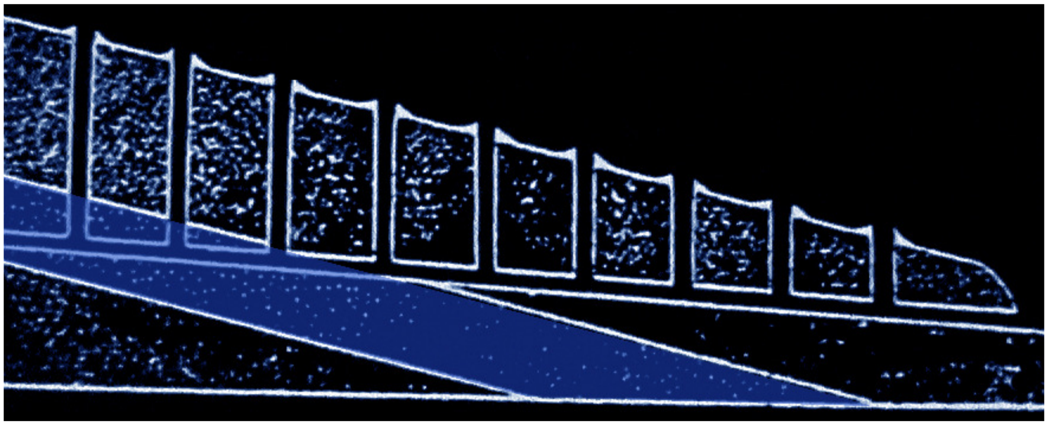
There are several sustainable development options to help the survival of Qanat systems in Iran which are briefly mentioned below:

- Establishement of a comprehensive 'data bank' rendering information on existing network of Qanats in Iran and worldwide (including related socio-cultural aspects and indigenious knowledge);
- An economical analysis of costs and benefits of new technologies (such as wells) compared to historically proven technique of Qanat systems;
- Identification of the root causes of threats to Qanats (especially focussing on the Kashan case study);
- Sharing lessons learned at national and regional levels;

More detailed description of this section and each option needs to be inverstigated in the field through a careful analysis of at least one case study.

Annex I:

Diagram 1- Diagram of a typical Qanat structure



Qanat Vocabulary:

Qanat Construction:
- Gamaneh zani
- Taraz keshi
- Tai'in mahal-e-milleha, tul-e-poshteha, jahat kureh
- Chah kani
- Douvel kani
- Tashkhees-e-jahat dar zirzamin

Qanat Excavation Team (schematic)

Moghanee
Guelband
Deloaviz
Charkhkesh
Deloguir

Rates of daily pay for each position:

Daily Pay (in Rls.)	Title/Position
60000	*Moghanee*
50000	*Guelband*
3000	*Deloaviz*
40000	*Charkhkesh*
30000	*Deloguir*

Qanat Tools:

- Nok teez, yek kadj beel, satl
- Vasayel-e-haml
- Vasayel-e-andazehgiri
- Vasayel-e-immani va roshanaie

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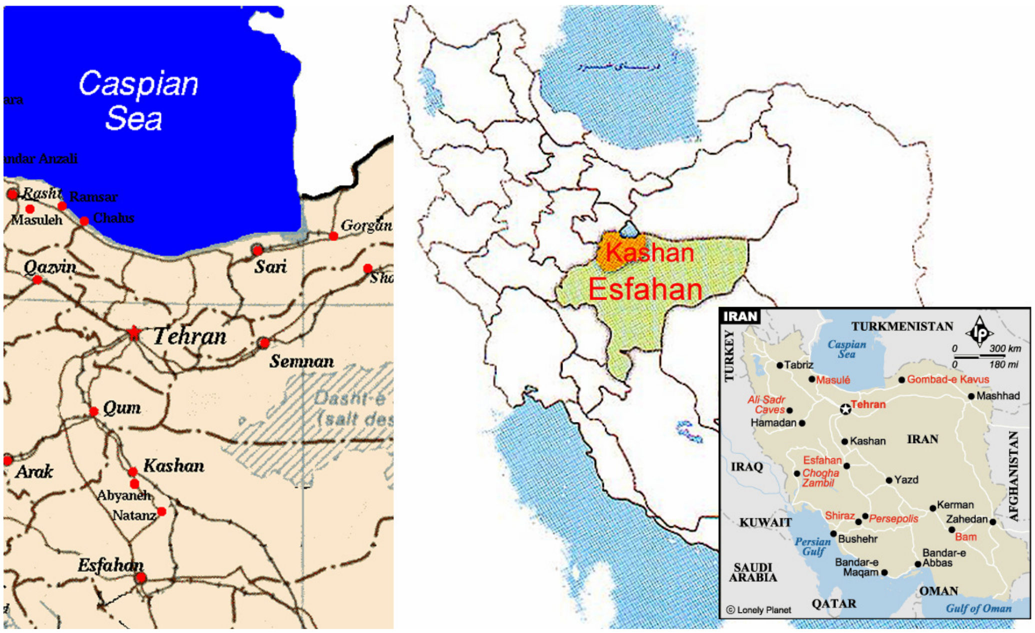
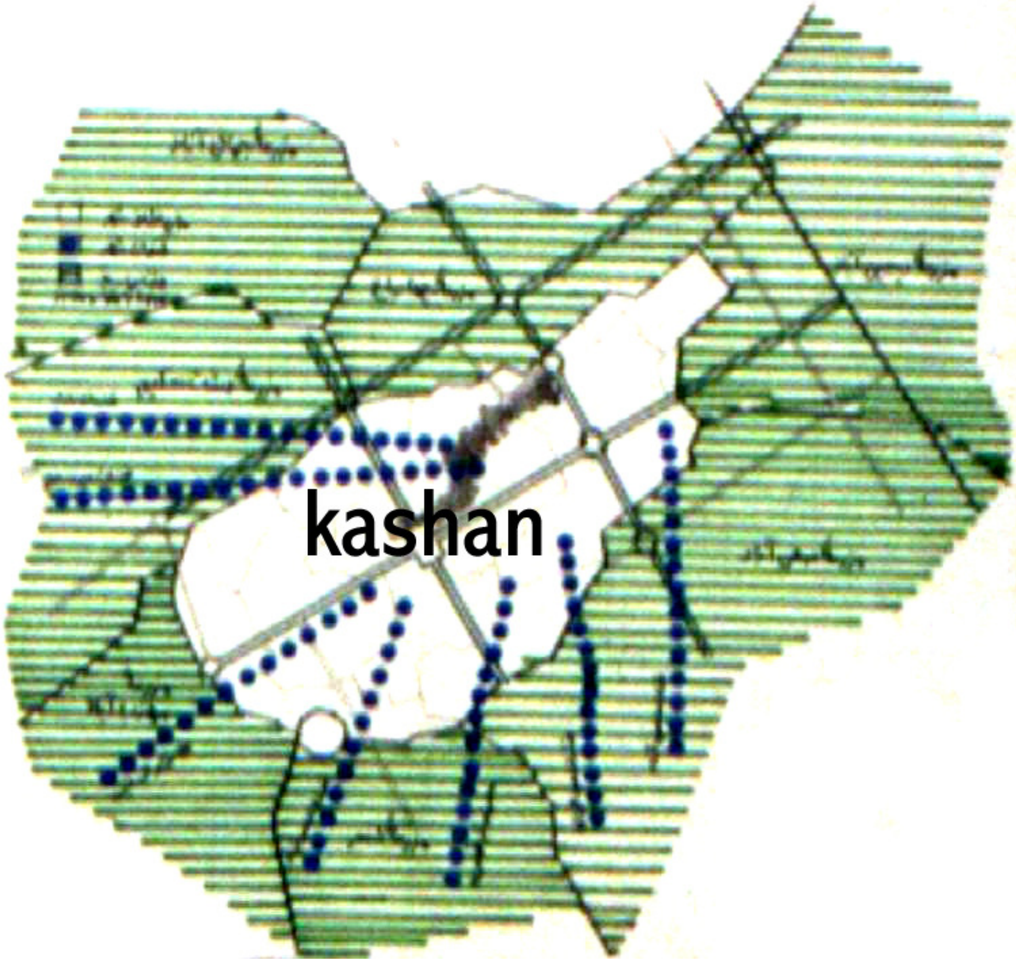
Annex II

Map 1- Map of the Qanat region showing cities along the Central Desert



Map 2- Map of Kashan showing location of Qanats



Annex III - Tables

Table 1: Illustrating the number of Qanats in circulation and those unutilized prior to 1976

Year	Utilized Qanats	Unutilized Qanats	Total
1954	21060	8570	29630
1961	22000	8000	30000
1963	20000	?	?
1971	14986	?	?
1973	15500	5300	20800
1976	15770	?	?

Table 2: Underground water resources and their annual discharge (in million m3) at national level (1999-2000)

	Spring		Qanat		Semi deep well		Deep well	Total discharge
Annual discharge	Number	Annual discharge	Number	Annual discharge	Number	Annual discharge	Number	
19023	49907	91758	31953	13327	301945	30646	112789	72174

Source: Ministry of Energy

Table 4: Classification of Kashan's Qanats according to ownership

+100	75-99	50-74	30-49	15-29	10-14	0-10	Number of owners
17	11	37	125	155	106	34	Number of Qanats

Table 5: Classification of Qanats according to area under cultivation

+100	80-99	60-79	40-59	20-39	10-19	0-10	Area under cultivation
4	5	12	50	260	143	14	Number of Qanats

Table 6: Classification of Qanats according to debis (rate of flow)

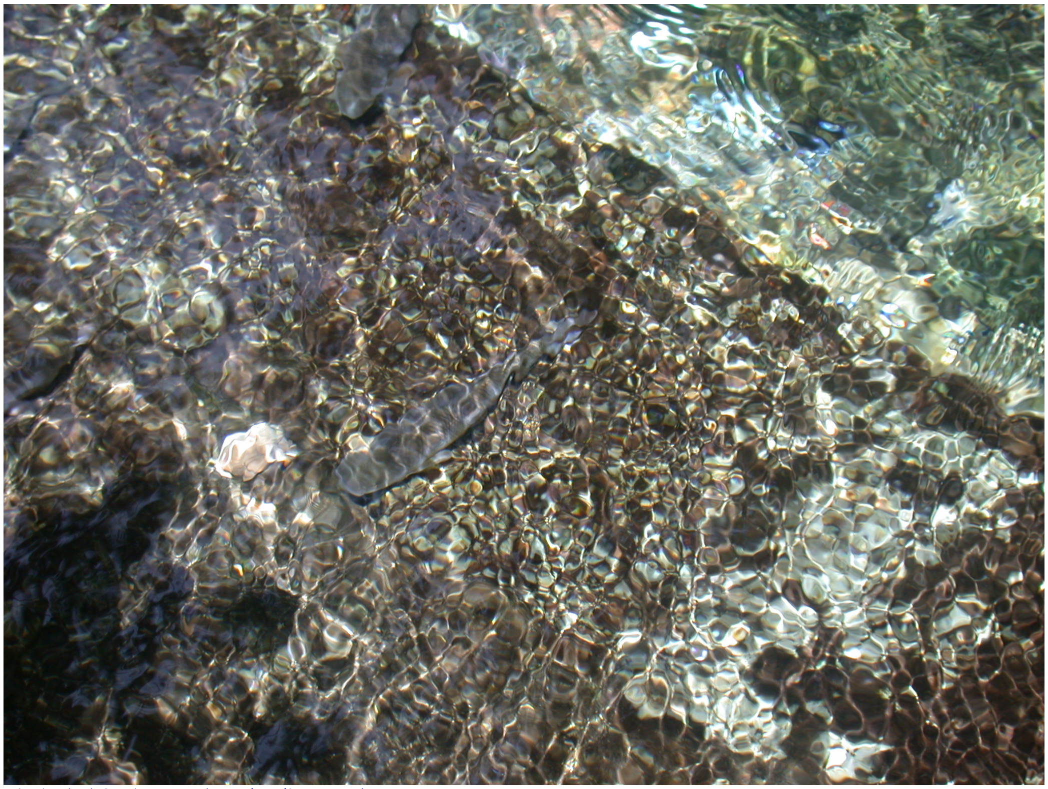
+10	7-10	5-7	3-5	0-3	Debis
134	68	113	148	32	Number of Qanats

Table 7: Classification of Qanats according to their length

+10000	5000-10000	2500-5000	1000-2500	750-1000	500-750	250-500	0-250	Length
2	13	12	81	77	190	85	27	Number of Qanats

شهر و قنات- قنات فین

چگونگی تقسیم اب و جوبهای ان


ماهی خوراکی(کورماهي) در اب قناتهای ایران


نمونه ای از محوطه سازی در پایین دست قنات

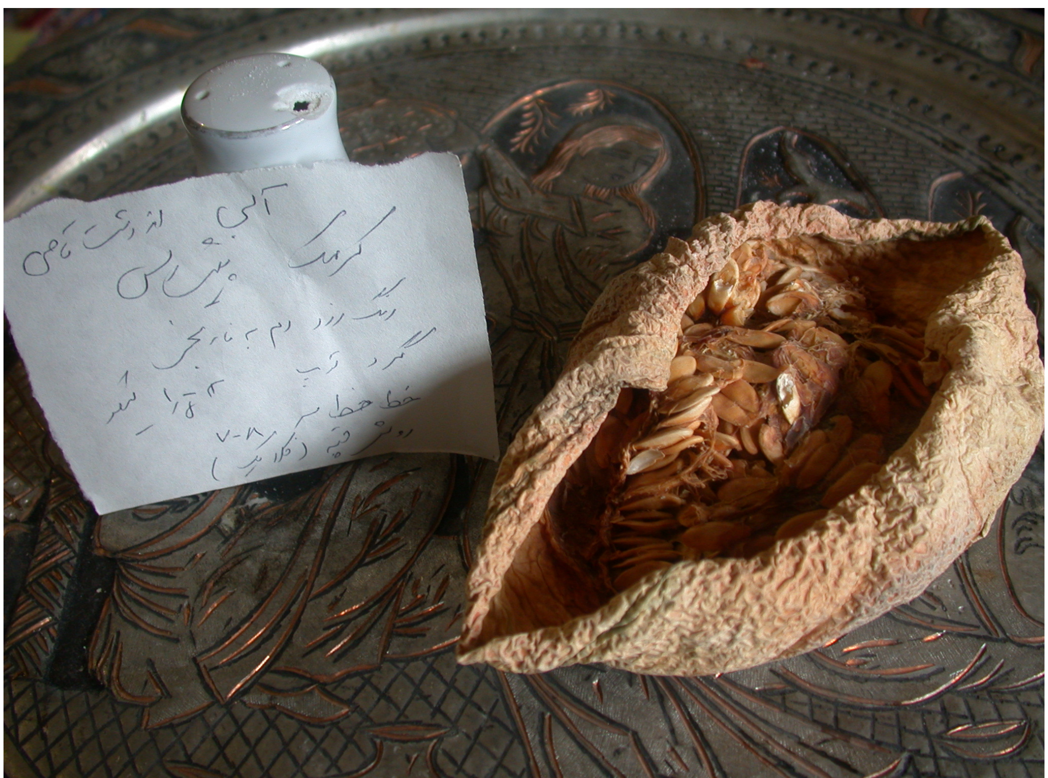
مظهر قنات قاضی

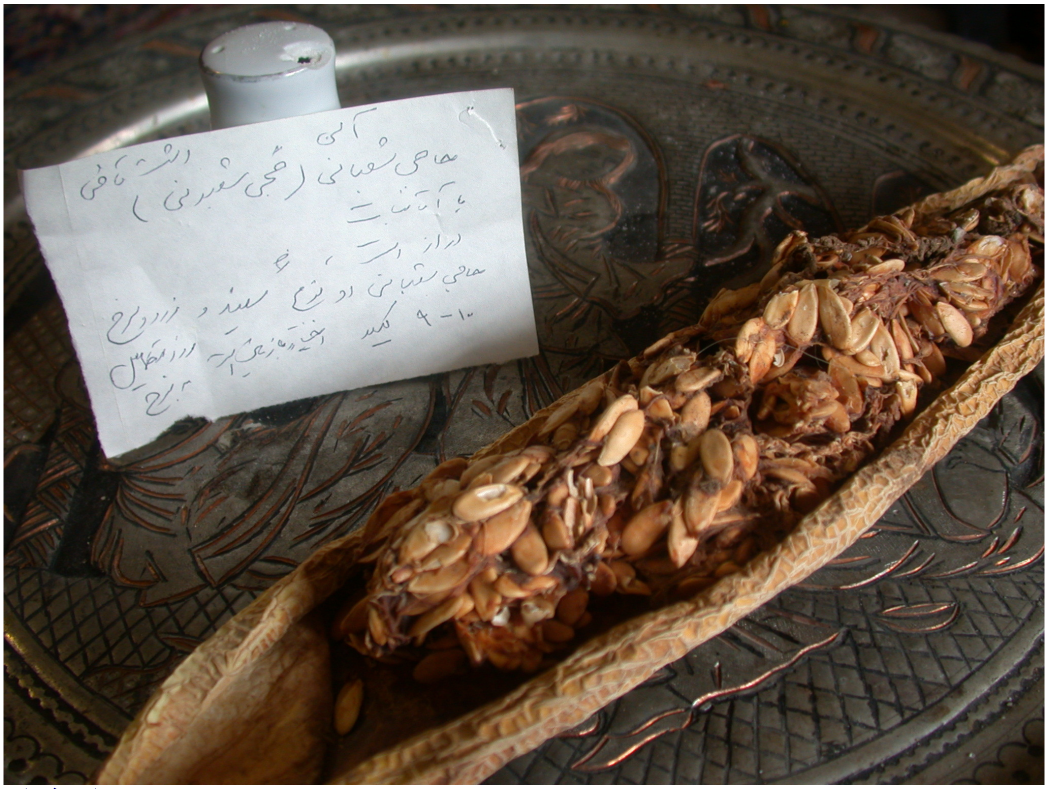
دروکردن جو ابی در دشت قاضی

سمبک نمونه ای از کشت سنتی هندوانه در دشت قاضی

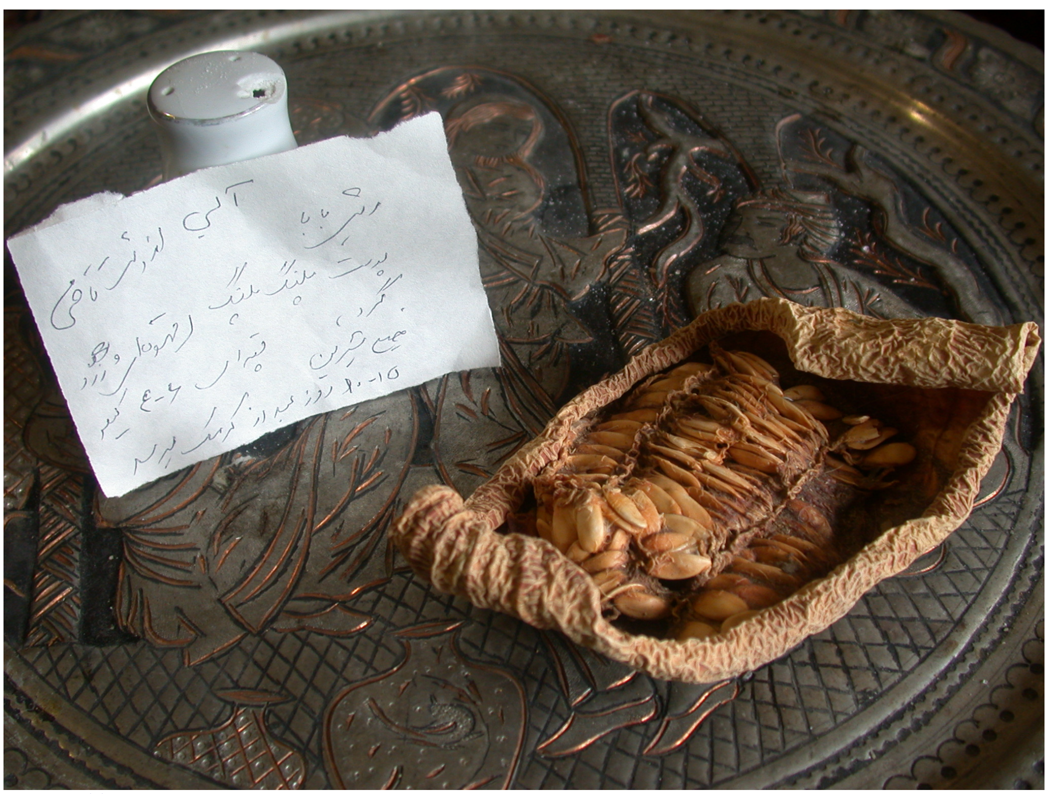
انجیر در دشت قاضی و نمونه ای از باغداری


توت سفید محصولی از اب قنات قاضی


گرمک ابی



خربوزه حاجی شعبانی



ریش بابا (خربوزه)

دشت قاضی نمونهای برای باغداری در سمت راست و کشاورزی در چپ

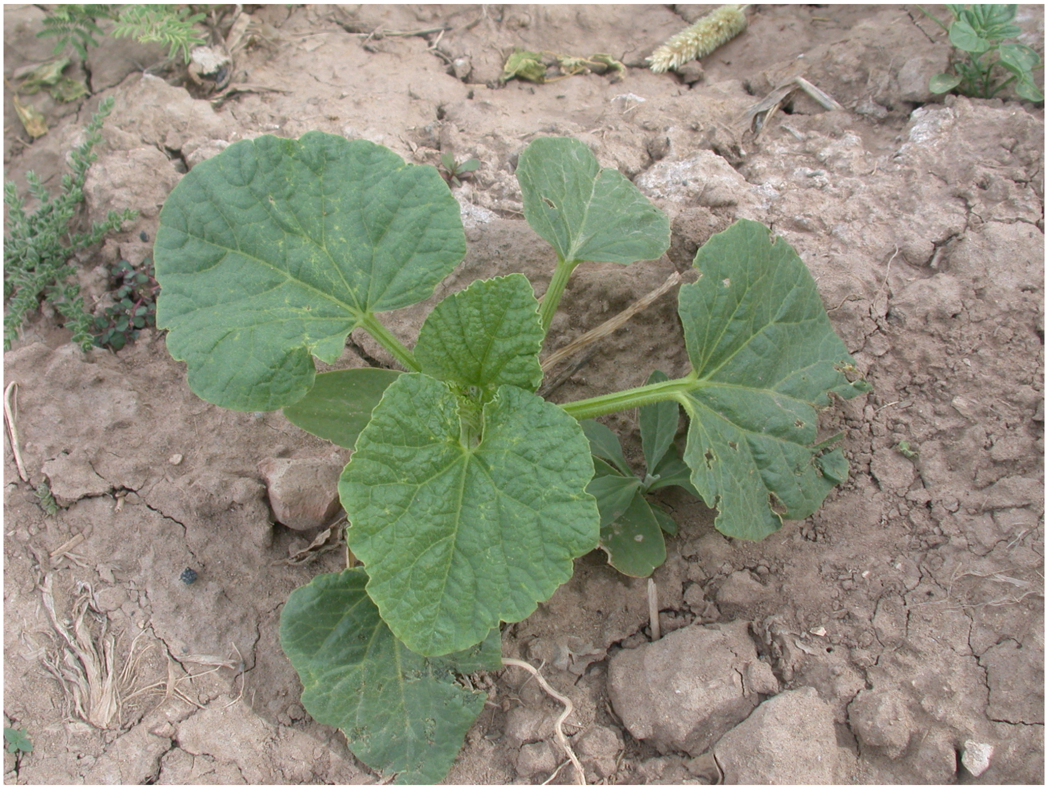
درخت انار


انگور


گوجه سبز

یاس برای محوطه سازی و مرز بندی در دشت

تنباکو


خربوزه


پنبه


باغاله


کلم

کشت تلفیقی گوجه فرنگی و خربوزه

کشت تلفیقی پیاز و کلم در راست و تنباکو و خربوزه در چپ
مدار ابیاري براي این دو کشت متفاوت است یعني پیاز وکلم نیازهاي ابي مساوي دارند و در ان سو تنباکو و خربوزه نیز نیاز ابي مشابه دارند.ولي نیاز ابي این دو گروه با هم متفوت است

هندوانه در کویر (سمبک)

یونجه