# Chapter 2
# The Role of Qanat and Irrigation Networks in the Process of City Formation and Evolution in the Central Plateau of Iran, the Case of Sabzevar

**Hassan Estaji and Karin Raith**

**Abstract** The main cities of the central plateau of Iran are mostly located on the outer edge of the region. This distribution is determined by climatic impacts. Due to scarce precipitation and rapid evaporation of water for more than six months each year, the region lacks permanent rivers, and for that reason it was initially hard to establish permanent settlements. The population had to move between mountains and plains seasonally, until the invention of 'qanats' changed the way of life and settlement. By means of these underground aqueducts water was funnelled from mountainous areas and aquifers to lower lands. Alluvial fans could be opened up to settlement and an agrarian civilisation evolved. The qanat system is one of the important influences on the location and morphology of desert cities. By comparing old maps of the Sabzevar qanats and water routes with maps of historical streets and alleys in Sabzevar we found that the urban development pattern of Sabzevar is based on the transformation of farming lots to urban residential spaces. When in the course of urbanisation the fields were turned into houses with gardens, main streets were laid out along the course of main qanats and alleys along subsidiary channels. The resulting street pattern corresponds with the old irrigation network and, interestingly, the hierarchy of streets follows the hierarchy of the water distribution network.

**Keywords** Qanat · Irrigation network · Iranian cities · Urban morphology · Sabzevar

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F.F. Arefian and S.H.I. Moeini (eds.), *Urban Change in Iran*,
The Urban Book Series, DOI 10.1007/978-3-319-26115-7_2

## 2.1 Introduction

This chapter addresses the evolution and transformation processes of cities on the central plateau of Iran specially focusing on Sabzevar. We cannot investigate cities without considering their environments. 'The primary physical factors for the development of Central Iranian cities have been the hostile climate and the shortage of water within the bowl-shaped physiography of the Iranian Plateau' (Kheirabadi 2000: 1). This chapter examines the role of a specific type of water supply—the qanat system—in the formation and morphology of Iranian desert cities.

## 2.2 Iranian Desert Cities

Dasht-e Kavir and Dasht-e Lut, Iran's two largest deserts, which together amount to one seventh of the total area of the country, are located in the central plateau. The region is characterised by a typical desert climate with cold winters and hot and dry summers, low relative humidity (about 60 % in winters and 20 % in summers) and an average annual precipitation between 150 and 300 mm (Ghobadian 2009: 24). The main cities of the central plateau of Iran are mostly situated on the outer edge. This distribution of the cities within the territory is determined by climatic conditions. Due to scarce precipitation and rapid evaporation of water prevailing for more than six months of the year, the region lacks permanent rivers, and therefore it was hard to establish permanent settlements. A society of livestock breeders had to move between mountains and plains seasonally in order to feed themselves and their animals, but the invention of the 'qanat' (from a Semitic word meaning 'to dig', in Persian 'Kariz') changed living conditions. By means of these underground aqueducts water was funnelled from mountainous areas and aquifers to lower lands. Alluvial fans could be opened up to settlements, and agrarian civilisations evolved. The qanat became a crucial element of the habitat. The nomadic herding was largely replaced by the settled farming. Nadji (1973: 938–939) states that the sedentary civilisation in the central plateau of Iran was evolved by the qanat (Kariz) technology and calls it '*Kariz's Civilisation*'. In his opinion, over the past centuries the qanat system has played a key role in various aspects of civilisation in this region.

## 2.3 The Structure of Qanat

A qanat is a water supply system that taps groundwater reserves and channels them to settlements and agricultural areas located at a lower level. It consists of a slightly inclined underground gallery and a row of vertical shafts giving access to the low-lying tunnel. Usually 'the first shaft (mother well) is sunk[en] … into an alluvial fan to a level below the groundwater table' (International Centre on Qanats and Historic Hydraulic Structures (ICQHS 2012).

The length of a qanat depends on various factors: the topography, the location of the aquifer and the material of underground layers. It is between a few hundred metres up to several tens of kilometres. According to the definition of the ICQHS (2012) each qanat consists of three main sections: *water production* (the section where underground water resources are developed), *water transport* and *water use*. The most important parts of a qanat are described as follows (Fig. 2.1):

- *Gallery*: The gallery serves both water production and transport, and extends over both sections, i.e. from the groundwater recharge zone to the zone where the water is used. It is a tunnel which taps a water bearing stratum (aquifer) and channels the water to the surface over a long distance. The extremely low gradient [maximum 1:1000 or 1:1500 according to English (1968: 173)] prevents the gallery from being eroded by rapidly flowing water.
- *Shaft wells*: are the vertical funnels or ducts which are dug at intervals between 20 and 200 m (depending on the depth of the gallery) while the qanat is being constructed. They are used to remove excavation material and are essential for ventilating and maintaining the qanat.
- *Mother well*: The mother well is the shaft located closest to the aquifer at the beginning of the qanat. As such, it is also the deepest of all the shafts along the gallery. Mother wells can have a depth of up to 300 m (the qanat of Gonabad).

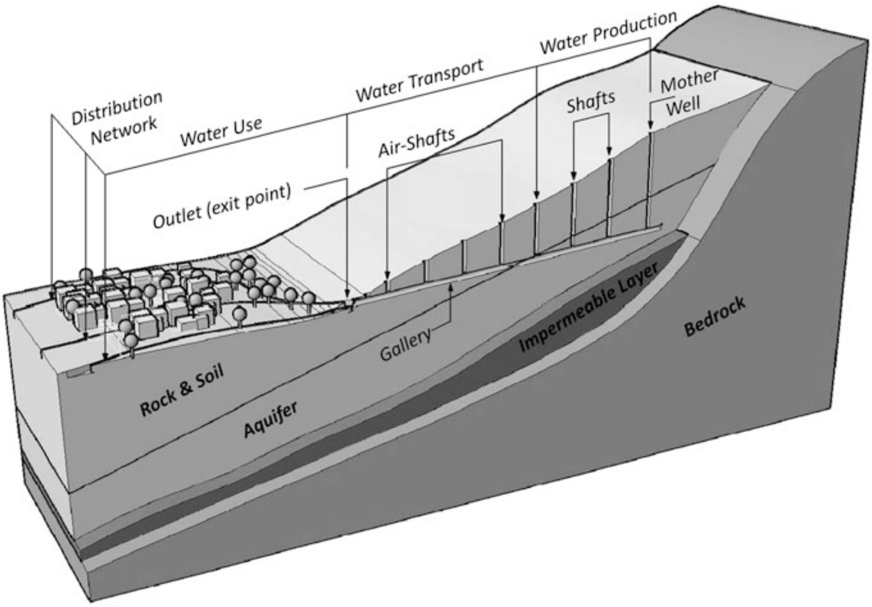


**Fig. 2.1** 3D cross-section of a typical qanat, illustration by authors, data from ICQHS (2012)

- *Exit point of the qanat*: At the exit point of the qanat or '*Mazhar*' (literally 'where the water appears') the gallery meets the surface.
- *Farm*: Agricultural areas located lower than the *Mazhar* are supplied with water via surface channels. 'The extent of the cultivated area depends on several factors such as the qanat discharge, soil quality, soil permeability, local climatic conditions, etc.' (ICQHS 2012).

## 2.4 Human Settlements and the Geographical Distribution of Qanats in Iran

'The qanat technology was known in Iran by the sixth century BC, when Indo-Iranians began to settle as agriculturists' (English 1998: 196). To correspond with positioning necessities of qanats almost all large towns and early settlements on the central plateau of Iran are situated in the plains between high mountains and the desert, on the outer edge of the central plateau of Iran. The statistics and the map of the geographical distribution of qanats in Iran clearly show this pattern (Fig. 2.2). By providing water for the fertile downstream lands qanats facilitated the development of Iranian cities in the plains of desert regions. ICQHS (2009: 5) states:

> In the years 1984–1985 the ministry of energy took census of 28038 qanats whose total discharge was 9 billion cubic metres. In the years 1992–1993 the census of 28054 qanats showed a total discharge of 10 billion cubic metres. 10 years later in 2002–2003 the number of the qanats was reported to be 33691 with a total discharge of 8 billion cubic metres.

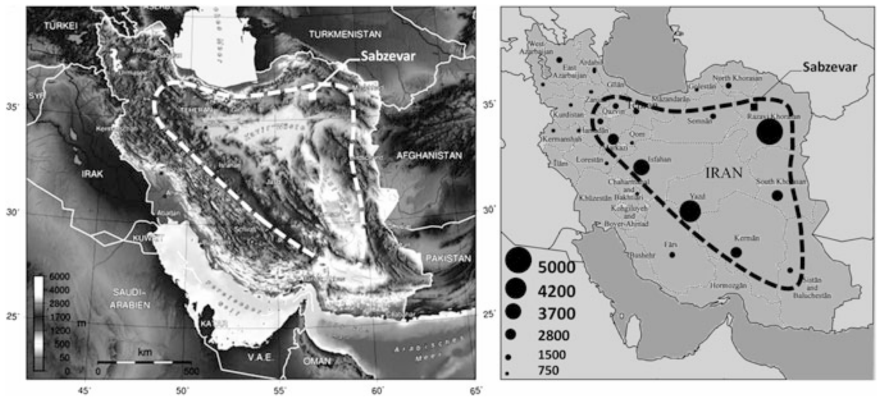


**Fig. 2.2** *Left* Topographic map of Iranian central plateau (World of Maps 2012). *Right* The number of qanats in 2005 in each province, based on Iranian qanat database (Iran Hydrology 2005), blank map: (Sankakukei 2012)

According to the latest statistics (Semsar Yazdi 2010: 7), ‘Iran is currently benefiting from 36,888 active qanats producing some 7 billion cubic metres of groundwater and forming around 11 % of the aquifer discharge which is annually mined across the country.’

## 2.5 Sabzevar

Sabzevar is located in the northeast of Iran, south of the Sabzevar Mountains (also known as Siah-Kuh or Joghatay Mountains) on the outer edge of the Central Plateau (Fig. 2.2). These mountains lie 80 km south of the East Alborz. The city and the neighbouring villages are situated between the mountain range and the Salt Desert, parallel to Sabzevar Mountains. According to the last statistics reported by the Ministry of Agriculture (Iran hydrology 2005), there are 864 qanats in Sabzevar and the surrounding villages. The position of the settlements and the main qanats confirms that Sabzevar and its surrounding rural settlements were established according to the qanat system. The distance between the mountains and the settlements is between 10 and 15 km depending on the length of the main qanats (Fig. 2.3).

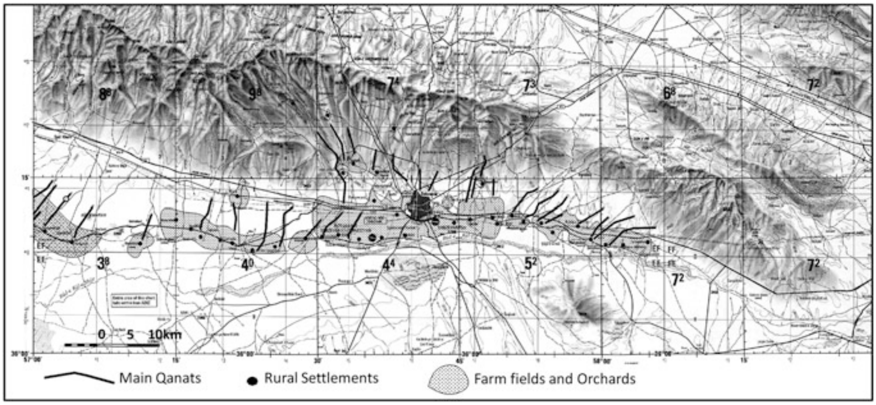


**Fig. 2.3** Distribution of main qanats in the Sabzevar region, base map: (National Imagery and Mapping Agency 1999). (This product was developed using materials from the United States National Imagery and Mapping Agency and are reproduced with permission. This product has neither been endorsed nor authorised by the United States National Imagery and Mapping Agency or the United States Department of Defense)

## 2.6 The Qanat Network

> The built environments of most alluvial fan towns and villages on the Iranian Plateau are aligned along the major watercourses (shahjub) that run from the mouth of the qanat down slope through the length of the settlement (English 1998: 198).

The hierarchy of the irrigation network is as follows (Fig. 2.4):

1. Main irrigation channels: main water streams usually run in parallel with the main slope of the land.
2. Sub-main irrigation channels (link channels): flowing into fields following land topographies.
3. Subsidiary channels: branching from main networks. These smaller streams irrigate the gardens and farms and provide water for 'water storages' in the houses.

In the dry climate, water ownership is more important than the ownership of the land. The qanat network allows land owners to buy water from several qanats. This flexibility makes the irrigation network a sustainable system. If one of the qanats

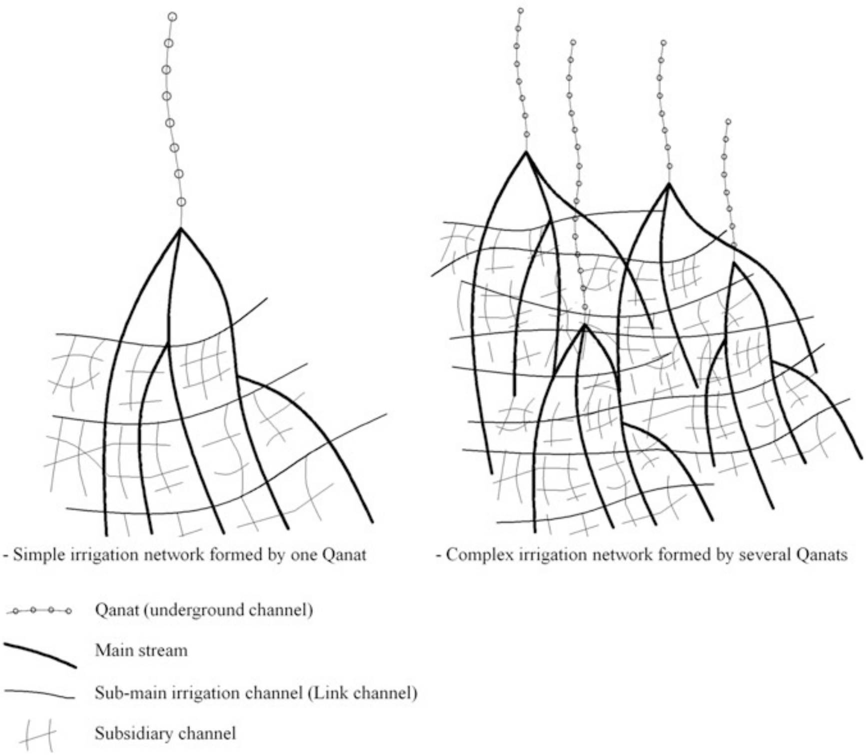


**Fig. 2.4** Irrigation network (Authors 2012)

dries up or needs repair, this organic network enables farmers to carry water from another qanat into their farms and gardens via link channels (sub-main irrigation channels).

## 2.7 The Role of the Qanat in the City's Morphology

For purposes of repair and maintenance of the qanat and irrigation networks, and in order to make gardens and farms accessible, ancient Iranians made narrow paths for humans and animals on one or both sides of the channels. The width of these paths depends on water discharge rate and the hierarchy of the qanat network. The primary function of qanats and irrigation systems was to supply water for household consumption and agriculture but as a side-effect a spatial pattern was created which played a formative role in the city layout and urban evolution. The water supply system, therefore, is one of the important influences on the morphology of desert cities. As an Iranian desert city Sabzevar was also formed according to this pattern: a point mentioned by Kheirabadi (2000: 33) in his book. For a more detailed study, two maps of the old Sabzevar irrigation network and the historic streets and alleys were prepared (Fig. 2.5). By comparing these maps, it turns out that the urban pattern of the old Sabzevar matches the irrigation network. When in the course of urbanisation farming lots were built on and turned into houses with gardens, main streets were laid out along the course of main irrigation channels and alleys along subsidiary channels. The resulting street pattern corresponds with the irrigation network and. interestingly, the hierarchy of streets follows the hierarchy of the water distribution net. This map shows the final years (around 1950) of the qanat system still fully functioning in Sabzevar. At that time three main and around 15 small qanats were included in the system providing water for 30,000 people.

In the early twentieth century a transformation from an agrarian to urban society took place. A growing wealth together with the development of fossil energies led to a sharp increase in motor traffic. As a result of population growth, the demand for drinking water rose. Cities expanded into suburban areas, and overran gardens. Surface channels were replaced by underground water pipes for sanitary reasons. The vital vessels of running water on the surface lost their life and gardens dried up. These developments happened about 60 years ago. Nevertheless the 'dead network' and the dried gardens and farms kept their formative role for urban development. The network of the irrigation system which was already accompanied by public spaces changed into new streets and alleys and dried farms and gardens were divided into smaller lots for residential buildings (Fig. 2.5). The first law concerning the 'widening and development of streets' in Iran approved by the Iranian parliament in 1933, speed up these changes.

The municipalities made a master plan with the objective of facilitating traffic. In the first years of this urbanisation the traffic density was still relatively low, and therefore problems could be solved by slightly modifying the dried irrigation network (Fig. 2.6).

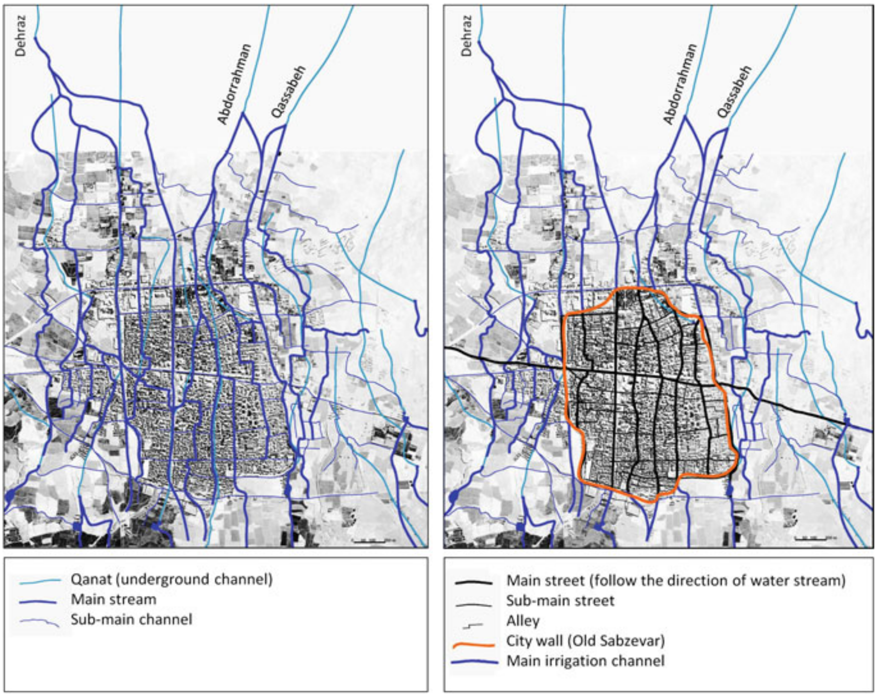


**Fig. 2.5** Old Sabzevar irrigation network and the position of old Sabzevar and city wall based on the 1956 Sabzevar map. (Authors based on the map by Zanganeh (2003a), the base map reproduced by permission of Yaghoub Zanganeh)

This picture shows the transformation process of farming lots to urban residential spaces in Sabzevar (the southwest of the old city is shown as an example). The last part of the old city wall can be seen clearly in the 1956 aerial photo—it was demolished and replaced with a new street in 1964.

Until 1975 the irrigation network determined the street pattern even after losing its original function. After that the organic network could not cope with the traffic any longer due to the increasing numbers of cars. In the last decades the traditional order of the city was abandoned. The authorities and urban designers chose the simplest solution for the traffic problem: starting in 1975, they cut a rectangular grid of new wide streets into the urban fabric of Sabzevar—ignoring the centuries-old structure of the city. These cuts can be seen in the Sabzevar aerial photo (Fig. 2.6).

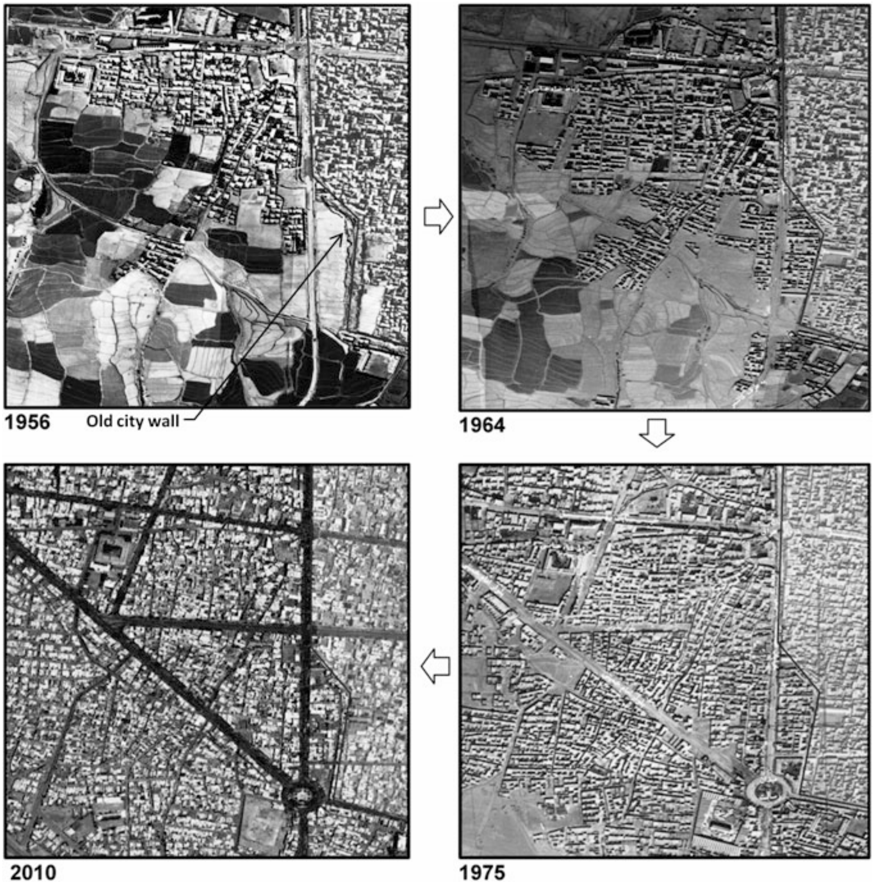


**Fig. 2.6** The development and transformation process of the southwest part of Sabzevar. (Authors based on the map by Zanganeh (2003a, b, c) and Google Earth (2010). The base map reproduced by permission of Yaghoub Zanganeh)

## 2.8 Conclusion

The qanats as sustainable irrigation systems had a key role in the foundation and development of agricultural settlements on the Iranian plateau. The local water conditions and the possibility to build qanats determined the location of the main Iranian cities in this region, in the plains between the high mountains and the desert on the outer edge of the central plateau of Iran. The ancient Iranians constructed qanats and irrigation networks primarily for household water supply and farming, but at the same time these networks determined the shapes and growth patterns of the cities. In fact they created a platform for city formation and urban evolution. Thus the water supply system is one of the crucial influences on the morphology of the Iranian desert cities. For example, the urban pattern of old Sabzevar matches the irrigation network and the hierarchy of the old Sabzevar streets follows the hierarchy of the water distribution network. This network kept its role as a formative force in urban development even after losing its original function. The urban development pattern of Sabzevar is based on the transformation of farming lots to urban residential spaces. The disused irrigation network and the path system connected to it kept their shape and changed into streets and alleys; the dried farms were divided into smaller lots of land for residential buildings.

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Urban Change in Iran
Stories of Rooted Histories and Ever-accelerating Developments
Arefian, F.F.; Moeini, S.H.I. (Eds.)
2016, XVII, 256 p. 64 illus., 10 illus. in color., Hardcover
ISBN: 978-3-319-26113-3