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Review Article

Qanat system, an ancient water management system in Iran: History, architectural design and fish diversity

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Abstract: Ancient Iran is one of the leading civilizations that actively appear to water resources management, especially by the invention of "Qanat", an artificial underground system/ subterranean tunnel-wells system where the water flows through gravity on a slight slope in arid and semi-arid regions at least 5000 years ago. Qanats were innovated in ancient Iran, spread throughout much of the Middle East, and extended into North Africa, Spain, Italy, and South Asia. Tools preparation, size selection, digging the first and deepest vertical shaft known as "mother-well", digging several other vertical shafts along a line between the mother-well and Qanat outlet, and constructing a horizontal connection between vertical shafts (known as the main tunnel), which guides the water out through an outlet, are the main steps in Qanat construction. By this innovation, Iranian solved their water-related problems using the basic concepts of Hydraulics. In the same way, water-related infrastructures were built using locally available materials to make a better life for humans and other wonderful well-designed and well-adapted organisms in dry and semi-dry regions, yielding great civilization with a simple, but a fantastic architecture that provides cold water in hot summer and warm water in cold winter. By means of these ancient underground structures, water was funneled from mountainous areas and aquifers to lower lands and thus alluvial fans could be opened up to settlement, and an agrarian civilization developed and evolved. In addition, Qanat provides a continual flow suitable for many aquatic organisms, including crabs, amphipods (gamarids), freshwater shrimps, and fishes. Qantas are home and refugia to about 42 fish species (36 native and 6 exotic species) belonging to 20 genera, 7 families, and 2 orders. The Qanat ichthyofauna is dominated by Cyprinidae with 19 species (45.2 %) followed by Leuciscidae and Nemacheilidae (6 species, 14.28% each), Poeciliidae and Aphaniidae (4 species, 9.52%), and Cobitidae (1 species 2.38%). It is about 14% of the total ichthyofauna of Iran. The Qanat ichthyofauna comprises 36 natives (including 20 endemics) and 6 exotic species. Qanat fauna dominates by species that are generally of small size, are broadcast spawners, nonmigratory, and have a wide tolerance of environmental conditions.

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Introduction

Water is one of the most important components in nature and daily life. The study of this very common substance is a subject of many different disciplines (Berking et al., 2019), including engineering, mathematics, art, agriculture, biology, and health. Water is crucial for the life support of all organisms and health promotion, food security, social development, economic improvement, political stability, and environmental function and sustainability. In terms of function and purpose, water is used as freshwater (domestic, drinking, tap, and portable water); for food production (water for irrigation and animal husbandry); fishery; navigation (transport); cult practices; energy (hydropower); status (political power); hygiene; and for entertainment, protection, cooling, and recreation (Berking et al., 2019). Especially in arid and water-scarce regions, water management is a fundamental need for humans and societies.

In arid areas like Iran, water resources management for sustainable development is far more noteworthy.

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To warrant proper water resources development, establishing a rational connection between the available resources (surface water and groundwater), spatiotemporal requirements, geo-climatic conditions, cultural values, legal rights, technological tools, political power, religious beliefs, and socioeconomic privileges is a critical issue (Berking et al., 2019; Mahan et al., 2019; Saatsaz and Rezaie, 2021). In this regard, ancient Iran is one of the leading civilizations that actively appear to water resources management, administration, and investment in infrastructure and technology, not merely water availability. Although there has been a long history of water governance in Iran, it has difficulty solving current water problems. In this context, understanding how water-related technology, rules, society, economics, and political systems worked in the past provides us with more profound knowledge of how our history shaped the present, allowing us to form our future (Mahan et al., 2019; Saatsaz and Rezaie, 2021).

Several historical studies have investigated ancient water-related topics of the world and Iran (e.g., Esmaeili and Teimori, 2006; Kuros and Labbaf Khaneiki, 2007; Mays, 2010; Mahmoudian and Mahmoudian, 2012; Gholikandi et al., 2013; Moteahed et al., 2014; Esmaeili et al., 2015; Hashemzadeh Segherloo, 2015; Alemohammad and Gharari, 2017; Sparacio et al., 2017; Manual et al., 2018; Berking et al., 2019; Labbaf Khaneiki, 2019; Mahan et al., 2019; Saatsaz and Rezaie, 2019; Teimori and Esmaeili, 2020). Most of these investigations focus on (i) water infrastructure such as qanats, dams, weirs, water-mills, (ii) water resources management, (iii) socioeconomic aspects of water, (iv) architectural design of water-related systems, and (v) habitat suitability and biodiversity.

One of the ancient water management systems is Qanat. Qanat is one of the important inland aquatic ecosystems commonly containing freshwater in arid and semi-arid regions. It is an underground tunnel, almost horizontal, which bores into an aquifer and guides the water out through an outlet. Qanat provides a continual flow suitable for many aquatic organisms, including crabs, amphipods (gamarids), freshwater shrimps and fishes (Esmaeili and Temori, 2006; Esmaeili et al., 2012, 2015, 2018; Hashemzadeh Segherloo, 2015; Sparacio et al., 2017; Teimori and Esmaeili, 2020). Based on the above-mentioned background, this study was conducted to (i) review the history of Qanat formation in Iran, (ii) characterize the architectural design of Qanat, and (iii) update Qanat fish biodiversity.

Materials and Methods

For the history and architectural design of Qanat several studies have been consulted (e.g., Kuros and Labbaf Khaneiki, 2007; Mays, 2010; Mahmoudian and Mahmoudian, 2012; Gholikandi et al., 2013; Salehi Moteahed et al., 2014; Alemohammad and Gharari, 2017; Sparacio et al., 2017; Manual et al., 2018; Berking et al., 2019; Labbaf Khaneiki, 2019; Mahan et al., 2019; Saatsaz and Rezaie, 2019). The data collected for the fish diversity are based on the previous works done by Saadati (1977), Armantrout (1980), Coad (1995, 1996, 2006), Esmaeili and Temori (2006), Rezaei Tavabe and Azarnivand (2013), Esmaeili et al. (2010a, b; 2015, 2017, 2018), Teimori and Esmaeili (2020) and several field trips.

Results and Discussion

Qanat definition: Qanat (also known as karez in Afghanistan and Pakistan, kanerjing in China, falaj in the Arabian Peninsula, qanat Romani in Jordan and Syria, fogarra (fughara) in North Africa, khettara in Morocco, and galeria in Spain), is an artificial underground system/ subterranean tunnel-wells where the water flows through gravity on a slight slope in the arid lands of the Old World/Eurasia (Fig. 1). In fact, Qanats are gently sloping tunnels dug far enough into alluvium or water-bearing sedimentary rock for extracting groundwater (English, 1968; Waterhistory, 2022). Once constructed, groundwater filters into the channel, run down its gentle slope, and emerges at the surface as a stream (English, 1968).

History of Qanat formation: Ancient water mechanisms changed and evolved in nature as “one species turns into another”, due to geographical advantages or disadvantages, analogous to “natural

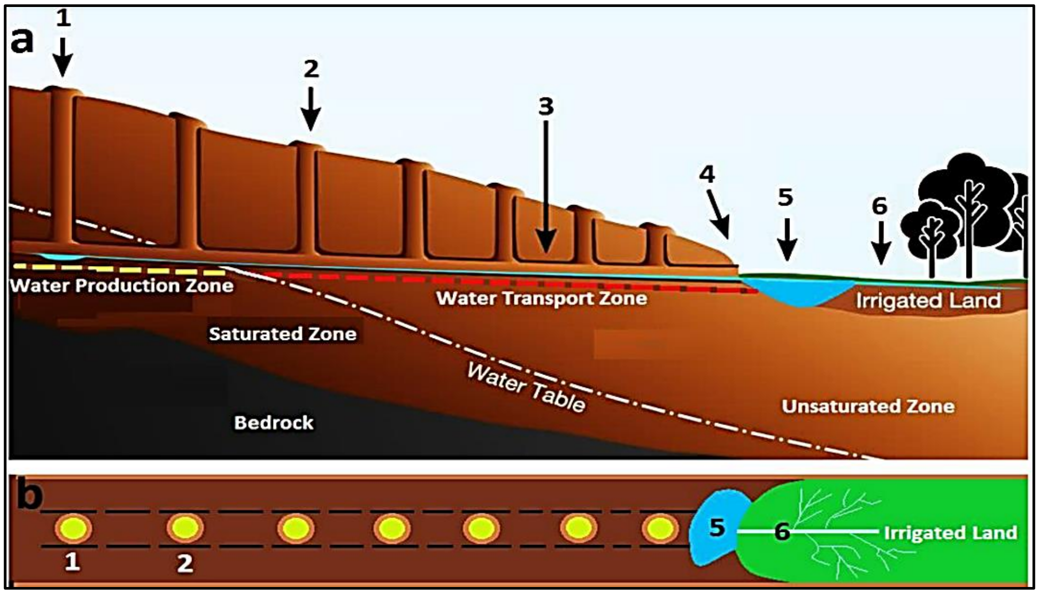

Figure 1. A simple schematic showing a typical Qanat system; (a) Cross-section, (b) Aerial view. 1, Mother well; 2, Vertical shaft; 3, Tunnel (gallery); 4, Qanat outlet; 5, Storage pond; 6, Field canal (Saatsaz and Rezaie, 2021).

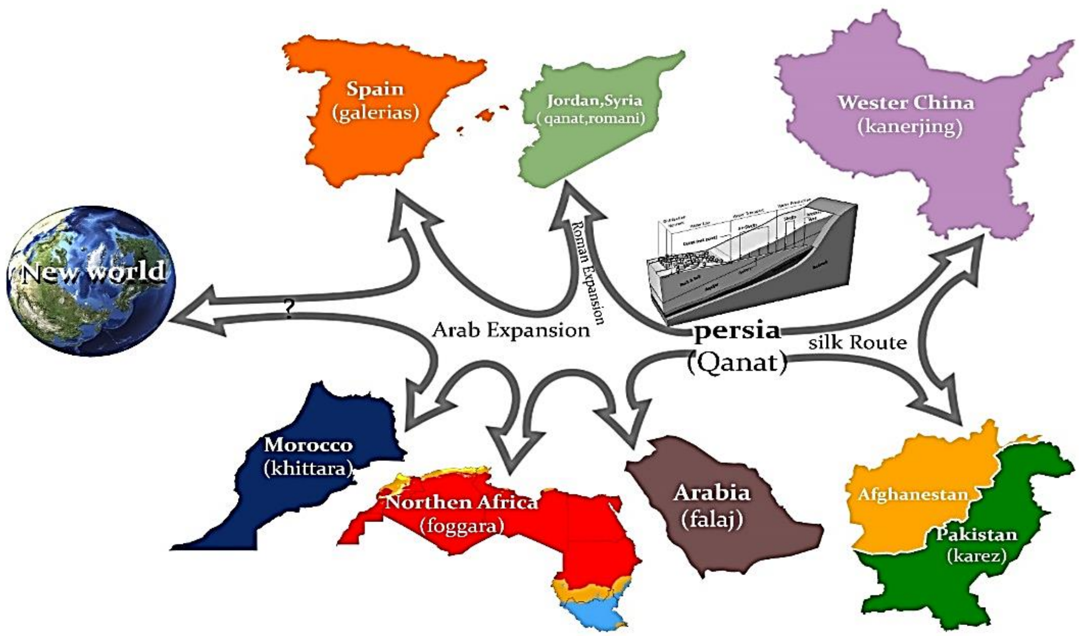

Figure 2. One possibility for the diffusion of Qanat technology. Modified from Waterhistory (2022).

selection", as described by Charles Darwin (1809–1882), but driven deliberately by the people of that time. Especially in arid and water-scarce regions such as the Iranian Plateau, water management has been a fundamental need for humans. Such evolution and changes in water management might have been coupled with the dispersal of modern humans to the Iranian Plateau. Probably, living on the Iranian Plateau started with the dispersal of early modern humans from Africa, dated between at least ~90,000 and ~50,000 years ago in the Middle-Paleolithic of the Stone Age (Delson, 2019; Saatsaz and Rezaie, 2019). Later, agricultural communities started to appear in the southwestern, western, and northwestern of the Iranian Plateau where perennial rivers, rainfall, and fertile alluvial soils allowed agrarian societies to develop (Riehl et al., 2013; Saatsaz and Rezaie, 2019). This was followed by animal domestication, construction, stone cutting, woodworking, mining, metalworking, trading, and other services (Saatsaz and

Rezaie, 2019). Almost 6,000 years ago, the southwestern and western parts of the Iranian Plateau were a part of the "Fertile Crescent" under the control of the Mesopotamian Civilization (Pollock and Susan 1999). In this region, the low gradient meandering Karun, Karkheh, Jarrahi, and Dez Rivers flow in vast floodplains, underlain by thick alluvial deposits. Meander cut-offs (oxbow lakes), marshes, and abandoned streams are developed alongside these rivers. This area, however, is susceptible to low, erratic rainfall and drought; only irrigated agriculture was feasible. Hence, to meet full irrigation, the Mesopotamians developed a complex of water systems, including canals with different sizes (one central canal and a network of secondary, tertiary, quaternary, and field canals), head-gate, distributors, regulators, inlets and outlets, weirs, levees, and storage reservoirs (Tamburrino, 2010).

Birth of Qanat: The exact dating of qanats is difficult unless their construction was accompanied by documentation or, occasionally, by inscriptions (Waterhistory, 2022). Most of the evidence we have for the age of qanats is circumstantial; a result of their association with the ceramics or ruins of ancient sites whose chronologies have been established through archeological investigation or the Qanat technology was introduced long ago by people whose temporal pattern of diffusion is known (Waterhistory, 2022). Based on different written records, the Qanat system has a Persian origin (Biancone and Tusa, 1997; Todaro, 2002; De Feo et al., 2010; Sparacio et al., 2017; Waterhistory, 2022). In fact, written records leave little doubt that ancient Iran (Persia) was the birthplace of the Qanat. As early as the 7th century BC, the Assyrian king Sargon II reported that he had found an underground system for tapping water during a campaign in Persia. His son, King Sennacherib, applied the "secret" of using underground conduits in building an irrigation system around Nineveh (Waterhistory, 2022).

Diffusion of Qanat technology: During 550-331 BC, when Persian rule extended from the Indus to the Nile, Qanat knowledge spread throughout the empire (Fig. 2). The Achaemenid rulers provided a major incentive for Qanat builders and their heirs by allowing them to retain profits from newly-constructed qanats for five generations. As a result, thousands of new settlements were established and others expanded (English, 1968; Waterhistory, 2022). To the west, qanats were constructed from Mesopotamia to the shores of the Mediterranean, and southward into parts of Egypt. To the east of Persia, qanats were constructed in Afghanistan, the Silk Route oases settlements of central Asia, and Chinese Turkistan i.e. Turpan (Waterhistory, 2022). During Roman-Byzantine era (64 BC to 660 AD), many qanats were constructed in Syria and Jordan. From here, the technology appears to have diffused north and west into Europe. There is evidence of Roman Qanats as far away as the Luxembourg area (see Sparacio et al., 2017; Waterhistory, 2022).

Architectural design of Qanat: In the early part of the first millennium B.C., Persians started constructing this elaborate tunnel system to extrac groundwater in the dry mountain basins of present-day Iran. Many researchers have discussed the architectural design of Qanat (e.g., English, 1968; Karki et al., 2017; Saatsaz and Rezaie, 2019; Waterhistory, 2022). A review is provided here under several headings:

Specialist Qanat diggers: Most Qanats in Iran are constructed by a group of professional/ specialist diggers known as Muqannis. They inherited this task from the slaves and captives of the Achaemenid and Sassanian kings (English, 1968; Waterhistory, 2022). These diggers form a community of traveling artisans, migrating from place to place as floods destroy Qanats in one area or a lowered water table demands that Qanat tunnels be extended in another (English, 1968; Waterhistory, 2022). The techniques of Qanat construction have changed little from birth to the present day (Fig. 3). The Muqannis must work with water flowing around them, ventilation is poor, and the chances of cave-ins are great.

Tools for Qanat construction: The tools for Qanat construction are primitive and include a broad-bladed pick, a shovel, a windlass, a long rope, a small lamp and bucket (Fig. 3).

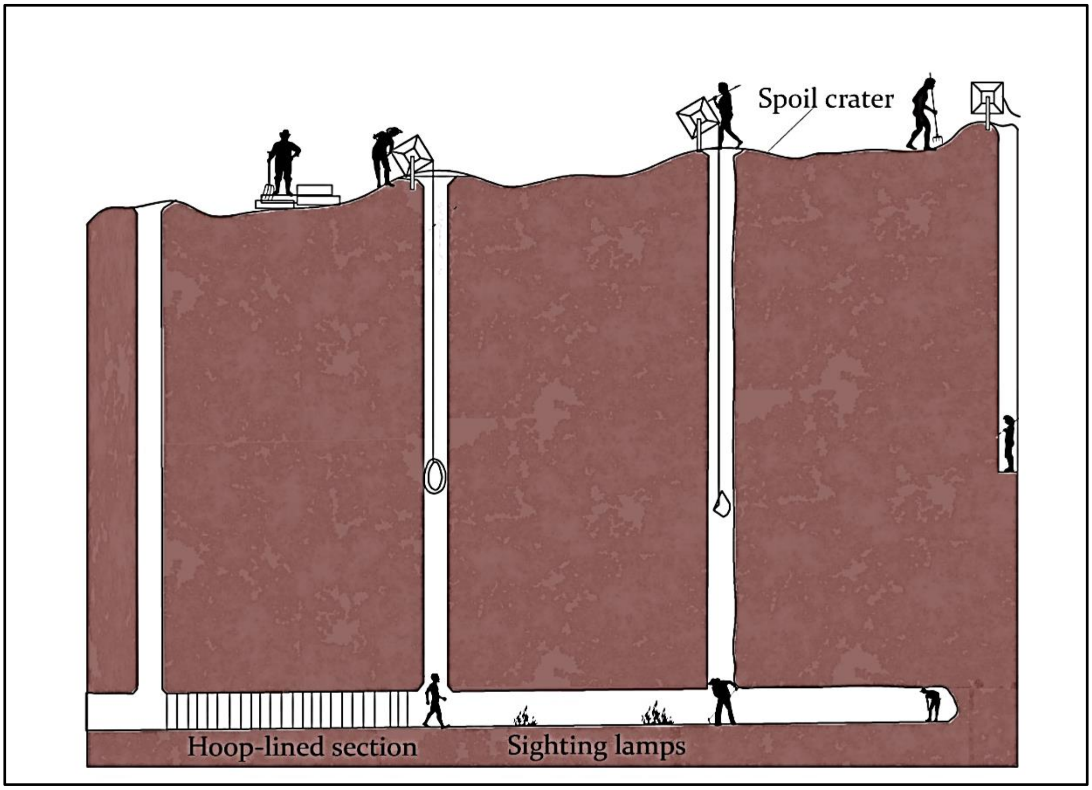

Figure 3. Constructing a Qanat using reinforcing rings. Modified from Waterhistory (2022).

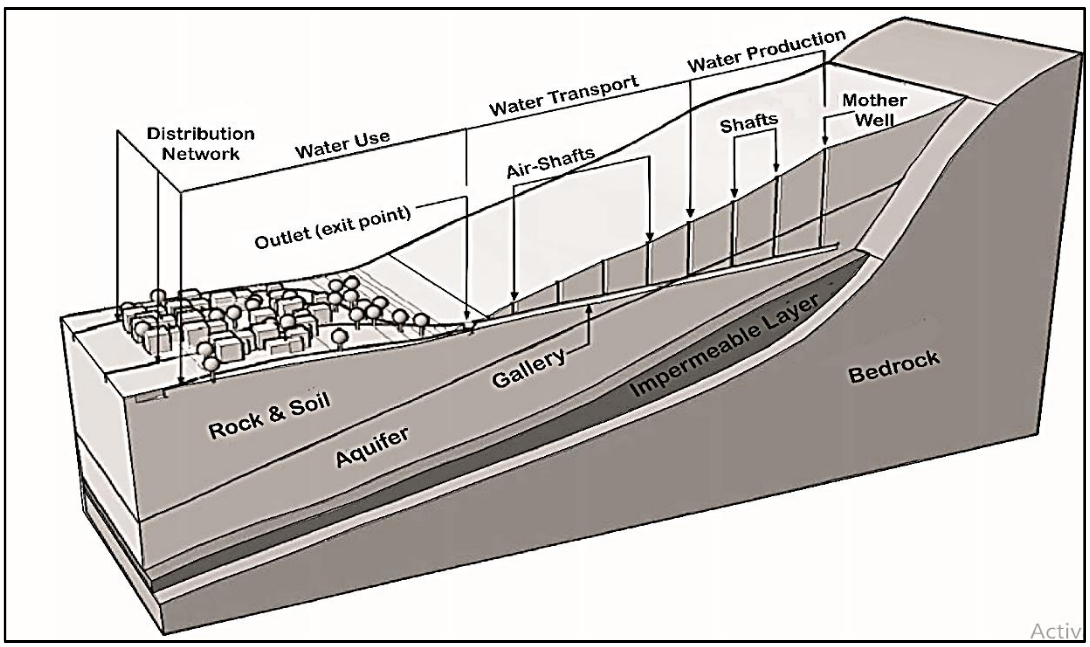

Figure 4. 3D cross-section of a typical Qanat (Estaji and Raith, 2016).

Site selection: Site selection is the first and critical step in the construction of a Qanat. Local slope conditions, landscape, anomalies in soil color and moisture, ground-water supplies, vegetation cover and the proposed location of the new settlement are conventional indicators to locate a Qanat construction point. Ancients likely knew groundwater could be available in foothills, wadies, dry riverbeds, and alluvial fans (English, 1968; Saatsaz and Rezaie, 2019; Waterhistory, 2022). These factors are weighed by an expert, usually one of the older, more well-known Muqannis, who chooses where a trial well

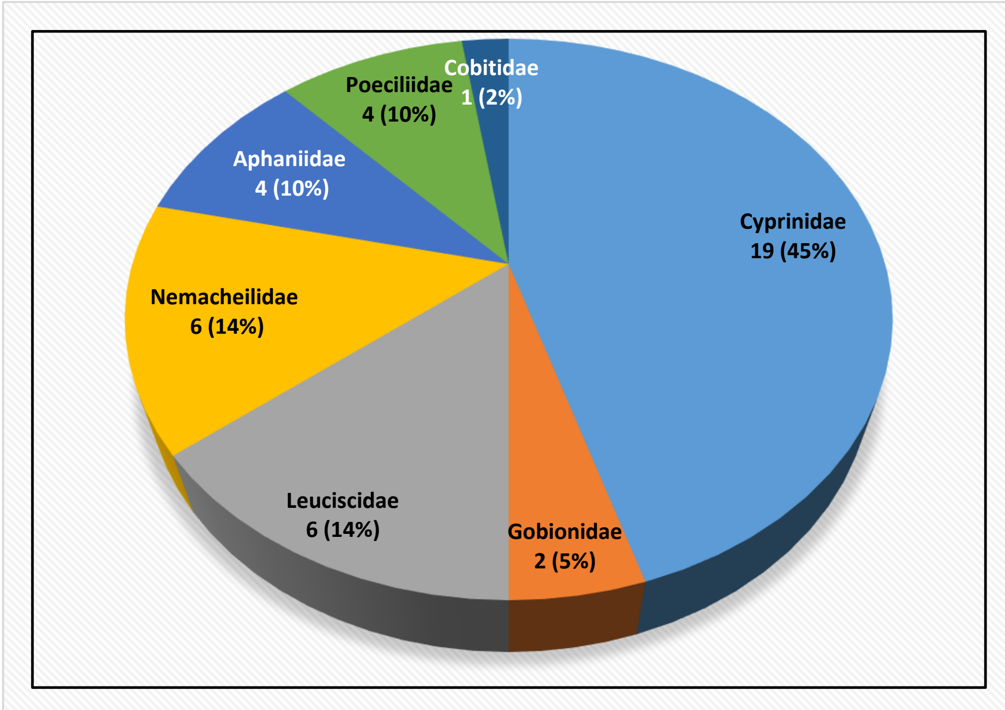

Figure 5. Number and percentage of different fish families in Qanats of Iran.

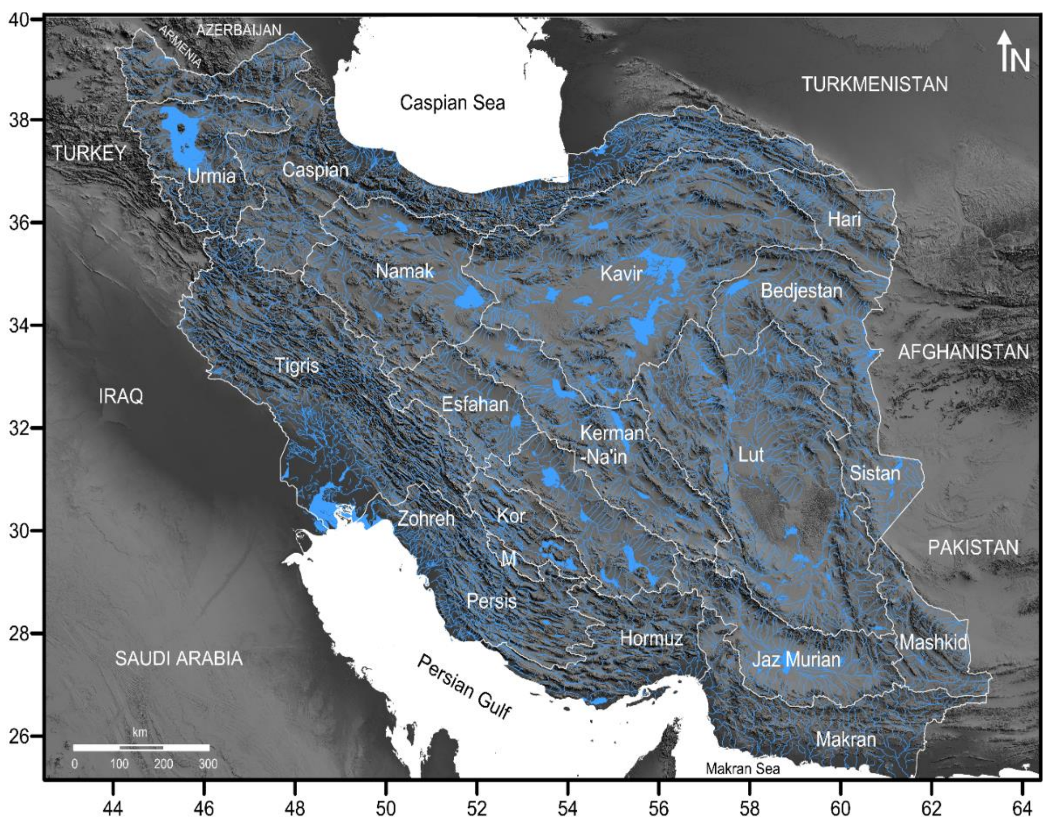

Figure 6. Map of Iran showing major drainage basins of Iran.

should be dug. A favorable site often lies near the mouth of a wadi, but where the water table is deep and the Qanat long, the general topographic setting and variations in vegetation are used as indices of the likely location of underground water supplies (English, 1968).

After viewing evidence, the first and deepest vertical shaft known as "mother-well" is dug by a team of skilled Muqannis using only simple hand tools. The mother well is sunk into the saturated zone for locating the water table and checking the quality, quantity, and regularity of the groundwater flow (Kheirabadi, 2000). In this stage, the aesthetic parameters of water (i.e., temperature, turbidity, color, taste, and odor) are detected by Qanat diggers through the senses. The sense of hearing is occasionally used to detect water movement. The length of the Qanat is measured from the mother well to the point where water surfaces. The Qanat length could also be short or long, varying from a few hundred meters to ~100 km. The depth of the mother well may vary from ten to several hundred meters usually 30-100 meters based on the water table depth, Qanat length, earth slope, and the owner's capital for excavation (English, 1968; Karki et al., 2017; Saatsaz and Rezaie, 2019; Waterhistory, 2022). The Qanat length and the mother-well depth are often high in dry regions. In Qanat design, the slope is one of the most critical parameters that control a Qanat length.

In the next step (Figs. 1, 3, 4), along a line between the mother-well and Qanat outlet, the Muqannis dig vertical shafts with a diameter ranging from 80 to 100 cm (Semsar Yazdi and Labbaf Khaneiki, 2016). At intervals of ~20 to 200 m, the shafts are used to remove the excavated materials from the main tunnel (a connection between vertical shafts), air circulation and provide access for repair and maintenance. The gently sloping main tunnel transports water from groundwater wells to the surface some distance away. During the digging process, excavated soils are dumped all-over the shaft opening to prevent entering surface runoff into the shaft and the main tunnel. If the soil is loose and unstable, the tunnel and shaft lining is necessary to improve the Qanat durability. If the soil is firm, no lining is required for the main tunnel. In loose soil, reinforcing rings are installed at intervals in the tunnel to prevent cave-ins. These rings are usually made of burnt clay. Mineral, salt, and other deposits which accumulate in the tunnel bed need periodic cleaning and maintenance work.

Architecture and social aspects of Qanats: The Qanat gadget changed into concerned with the social systems of nearby groups and cities (English 1966; Bonine 1982). For instance, wealthier households often had non-public and direct get entry to water networks, or they lived toward the opening or upstream of it. At the identical time, the relaxation of a metropolis`s population used the collective and public offerings to be had in every mahalleh which may encompass that neighborhood`s water storage. Sharing and keeping the not unusual place primary sources helped shape near social relationships inside a neighborhood. Furthermore, the principal public establishments together with the bazaar, mosques, baths, and faculties commonly had direct get entry to freshwater. This method that the financial shape of the metropolis had a near courting with the qanats and the water community in general. In short, a multiplicity of interwoven elements has formed how human beings assemble and keep qanats throughout the records in their use, growing precise methods of residing and inhabiting the territory.

The use of Qanat water became observed via way of means of a collective agency of manufacturing control, in the location around Tehran, the typical Qanat primarily based totally collective device is known as Boneh. The volume of improvement of the social and technical agency relies upon manufacturing Boneh advanced out of the want for cooperation in building and keeping Qanat and its water control prolonged to cowl agriculture manufacturing and associated socioeconomic device. A typical quantity of irrigation is cultivated on all Bonehs, and normal collective water divisions primarily based totally on crop desires are made among the Bonehs. Within the collective device, a social hierarchy defines roles and duties.

Number of Qanats: It seems that about 120,000 Qanats have been constructed in Iran, of which about 37,000 are still in use in arid and semi-arid regions of the country, producing some 7 billion cubic metres of groundwater and forming around 11% of the aquifer discharge which is annually mined across the country (Estaji and Raith, 2016).

Figure 7. Live specimen of *Capoeta aculeata*, Iran: Lake Namak Basin.

Figure 8. Live specimen of *Capoeta fusca*, Iran: Sharifabad Qanat, Birjand.

Figure 9. Live specimen of *Capoeta macrolepis*, Iran: Kor River basin.

Persian Qanats in the UNESCO world heritage list: At its 40th meeting in Istanbul, Turkey on July 10, 2016, the World Heritage Committee (WHC) listed eleven Iranian Qanats as the 20th in the list of Iran's UNESCO World Heritage Site due to the historical importance of Iran's aqueducts, their sophisticated and civilized systems, and their environmental benefits. These registered Qanats are Qassabah (in Gonabad), Baladeh (in Ferdows), Zarch (in Hassan Abad), Mirza Nasrollah Water Mill (in Mehriz), Juppar (in Kerman), Akbarabad and Qasemabad (in Bam), Moon (in Ardestan), Wezwan and Mazdabad (in Isfahan) and Ibrahim Abad (in Arak).

Qanat fish diversity: The data collected from different sources, including several field works,

Figure 10. *Paraschistura turcmenica*, ZM-CBSU J2929, 36 mm SL; Iran: Khiyaban Qanat.

Figure 11. *Paraschistura cristata*, Iran: Zanglanlou River.

Figure 12. Male (upper) and female (lower) *Aphanius pluristriatus*, Iran: Jahrom, Qanat, Mond River drainage.

showed that there are 42 fish species (Fig. 5) in qanats of Iran in several basins (Fig. 6) belonging to 20 genera, 7 families, and 2 orders. The Qanat fish species are listed in Table 1 and a selection of species, showing variation in body form, is given in Figures 7-14, and a representative fish habitat is given in Figures 15-16. The Qanat ichthyofauna is dominated by Cyprinidae with 19 species (45.2%) followed by

Figure 13. Live specimen of *Garra nudiventris*, ZM-CBSU H1500, 54.5mm SL; Iran: Kalat e Baba Qanat.

Figure 14. *Alburnoides qanati*, Iran: Moshkan Qanat, Kor River basin.

Figure 15. Kalat e Baba Qanat. habitat of *Garra nudiventris.*

Leuciscidae and Nemacheilidae (6 species, 14.28% each), Poeciliidae and Aphaniidae (4 species, 9.52%), and Cobitidae (1 species 2.38%). It is about 14% of the total ichthyofauna of Iran. The Qanat ichthyofauna comprises 36 natives (including 20 endemics) and 6 exotic species. Qanat fauna dominates by species that

Table 1. Fish biodiversity in Qanats of Iran. E, endemic; N, native; EX, ecotic.

Order	Family	Species	Status	Qanat/Basin
Cypriniformes	Cyprinidae	*Barbus miliaris* De Filippi, 1863	E	Namak
		Capoeta aculeata (Valenciennes, 1844)*	N	Kavir, Namak
		Capoeta birunii Zareian & Esmaeili, 2017*	E	Zayandehrud
		Capoeta buhsei Kessler, 1877	E	Namak, Kavir
		Capoeta capoeta (Güldenstädt, 1773)	N	Urmia
		Capoeta ferdowsii Jouladeh-Roudbar, Eagderi, Murillo-Ramos, Ghanavi, Doadrio, 2017	E	Zohreh
		Capoeta fusca Nikolskii, 1897	N	Sistan,Tedzhen, Bedjestan, Lut
		Capoeta macrolepis (Heckel, 1847)*	N	Kor
		Capoeta saadii (Heckel, 1847)	E	Kor, Maharlu, Makran, Persis, Kerman–Na'in, Sirjan, Lut, and Hamun-e Jaz Murian
		Carasobarbus luteus (Heckel, 1843)	N	Hormuz, Persis
		Carassius auratus (Linnaeus, 1758)	EX	Kor, Maharlu
		Cyprinion microphthalmum (Day, 1880)	N	Lut, Mashkid, Hormuz, Jazmurian, Kavir
		Cyprinion tenuiradius Heckel, 1847	E	Persis
		Garra nudiventris (Berg, 1905)	E	Lut
		Garra persica Berg, 1913	E	Hamun-e Jaz Murian
		Garra rossica (Nikol'skii, 1900)	N	Hari, Bejestan, Sistan, Lut, Hamun-e Jaz Murian
		Garra rufa (Heckel, 1843)	N	Persis
		Schizothorax pelzami Kessler, 1870	N	Hari, Kavir
		Tariqilabeo adiscus (Annandale, 1919)	N	Sistan
	Gobionidae	*Gobio nigrescens* (Keyserling, 1861)	N	Hari
		Pseudorasbora parva (Temminck & Schlegel, 1846)	EX	Kavir
	Leuciscidae	*Acanthobrama persidis* (Coad, 1981)	E	Kor, Persis
		Alburnoides idignensis Bogutskaya & Coad, 2009	E	Tigris
		Alburnoides namaki Bogutskaya & Coad, 2009	E	Namak, Kavir
		Alburnoides qanati Coad & Bogutskaya, 2009	E	Kor, Sirjan
		Alburnus sellal Heckel, 1843	N	Hormuz, Persis, Kor, Maharlu
		Alburnus ulanus (Günther, 1899)	E	Urmia
	Nemacheilidae	*Oxynoemacheilus persa* (Heckel, 1847)	N	Persis
		Paraschistura abdolii Freyhof, Sayyadzadeh, Esmaeili & Geiger, 2015	E	Sirjan
		Paraschistura bampurensis (Nikolskii, 1900)	N	Hamun-e Jaz Murian, Mashkid
		Paraschistura cristata (Berg, 1898)	N	Hari
		Paraschistura naumanni Freyhof, Sayyadzadeh, Esmaeili & Geiger, 2015	E	Persis, Maharlu
		Paraschistura turcmenica (Berg, 1932)	N	Hari, Kavir
Cyprinodontiformes	Aphaniidae	*Aphanius farsicus* Teimori, Esmaeili & Reichenbacher, 2011	E	Maharlu
		Aphanius pluristriatus (Jenkins, 1910)	E	Persis
		Aphanius isfahanensis Hrbek, Keivany & Coad, 2006	E	Zayandehrud
		Aphanius sophiae (Heckel, 1847)	E	Kor, Sirjan
	Poeciliidae	*Gambusia holbrooki* Girard, 1859	EX	Widely distributed
		Poecilia latipinna (Lesueur, 1821)	EX	Namak
		Poecilia reticulata Peters, 1859	EX	Namak
		Xiphophorus hellerii Heckel,1848	EX	Persis, Namak

are generally of small size, are broadcast spawners, non-migratory, and have a wide tolerance of environmental conditions (Coad, 1996).

Conclusion

Qanat is one of the ancient water management systems and is one of the important inland aquatic ecosystems

Figure 16. Abdolrahamati Qanat, Birjand, habitat of *Capoeta fusca*.

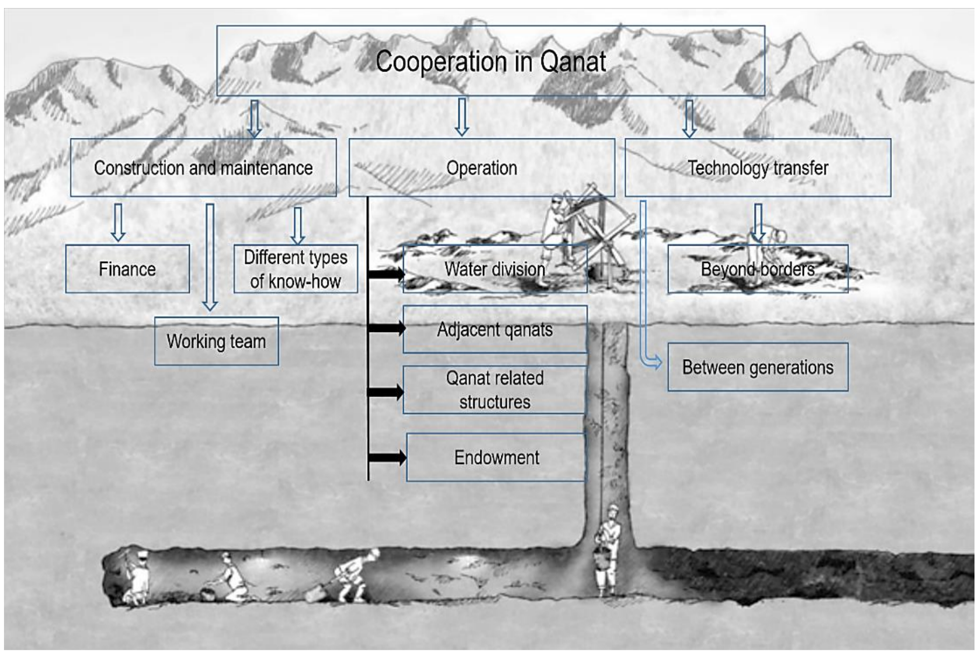

Figure 17. Aspects of cooperation in Qanat, arrows do not denote causal relationships (modified from Semsar Yazdi and Labbaf Khaneiki, 2016).

commonly containing freshwater in arid and semi-arid regions and must have been started at least 5000 years ago in Iran, working mainly based on the cooperation (in construction, maintenance, operation and technology transfer) which is, in fact, inherent in the technical traits and mechanism of Qanat (Fig. 17). This unique ecosystem with specific architectural design provides habitat to about 40 fish species, about 13% of the total natural fish fauna of the country, and many other aquatic organisms (e.g., invertebrates, amphibians, reptiles). At present, many factors threaten the Qanat systems in Iran. Climate changes and increasing risks of desertification, over-consumption of freshwater resources due to population growth and introduction of new technologies, pollution, as well as inadequate policies have all contributed towards the degradation of the ingenious system of Qanat construction and maintenance. Traditional Qanats systems are being replaced by pump-wells which are faster and easier to excavate but do not offer a fish habitat. Pump wells often dry up Qanats and natural springs by lowering the phreatic level.

In ancient Iran, water-related problems were solved by basic concepts of Hydraulics. In the same way, water-related infrastructures were built using locally available materials to make a better life for humans and other wonderful well-designed and well-adapted organisms in dry and semi-dry regions, yielding great civilization with a simple, but a fantastic architecture that provides cold water in hot summer and warm water in cold winter. By means of these ancient underground structures, water was funneled from mountainous areas and aquifers to lower lands and thus alluvial fans could be opened up to settlement, and an agrarian civilization developed and evolved.

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