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At the Crossroad of Nature and Culture in Iran: The Landscapes of Risk and Resilience of Seismic Space

Michaela Ibrion [1+], Haakon Lein [1], Mohammad Mokhtari [2], and Farrokh Nadim [3]

[1] Department of Geography, Faculty of Social Sciences and Technology Management, Norwegian University of Science & Technology (NTNU), Trondheim, Norway

[2] International Institute of Earthquake Engineering and Seismology (IIEES), Tehran, Iran

[3] Norwegian Geotechnical Institute (NGI), Oslo, Norway

Abstract. The landscapes as well as cultural landscapes of seismic space in Iran are highly influenced and controlled by fault lines and undoubtedly, by the earthquakes. The contribution of fault lines to the vulnerability of communities is balanced by their role in existence of water resources which are accessed through qanats. Qanats are sustainable systems built upon the local resources, in terms of water, land, natural environment, through the capacities of local people and the local knowledge. Qanats offer illustrative lessons of adaptive and sustainable strategies of local communities to the seismic landscape of arid and semi-arid areas. For centuries, the cultural landscape of qanats sustained the human being habitat and their well-being, thus it was critical for their survival and resilience. The life of communities within the seismic landscapes of arid and semi-arid areas has been unceasingly shaped by the landscapes of resilience and risk. The resilience of communities entangles with the seismic risk and their power of adaptability is conditioned not only by the uncertainties about where and when the next earthquake may strike, but also if communities are aware and adequately prepared for an earthquake.

Keywords: Culture, Landscape, Qanats, Earthquake, Risk, Resilience.

1. Introduction

Iran is situated in a highly seismic part of the Alpine-Himalayan belt and has a long history of frequent earthquake disasters that brought large number of death, injuries and massive destructions [1]-[3]. Earthquakes are challenging geological phenomena with a sudden onset. In spite of the tragedies and damages caused, earthquakes are phenomena that are part of the course of nature and the life in Iran. During millennia, people have developed a close and unique connection with the land, environment and nature in the seismic space of Iran. Even the harsh climate of arid and semi-arid areas of Iran is habituated by communities [4].

During human generations, various aspects of the seismic space in Iran have gone through continuous changes, which indicate their inherent dynamic performance in a multitude of perceptions. Today, the degree of complexity of Iranian seismic space is higher than before and this recommends for more exploration and further research. The landscape is the most perceptible and eloquent expression of the variable and ever changing culture-nature relationship. Landscapes involve various interests and cultural objects and establish the stages and arena for human life.

The main objective of this paper is to explore the various landscapes of seismic space in Iran and to analyse their intricacies and relationships. Four types of landscapes are analysed: the cultural landscape of qanats, the seismic landscape of arid and semi-arid areas, the landscapes of resilience of the communities and the landscapes of risk. Qanats, underground water channels and samples of Persian engineering wonders, are the common cultural objects shared by all four presented landscapes. The earthquake disaster of Bam in 2003 is chosen as a case study in present paper.

2. Cultural Landscape of Qanats

+ Corresponding author. Tel.: +47 73591809; fax: +47 73591809.
E-mail address: Michaela.Ibrion@svt.ntnu.no

Qanats are underground tunnels which take the water from the aquifers of mountains to the human settlements. Qanats represent a vibrant example of the ingenious hydraulic structures as the gravitational flow of water inside the qanats is assured by a very gentle slope. Qanats epitomize Persian hydraulic structures. The Persian scientist, Karaji, presented the principle of Earth gravity and the flow of surface water, more than 1000 years ago [5]. The origins of the word qanat are subject to the controversies, but one of the possibilities is that qanat may has been derived from Persian "kene" which means digging [6]. Qanats exist in more than 34 countries of the world [7] and there are various theories which support that qanats originated from Persia [5], [7], [8]. Qanats stand among the oldest systems of water supply not only in Iran; but also in the world [7] which are considered as "a unique form of irrigation" [9]-see Fig. 1. Qanats influenced the survival, life and development in arid and semi-arid areas and created specific cultural, socio-economic patterns, even "Qanats civilizations" [5], [6].

Fig. 1: Qanat line, Yazd province, Iran (Photo by: Michaela Ibrion, 2012).

Within arid and semi-arid areas of Iran, the water ownership rights were vital. These water rights were considered as valuable as the land ownership rights, or even more important [7]. Both ownerships of land and water conferred to people a high social status. The location near qanat or the neighbourhood of qanat was highly appreciated and the social hierarchy and status was determined by the position of the house or other properties, versus upstream or downstream of qanat [5]-see Fig. 2 and 3. Moreover, the method of water distribution determined a special cohesion and cooperation between the members of communities. Qanat system was in closed bonds with the spiritual life of communities, their beliefs and values. Water of qanats was seen as sacred and it was an essential part for various ceremonies and rituals. Wastage of water was something to be condemned and not accepted by the communities [5]. Qanats have been an integral part of Iranian cultural heritage and their harmonious relationships with nature and culture thrived during centuries till present days.

Fig. 2: Qanat water channel entering the village, Yazd province, Iran (Photo by: Michaela Ibrion, 2012).

Fig. 3: Qanat water storage in front of "kadkhoda" house (literally ruler of village), Yazd province, Iran (Photo by: Michaela Ibrion, 2012).

The number of qanats and the quantity of water discharged by qanats in Iran has dramatically decreased in the last decades. Various reasons can be invoked for this situation including the land reform, massive usage of wells and pumps, the high number of built dams, the depletion of water reservoirs and the unsustainable policies.

3. Seismic Landscapes of Arid and Semi-Arid Areas, Qanats & Water

Iran is situated in the mid-latitude part of arid and semi-arid regions of the Earth [10]. The climate of Iran is divided into eight climatic groups and the group that shares the biggest part, more than 60% of Iran's surface, represents the arid and semi-arid areas. 77% of qanats are located in arid and semi-arid areas of Iran, in central and eastern parts which receive the lowest annual rainfall and no rainfall during the summer months [10]-[12].

In Iran, the patterns of the early settlements of people were ruled by the vital access to the water, to the various sources for creating and sustaining their livelihood, to the possibility of agriculture and to the access to trade routes and building materials. However, the mountain and spring valleys areas not only accommodate the water; but also the seismic fault lines [4], [13], [14]. Between mountains and plains, there is a network of fault lines. Because of the fault activities, the constant grinding of the rocks creates impermeable and fine clay named "fault gauge" [4]. The fault gauge forms an underground barrier that performs similar to a real underground dam and elevates the water table. In order to access this water resource in fault areas, the underground tunnels of qanats were dug by people called muqannis. Their knowledge for this type of job was transmitted from father to son, for many generations and their work was essential for the existence of qanats in terms of building, maintenance and repair after the earthquake. In the last case, muqannis used among other practices, a special technique called "koor kardan-e cheshm-e zamin", literally meaning "making blind the eyes of the earth" [6] to seal the damaged tunnels. The experience and expertise of muqannis was highly respected by the local communities [5]. Muqannis from Yazd were very famous for their legacy and skills. There were many Afghan immigrants muqannis which worked for a while in Iran, but part of them returned in the last decade to Afghanistan [7].

Through qanats, the water was brought to the surface just simply relying on the gravity law. In amazing and miraculous ways, water was tapped from the range front of the mountain, for distance of several tens of kilometres and brought it to the human settlements. In case of earthquake the water table level near the fault gauge was affected and a lot of qanats were destroyed. Some qanats were repaired, others abandoned, and new ones were being dug. The builders of qanats were aware about the advantages offered by the fault line and the existence of water. The fault lines gave life to the people through the water of qanats, but also the fault line took away the life with the occasion of numerous earthquakes [4]. This was the case of Bam earthquake which took merely seconds to bury his inhabitants and to destroy the cities of Bam, Baravat, and the villages around. Fault lines generates the water, but also determines the vulnerability of place for the cities and villages nearby [13], [14].

4. Landscapes of Resilience

Resilience is defined as "the ability to prepare and plan for, absorb, recover from or more successfully adapt to actual or potential adverse events" [15].

Earthquake resilience is primarily affected by the human life loss and the injured people. Secondly, the destruction and the socio-economic loss add its contribution to the dramatic diminution of earthquake resilience. On 26 December 2003, the earthquake of Mw 6.6 (moment magnitude) destroyed cities of Bam and Baravat and nearby villages in Kerman province, southeast part of Iran. The population of Bam, Baravat, and vicinities was approximately 150,000 people at that time. After earthquake, the death toll was between 26,000 and 40,000. There were about one-third of students of Bam, between one-fifth and half of the teachers of Bam and over 200 healthcare staff among the victims. More than 6,000 children become orphaned, approximately 30,000 people injured, about 75,000 became homeless and more than 70 % of buildings destroyed [13], [16]. "The reason for this tragedy was an unfortunate combination of geological, social and human circumstances" [14]. Bam earthquake was an earthquake of medium magnitude, but it was a distressing example of the way how a moderate geological event interfaced with an unprepared society and the result was a terrible disaster [16].

Bam earthquake disaster brought to the attention the vital lifelines for arid areas: the qanats. Before the earthquake, the agriculture of Bam and Baravat was highly dependent on the water provided by more than 60 qanats [13]. Citrus orchards and the famous "rotab" dates owed its existence to the hydraulic wonder of qanats. At the time of earthquake, in Bam and its vicinity were about 1,600,000 date trees [13] which were sold around Iran and sent for export, making a sound contribution to the livelihood of communities. More than 55 qanats suffered various damages during earthquake which had negative effects on the resilience of communities. Resilience framework encompasses two facets: first the inherent resilience specific to normal periods and, second the adaptive resilience. The second facet is specific to difficult periods like disaster [17]. Consequently, one of the priorities after earthquake was the repair of qanats [13]. Qanats acted during the centuries as catalysts for the adaptation of local communities during seismic quiescence and post-disasters.

Resilience of communities is strongly interlinked with the harmonious relationships with nature and its resources. Sustainability concept is at the core of communities' resilience [17]. Qanats had positive effects on the sustainability of groundwater resources and conferred to the communities' great socio-economic and cultural bonds [7]. During the centuries, qanats affected the foundation of life for local communities in positive, sustainable and resilient way. Moreover, qanats empowered local people regarding the management of water and contributed to the livelihood patterns and cultural landscape [5].

People living in arid and semi-arid lands had well recognized the potential of alluvial fans systems for providing water in harsh environmental settings. Communities, villages, cities were created and developed based on the traditional water harvesting system and potential water reservoirs in alluvial fans. In arid and semi-arid areas, the only reliable source of water was the underground water, so qanats system made possible the existence of agriculture and assured constantly the livelihood of human settlements.

The resources of water in the world are falling into three distinct categories: internal renewable resources, external renewable resources and non-renewable resources. Water in Iran belongs to the first category [18]. Rapid demography, modern technologies, land reform, socio-cultural changes, an effervescence of policies and legislations in Iran has encouraged a high demand of the water supply. Over few decades, it has dramatically been demonstrated that various technical solutions such as pumps, dams and modern water management are unsustainable and with severe effects for the sustainability and life of qanats [5]. In addition, other negative consequences followed shortly, such as the depletion of water resources, the subsidence of soil and the salinity threat to agricultural places. Water is a unique and vital resource in the world [19] and can bound the communities of seismic landscapes for arid and semi-arid areas. However, if water reserves are in shortage or depleted the resilience of communities are seriously undermined.

5. Landscapes of Risk

Risk is seen as a "Measure of the probability and severity of an adverse effect to life, health, property or environment" or in the other words: "Risk is defined as Hazard multiple Potential worth of loss" [20].

On the west side of Kavir-e-Lut (literally Lut desert) in Kerman province, the tectonic faults system of Nayband, Kuh Banan, Jorjafk, Gowk, Sabzevaran, Rafsanjan and Bam was reactivated by the Bam earthquake in 2003 [16]. However, the Bam earthquake did not considerably rupture the active fault system and a significant seismic hazard continues to remain in Bam. A potential seismic hazard for future is represented by the blind faults along Jebel Barez Mountains to the south and Sarvestan fault, to the west [21]. The seismic risk cannot be eliminated, but can be reduced to an acceptable or tolerable level [20]. Among the strategies used for mitigation of the seismic risk, the preparedness of community and awareness campaigns can make a sound contribution [20].

The seismic risk was not considered by inhabitants of Bam, Baravat and the villages situated in vicinity. People of Bam believed that an earthquake will not happen during their lifetime. Three elements of cultural landscape strongly influenced people' beliefs and their strategies of action regarding the earthquake: the Bam Citadel, the qanats and the dates trees [22]. Bam Citadel was believed to be between 2,000 and 2,500 years old implying that no destructive earthquakes took place in Bam during this period. However, the historic reality appears to be different. The Bam citadel was destroyed during King Ardeshir Babakan, Sassanid dynasty, more than 1,774 years ago. From that historical time till 2003 earthquake, the Bam Citadel went through minimum ten documented periods of reconstructions. Many parts of architectonical complex of Bam citadel dated from eighteenth and nineteenth centuries and it seems that the Friday praying mosque reconstructed in 1751 was the "the oldest recorded partially standing structure in the citadel" [16]. It was the myth of citadel that contributed to the fame of the Bam cultural landscape, and the same myth affected Bam earthquake preparedness. Qanats had also their influence on people's beliefs and on the earthquake mitigation. According to the Bam's beliefs before the earthquake, the qanats would act as powerful pressure valves which would not allow Earth energy to build up and create earthquakes. In addition, the famous date trees were believed that will keep Earth with their strong roots and will not allow the shake to produce many damages [22]. People's beliefs were so strong that only few people took action after the three alarming foreshocks that occurred before the main shock in Bam. The last foreshock occurred just 53 minutes before the main shock which completely destroyed Bam, at 05.26 local time, Friday, 26 December 2003 [16].

Furthermore, the earthquake awareness was influenced by strong references to "a lack of seismicity in the Bam area for the last 2,500 years", or "seismic quiescence" during pre-instrumental time and "low seismicity" during instrumental time [16]. Vulnerability of the buildings and the timing of the main shock, early morning in a weekend day, when many were still in sleep, added massively to the proportion of the earthquake disaster.

Vulnerability of the place had its contribution to the proportion of earthquake disaster. For thousands of years in Iran, there has been a strong correlation between mountains, fault lines and the access to the water [4], [13], [14]. Bam is situated in a valley between the mountain Kafut to the north and the Jebel Barez Mountain to the south, in Kerman area, on the west side of Kavir-e Lut (literally Lut desert). The oasis of Bam is famous in Iran as well as in the world, for the cultivation of date palms and most of the trees are growing in the east part, near Baravat. In the S-SE part, between Bam and Baravat, is a ridge uplifted by a blind fault and the water is provided by the aquifer in the wall of this fault [4]. This fault carried the blame for Bam earthquake in 2003. Paradoxically, it is the same fault line that trapped the groundwater and formed a type of natural underground dam which recharged continuously the aquifer for the water of Bam, Baravat and vicinity. Bam earthquake was a dramatic example of remembering the essential lessons of learning to live with the seismic risk to communities and Iranian society. In addition, the particular landscape of water and qanats systems, in the area around Kavir-e Lut, may have the potential to contribute in mapping the faults lines [13], [14]. Despite various academic rigorous perspectives and controversies about this subject, each effort and step that contributes to the mitigation of seismic risk is highly encouraged.

It is well worth considering the seismic narratives which refer to the unsustainable anthropogenic activities with potential to induce or trigger earthquakes. One of these narratives relevant for this case study refers to the consequences of excessive groundwater extraction. The drainage of the aquifer through the excessive pumping, subsiding and other relative phenomena may induce the earthquakes, like in the case of Lorca earthquake in Spain [23], [24]. The removal of water that affects the stresses within the crust and may trigger seismic phenomena needs further consideration. These type of narratives referring to water and

induced or triggered seismic events, may create numerous polemics and dilemma within the scientific landscape. However they contribute to the understanding of the rapid changes, the dynamics of Earth, the correlation between human activities and environment, the relationships culture-nature and the earthquake preparedness of the communities and society.

6. Conclusion

The cultural landscape of qanats, the seismic landscape of arid and semi-arid areas and the landscapes of risk and resilience are intertwined; thus it is needed to be carefully considered and analysed together. Seismic landscape of arid and semi-arid areas can challenge the tolerance limit of people. In the same time, this landscape remains the context of human lives and place of the resources vital to their livelihood. It is essential to understand not only the vulnerability of place in the seismic and arid /semi-arid landscapes, but also the vital contribution of fault lines to the existence of water and to the resilience of local communities.

For communities situated in seismic and arid areas, their landscape of resilience is highly influenced by the water resources and qanats. During centuries, qanats empowered the local communities and offered illustrative examples of bottom-up approaches to resilience and sustainable development. Nowadays, the existence and function of qanats is constrained and menaced by the modern development, policies, depletion of water reservoirs and unsustainable actions.

The landscape of risk can be subject to a combination of strong beliefs and assumptions which severely influence the earthquake disaster preparedness and affect seismic risk reduction. For instance, the strong beliefs of the communities in Bam and neighbourhoods, created the confidence that through the cultural objects of Bam citadel, dates trees and qanats, they can negotiate in their own terms with the powerful forces of nature. In order to have resilient communities and society it is essential to understand the meanings of the seismic risk and its strategies for mitigation and disaster reduction. Otherwise the resilience is condemned to remain just as a simple metaphor for the present generations and for those yet to come.

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