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# Qanat (Subterranean Canal) Role in Traditional Cities and Settlements Formation of Hot-Arid Regions of Iran

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***Abstract*—**A passive system "Qanat" is collection of some underground wells. A mother-well was dug in a place far from the city where they could reach to the water table maybe 100 meters underground, they dug other wells to direct water toward the city, with minimum possible gradient. Using the slope of the earth they could bring water close to the surface in the city. The source of water or the appearance of Qanat, land slope and the ownership lines are the important and effective factors in the formation of routes and the segment division of lands to the extent that making use of Qanat as the techniques of extracting underground waters creates a channel of routes with an organic order and hierarchy coinciding the slope of land and it also guides the Qanat waters in the tradition texture of salt desert and border provinces of it. Qanats are excavated in a specified distinction from each other. The quantity of water provided by Qanats depends on the kind of land, distance from mountain, geographical situation of them and the rate of water supply from the underground land. The rate of underground waters, possibility of Qanat excavation, number of Qanats and rate of their water supply from one hand and the quantity of cultivable fertile lands from the other hand are the important natural factors making the size of cities. In the same manner the cities with several Qanats have multi central textures. The location of cities is in direct relation with land quality, soil fertility and possibility of using underground water by excavating Qanats. Observing the allowable distance for Qanat watering is a determining factor for distance between villages and cities. Topography, land slope, soil quality, watering system, ownership, kind of cultivation, etc. are the effective factors in directing Qanats for excavation and guiding water toward the cultivable lands and it also causes the formation of different textures in land division of farming provinces. Several divisions such as orderly and wide, in-orderly, thin and long, comb like, etc. are the introduction to organic order. And at the same time they are complete coincidence with environmental conditions in the typical development of ecological architecture and planning in the traditional cities and settlements order.

***Keywords*—**Qanat, Settlement Formation, Hot-Arid Region, Sustainable Development

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## I. Introduction

IRAN is a water short supply land and our predecessors have been using so many ways to supply water for cities and farms without any kind of modern technology or pumping system, one of which has been using Qanat. Qanat technology which is invented by Iranian pitmen ages more than five or six thousand years and its age equals Iran's old history and is known since ancient times [1]. To achieve Qanat technology including design, preparing plans, discussions, operation and establishment has been known as one of the most important work of engineering history of Iran and world. Because, by the use of this technology some very important problems of water provision are solved in better way:

a) Due to the limits of the time in capturing energy sources, the water in hillsides of mountain were flowed into cities and villages of plain lands using the natural flow and gravity force of earth.

b) Prevention of water vaporization especially in hot and dry and less water lands. The covered tunnels of Qanat particularly earthen tunnels prevented water waist to a high degree. Recently in Iran water channels are made of cement to prevent the penetration of water to soil on its way.

c) Keeping water clean of surface pollutants and keeping it cool till it reaches to earth surface.

d) The immunity of underground tunnels against surface damages. In most battles the invaders destroyed everything on their way but Qanat has remained safe after all.

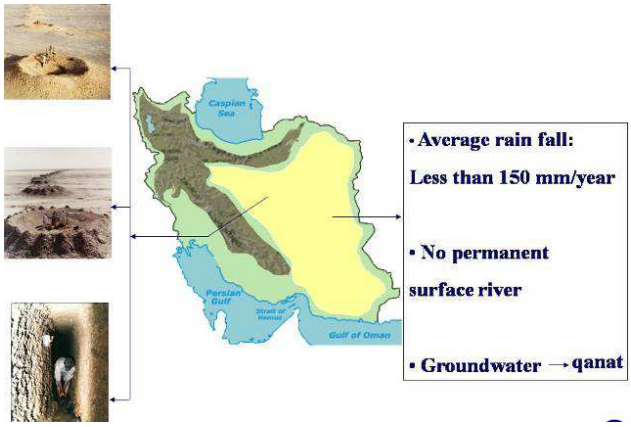



Fig. 1 Precipitation of Iran in Comparison to the world

This paper will present examples, of Iranian cities at the central Kevir parts of Iran, taking into account the function of the Qanats as the major factors in the establishment of the settlements.

## II. Qanat Structure and Specifications

Qanat is composed of an open opening and an underground

tunnel like vessel and some vertical shafts which connect the underground base shaft with earth surface in different points. Apart from transferring the excavated material outside the tunnel, the sub-shafts do the ventilation operation of underground channels and considered as connecting ways to dredging, repair and visiting inside the Qanat. The main parts of Qanat are:

a) The first shaft: This shaft is first dug, so it is the deepest one and the farthest from the water appearing point.

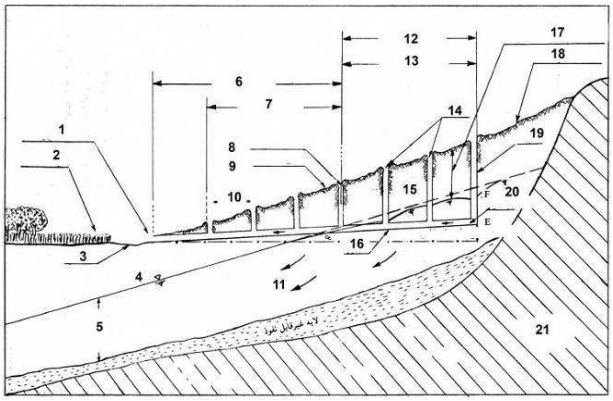
b) The appearing point: This is point water the tunnel meets the ground at a low point and the water flows on to the ground.

c) Shafts: There are well shafts that dug vertically to take out the soil of the tunnel and for the ventilation.

d) The tunnel: A long underground tunnel that carries the collected water to the ground, the tunnel has a mild slope [2].

Fig. 2 Shafts, Manholes, Tunnel

Fig. 3 Appearance (left) and Excavation (right) of Qanat

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|---|---|
| 1. Qanat outlet | 12. Saturated region |
| 2. Irrigated land | 13. Yielding wells |
| 3. Surface storage (Herang) | 14. Vertical shafts (wells) |
| 4. Water table | 15. Permeable layer |
| 5. Aquifer | 16. Yielding tunnel |
| 6. Dry region | 17. Depth of water table |
| 7. Dry wells | 18. Aquifer catchments |
| 8. Transition well | 19. The main well |
| 9. Ground surface | (Mother well) |
| 10. Well distance | 20. Dynamic water table |
| 11. Ground water flow direction | 21. Rock bed |

Fig. 4 Longitudinal section and main parts of a Qanat

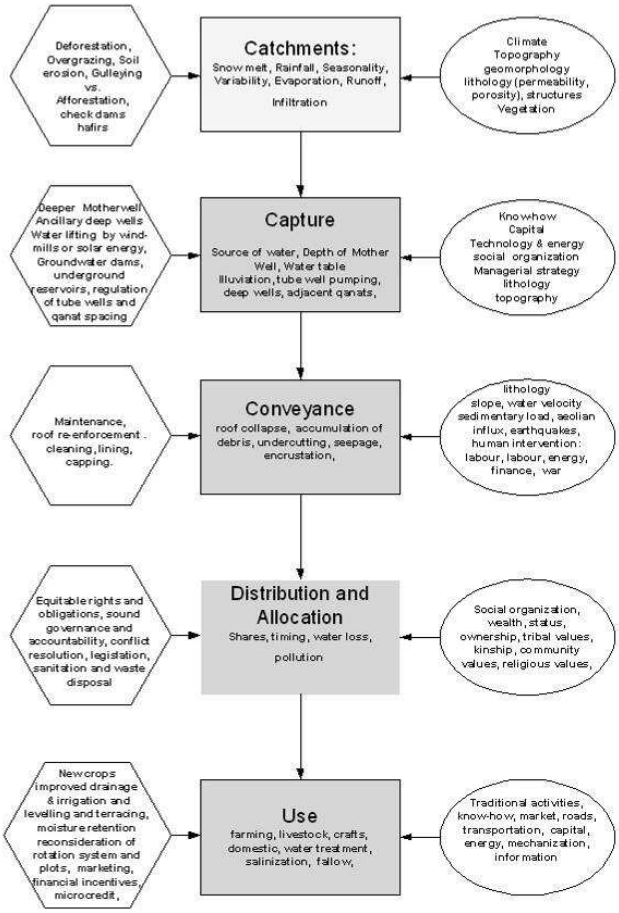


Fig. 5 Qanat cycle from catchment to use

## III. Qanat classification

Based on the length, Qanats are classified as long and short Qanats. Qanat conditions in Iran is also function of weather; the more the annual rain the less the length of Qanats and the less the depth of mother shaft and vice versa [3].

### *A. Short Qanats*

In mountain foot and hillside the slope of earth is more and the impenetrable layers and penetrable layers are prone to each other due to the earth slope. The lengths of these Qanats usually do not exceed some hundred meters and their prosperity in different years is a variable of rain level.

### *B. Long Qanats*

In plain land the impenetrable layers have smooth slope and are located parallel to penetrable layers; to obtain the path of impenetrable layer some hundred meters of base shaft should be excavated to reach the first point of impenetrable layer. To achieve a suitable and enough level of water provision we should proceed hundreds of meters in impenetrable layer path. Thus, the length of such Qanats may be more than tens of kilometers. Such classification could be based on the depth of base shaft from earth surface and classify Qanats to surface and deep Qanats. Another important classification is based on the water provision of Qanats; the stable or continual water provision Qanats and varying and seasonal water provision Qanats [4].

## IV. Environmental, Geographical, and Climatic Features of the Kevir and Margin of the Kevir Areas in Iran

The largest field of water – shed on Iran is the central Kevir plateau, specifically the Kevir-e-Lute. the central Kevir plateau is characterized by the very low rate of rainfall, poor plants coverage, salty soil, very hot temperature on the not days of the gear, dramatic difference in temperature between nights and day, the high heat of the radiation of the sun, the relative dryness of the air, and very sparse population. The central plateau of Iran is also formed of various fields with different sizes and forms different climatic conditions, and different rate of the rain fall. In all parts of the plateau, as one goes toward the center of the field, the soil granule becomes tiny until it leads to the center of Kevir with swamps or permanent salty lakes such as the salty lake of Qom, or the Swamps at Ardakan and Bafq cities (Kevir Area). It is worth noting that the living traditional settlements are dependent on farming. These farming fields are watered by the Qanats that drain water from the sand and big granule dispositions.

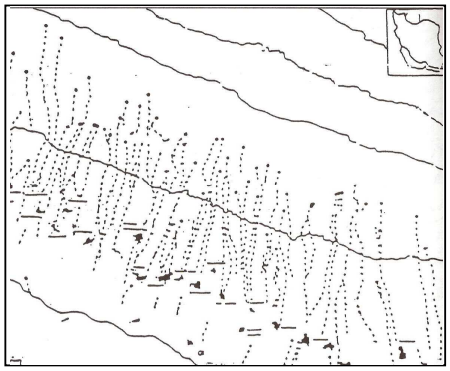

Fig. 6 Environmental capacity approach in compact settlement

## V. Determining Factors in Formation Establishment, and Location of Kevir Area Cities in Iran

### *A. The Function of Underground Water Resources as one of the Natural Factors in the Formation of the Cities in Kevir Areas*

Most of the settlements in the central part of Iran are located on the margins of Kevir and on the mountain sides at the Alborz and Zagros mountain ranges. The settlements are centralized cities with dense texture and at various distances. The water supply of these settlements is provided through the underground water resources brought into use by the Qanats [5].

### *B. The Function of Waters Supply Systems Technology as an Artificial Factor to Determine the Forms of the Cities in Kavir Areas*

The use of the Qanats as a technique of extracting underground water resources, the method of leading the water onto the farming fields and the cities from the water head of a Qanat to the farming fields, and altogether in a hierarchy formulate the roads system, among the cities in Kevir areas.

### *C. The Function of Qanats in the Systems of Establishment, and Location of the Cities in Kevir Areas in Iran*

Their function related to: a) The ground slope & topography and b) The composition & fertility of the soil.

The cities in Kevir areas in Iran are located on some special ground at specific distances. The slopes of the ground and its topography have been significant factors to help the people extract from underground resources via Qanats to be used for the agricultural purposes. These factors have determined the location of the cities. Moreover, the composition and fertility of the soil have determined the lands for farming on which the lives of the people depend. This factor has also been significant in the establishment of the cities. Therefore, the cities are establishes where the slope of the ground has allowed the People to supply water and the fertility of the soil has tempted to start cultivating the land. Consequently, the people have settled their lives on the clay soiled ground and they have dug Qanats in the big granule sediments [6].

*D.The Functions of Qanat in the Form of the Cities in Kevir Areas*

This type of function includes:

a) The amount of the Qanat water supply and the methods of extracting water from underground Resources and including three items: the texture of the cities; the passageways and the roads, network among the cities; The Size of the cities.

b) The density and the sparseness of the Qanats (the number of the Qanats).

c) The direction of the Qanats.

d) The form of the Qanats.

e) The permitted spaces to construct Qanats

*E. The Texture of the Cities*

Qanats are determining factors in blocking the ground for the agriculture purposes. The blocking systems of the agricultural lands have been affected by an organic order which is compatible to the condition of the ground, the irrigation system, the possibility of constructing Qanats and the amount of their water supply [7]. The ordering of the blocking systems of the grounds has been the basis of the rural settlements and, consequently, of the Kevir areas. There were three major production systems in the traditional Iranian civilization:

a) The production system based on grazing fields.

b) The production system based on the river water and the rainfall.

c) The production system based on Qanats.

d) The production system based on grazing fields has been used in the Northeast of Iran.

e) The production system based on the river water has been dominant around the Persia Plateau, including Mesopotamia, Khuzestan, and some parts of the Middle Asia.

f) The production system based on the Qanats has existed inside the Persia plateau and all around the central deserts is Iran.

g) The production system based on grazing fields and rivers produced some regular blocking forms narrow and long sizes.

These forms were used for the large fields with mild slopes or some flat fields. In this kind of blocking systems the urban centers were far from the farming fields causing the large segments of the grounds for the cities. The ownership system of feudalism is the result of this kind of blocking systems. The production systems based on the Qanats produced irregular form of blocking with small size scales. These forms were used for the fields with sharp slopes and for the farming fields with the dense cultivation systems. The farming fields were close to the dwelling centers of the people, causing the small segments of the grounds for the cities [8].

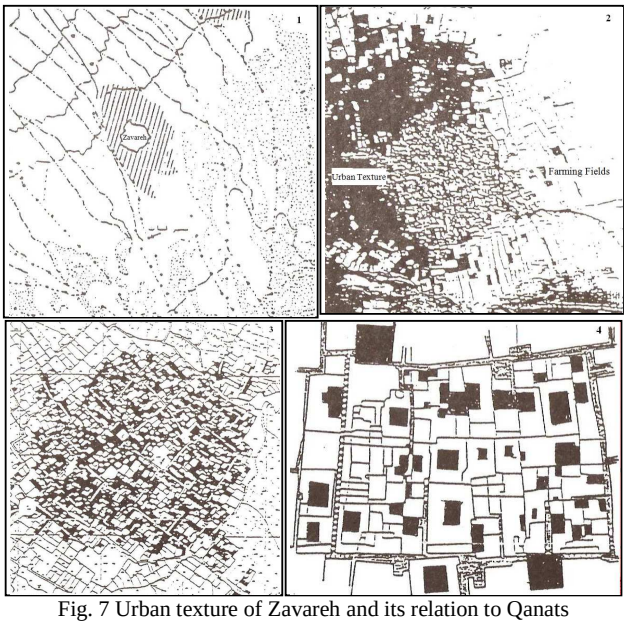


Fig. 7 Urban texture of Zavareh and its relation to Qanats

The dwelling places were densely located and were hear the farming fields. The petty landowner – ship was the result of this kind of blocking systems. The blocking forms of the farming fields were, directly or indirectly, changed into the dwelling lands. Since this replacement took place according to the legal procedures, the irrigation canals affected the size, shape, and the form of the urban constituents.

The farming fields that have Qanats with low amount of water supply are divided into small irregular lands in order that the irrigation can be easy. The urban texture affected by the irregular order of blocking the lands, is consequently having an organic checkered geometry. The farming fields with Qanats producing a high amount of water were divided into large blocks, and the texture of the cities are formed very regularly.

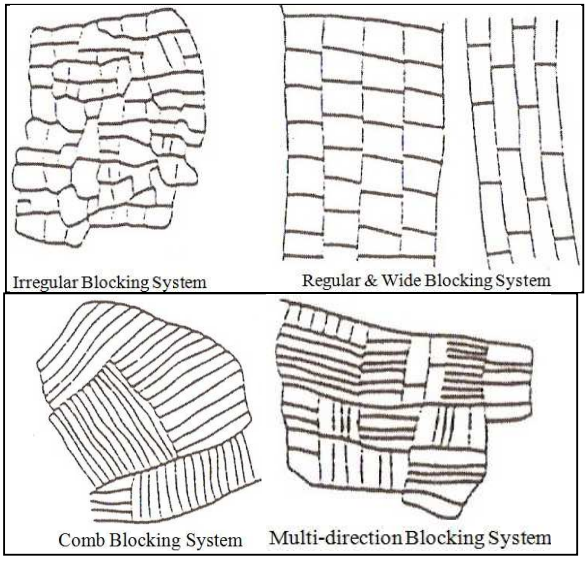


Fig. 8 Blocking system types for farming fields based on Qanat

*F. The Size of the Cities*

The Size of the Cities in Kevir area of Iran is directly dependent on the amount of water in the central watershed basin, the rate of the rainfall and the water reserves in the highlands, the depth of the underground water resources, the slope and also the penetrating forces of water into the ground as well as the capability of extracting the water. The amount of the water supply by the Qanats is an important factor in determining the size of the cities.

When the rate of the water supply hardly met the requirements of the population, the construction of the new houses reached its limit and the expansion of the city stopped physically. These villages and cities must remain fixed in terms of size, due to the limitations in the water supply.

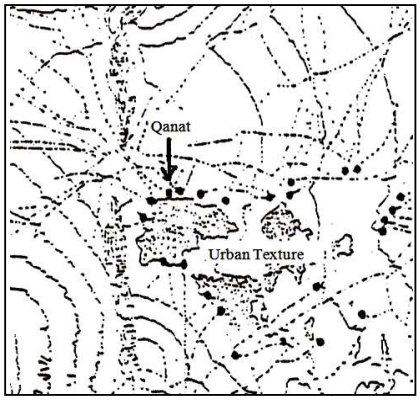


Fig. 9 The establishment of Mehriz City (Kevir Area), Iran in an ecological environment

*G.Density and Sparseness of Qanats*

The density and sparseness of the Qanats are two significant factors in the morphology of the urban structures. They affect the cities to be centralizes or spread in large areas. As the Qanats are close to one another, the urban sections become denser and denser, and as the Qanats are far from each other, the parts of the cities sparse over large areas. The alleys and passageways, too, are shaped accordingly: some narrow, long, winding valleys and some regular, wide, and straight roads [9].

*H.Density and Sparseness of Qanats*

The slope of the round and the topography of the land have been determining factors in the construction and direction of the Qanats. The direction of the farming lands and accordingly the direction of the dwelling sections of the cities are influenced by the direction of the Qanats. This factor is so important that it influences the climate. In the cities where the grounds as a north-south slope, for instance, the Qanats are directed from the north to the south. The irrigation system and the dwelling sections of the cities as well as the roads systems had followed the same pattern. This orientation is obviously observed in the dominant form of the city.

*I. The Form of the Qanats*

The structure of the villages that use the water supplied by Qanats is very dense and centered at a point. Indeed, it is the pointed nature of the Qanats water that provides centralized and spot-like structures. The cities, consequently, are formed with only one core of dwelling or multi core of settlements.

*J. The Distance Relation between Rural Places and between Qanats*

The Distance between the Rural Places are affected by the Distance between Qanats. The southern parts of the Alborz Mountain and the northern parts of the Iran central Kevir is a borderline on which many densely populated places are located. The cities are located at a special distance from the mountain and in an organic order. To keep the permitted space between the Qanats is a determining factor for the distance between the cities. The improper frontage of two Qanats causes the water supply from them grows less and less. The permitted space for the two Qanats is 500 meters in the alluvial fields and 1500 to 2000 meters in the dry areas. The frontage usually varies for the various areas [10].

## VI. Conclusion

Qanats (viable water management system) need long-term maintenance and depend on eliminating activities that harm the ecological integrity of the system and the catchment area as well as the viability of social mechanisms that allows the system to function, without compromising the prominent historical and cultural values of the system. Development may be necessary for sustainability as cost of labour and material increase and as opportunities for improving living conditions, health and growth potential arise.

The production system of Qanat is such that water comes out of earth only by gravity force of earth and with no other help or costing. Regarding present shafts and Qanats we can deduce that the water coming out of Qanat costs cheaper than the other. Qanat water is consistent and does not cut when it is highly needed for agriculture and planting purposes. The underground water sources last longer and have long time use even though it comes out of earth independently of its consumption. Thus, Qanat has lots of advantages and only a few of them mentioned here.

The urban and rural places in Kevir margin areas are located and formed according to some principles and appropriate for the environmental conditions. The Qanats, as the natural factors, have had major functions in the establishment systems, the size and form of the cities. The dense structure of the cities, the farming fields and gardens surrounding them, the roads systems designed according to the organic order and irregular blocking of the ground, and the size and form of the cities are all determined by the systems of Qanats. Thus, any change and developments in these areas should be in accordance to the ecological capacities of the nature and to the water and Qanats. The designing and planning new cities on these areas should be directed toward a permanent living and from ecological point of view. A proper employment of the local underlying structures will lead to the decrease of the expenses and finally to a persistent development.

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