AEXTJ
AGRICULTURAL EXTENSION JOURNAL
ISSN 2582- 564X

Available Online at www.aextj.com
Agricultural Extension Journal 2023; 7(2):35-47

RESEARCH ARTICLE

Indigenous Knowledge for Sustainable Exploitation of Water Resources in the Desert Areas: Aqueducts (Qanats) Repairing and Reconstruction in the South Khorasan Province, East of Iran

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Received: 25-02-2023; Revised: 20-03-2023; Accepted: 05-04-2023

ABSTRACT

The central plateau of Iran is located in the desert belt of the world, making dryness and water scarcity inherent characteristics of the region. Access to sustainable water sources has always been a significant challenge for the area's residents. However, ancient Iranians created the aqueduct, a system that respects the environment and is compatible with nature, to address this challenge. This invention gave birth to a brilliant civilization on the central plateau of Iran, which is sometimes referred to as the "Karizi Civilization." Iran's aqueducts serve as a model of sustainable development, promoting respect for nature and coexistence with the environment. The aqueducts play an essential role in the social and economic structure of dry areas, such as the central plateau of Iran. The precise engineering system of water distribution and the appropriateness of land and water ownership have prevented social tensions over the use of aqueducts, making them a factor of social unity, solidarity, and great social capital for the residents of those areas. The efficiency of the aqueduct system for more than 3000 years demonstrates the success of the sustainable development model observed in the structure and system of the aqueduct. Throughout history, the residents of the central plateau of Iran have faced water scarcity due to dryness and low rainfall. While the introduction of new technologies for underground water extraction in the second half of the 20th century has been a significant threat to the aqueduct and its system and social structure, it has also destroyed several 1000 years of Iran's achievements in water and water management. This article investigates the different dimensions of aqueducts as a solution based on the indigenous knowledge of ancestors for sustainable use of water resources in the desert areas of Iran. The authors emphasize the restoration of the aqueducts and their role in the development of rural tourism, sustainable employment and livelihood, and reverse migration. These solutions can be implemented in South Khorasan Province and other areas facing similar water scarcity challenges.

Key words: Aqueducts, desert areas, indigenous knowledge, Iran, sustainable use, water resources

INTRODUCTION

Water is the most crucial element for life and has played a significant role in the construction and development of the world for a long time. The uneven distribution of rainfall and water resources, combined with successive droughts and non-compliance with principles related to water conservation and protection, have stimulated human creativity throughout history to find innovative solutions and promote education in this field. Therefore, it is essential to pay attention to the unique situation of water resources.

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Most of Iran's land is situated in arid and semi-arid regions within the global desert belt. Thus, the central plateau of Iran has a natural shortage of water, making access to sustainable water sources a crucial challenge for its residents. The ancient Iranians invented the aqueduct, a sustainable method of accessing water that respected the environment and nature's balance, and it became the source of a brilliant civilization in the region. The principles of sustainable development, which are now in vogue, were already embedded in the structure and system of the aqueduct, which remained efficient for more than 3000 years.[1]

For many years, the Aqueduct has been a crucial pillar of social life and development in Iran. Until the 1960s, most of the central regions of Iran relied on the Aqueduct to meet their water needs. The aqueduct, also known as an Aqueduct or Kariz, is an underground channel that allows water to flow to the surface of the earth. This channel connects a string of wells to the mother well, which is typically an underground spring. The Aqueduct is primarily used for managing and directing water for agriculture and other purposes. It can span several kilometers and the point where the water exits is referred to as the Kariz mouth, the head of the aqueduct, or the mouth of Farah. The Iranians were the first to construct the Aqueduct.[2]

Kariz was a remarkable system that was capable of irrigating the fields of more than 60,000 villages in Iran. However, introducing new technology resulted in deep wells replacing aqueducts and the gradual adoption of motor pumps throughout the country. Unfortunately, the construction of deep wells without proper planning caused 90% of the aqueducts to dry up, making it impossible to restore them. This is because digging deep wells has significantly lowered the water level, and no one has taken responsibility for resolving this issue. It has been over 1000 years since our ancestors dug thousands of meters into the ground with simple tools to bring water to the surface and provide life to the area. It is our responsibility to protect this inheritance [Figure 1].[3-5].

The introduction of new technologies in the field of underground water extraction in the second half of the 20th century posed a significant threat to the aqueduct system and social structure on the central plateau of Iran. This destroyed the achievements of several 1000 years of Iran in the field of water and water management. Many modern technologies are not suitable for Iran's climate and arid land, contrary to the indigenous knowledge and experience of Iran's ancestors. This has caused numerous problems in the field of water resources in the central part of Iran. Restoring aqueducts based on indigenous knowledge can serve as a sustainable development initiative, providing irrigation and productive, social, and economic systems in a large part of Iran.[1]

INTRODUCTION OF THE AQUEDUCT

An aqueduct comprises multiple wells and an underground tunnel, which transports water from the mother well (the initial well connected to the groundwater table) to the aqueduct (where the water emerges on the surface). Aqueducts have sloping surfaces that guide water from underground layers to higher ground. Water flows out of the underground tunnels naturally, without requiring any energy. Physically and materially, aqueducts are downhill underground channels that direct water from upstream areas and underground to the same level as agricultural fields. Typically, aqueduct systems are found in regions with medium rainfall between 100 and 300 mm.[4]

The construction of aqueduct technology began during the first millennium BC in the dry mountainous areas of Iran, allowing farmers in those areas to farm for extended periods of time during droughts when surface water was unavailable. Aqueducts gradually became popular in other parts of the world, and today there are many aqueducts from China to Morocco. Even in America, there are aqueducts. The ancient Iranians began this innovative technique several 1000 years ago, calling it Kariz or Kehriz. The first and longest aqueduct in the world is located in Iran. This unique invention makes it possible to collect a significant amount of underground water and bring it to the surface of the earth, where it flows all year round, just like natural springs, without requiring any assistance. Kariz, which was crafted by the skilled hands of Maghnian (skilled workers for building and repairing aqueducts), also brought with it the water mill, making it a blue-hour profession. Despite the several 1000 years that have

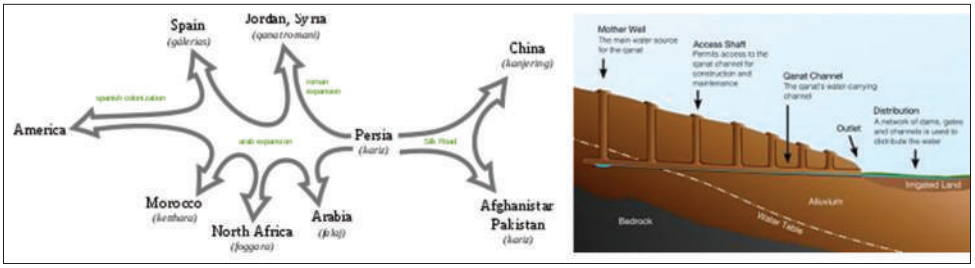

Figure 1: Historical expansion of an aqueduct (qanat) from Iran to other regions (left picture), and cross-section of an aqueduct (qanat) (right picture)[1,7]

passed since its invention, this method of water utilization is still used in some villages and areas for residential, agricultural, and animal husbandry purposes. It is a common practice and the primary method of cultivation in dry areas.[5]

The process of digging a Kariz begins by excavating a mother well or a well with water. Typically, this well is dug at the base of mountains, streams, or areas with thick vegetation as a sign of underground water. Next, an aqueduct is dug to transport the water from the well to the surface of the earth. To ensure ease of soil removal, air flow for breathing, and lamp lighting, vertical wells are constructed until the water reaches the earth's surface. In areas where surface water is scarce, the management of aqueducts plays a critical role in the production, allocation, distribution, and utilization of water. The aqueduct serves as proof of the need for careful management, and this management is divided into two fundamental parts. Structural management encompasses planning and addressing construction-related challenges such as reconstruction, repair, and maintenance of the aqueduct. Non-structural management involves the digging and upkeep of the aqueduct, various distribution systems, and the use of the aqueduct. The construction and management of aqueducts over thousands of years have been based on these principles. The sustainability and durability of aqueducts have been sought in these practices. To achieve sustainability, it is crucial to consider techniques and methods that are in harmony with ecological laws. Indigenous knowledge and experience are vital to these methods and techniques. Among these, the Iranian aqueduct holds a special place. As a case study, Kashan aqueducts have been analyzed from the perspective of indigenous knowledge and cultural heritage to demonstrate the compatibility of this system with environmental conditions.

Aqueducts have played a critical role in providing drinking water and agriculture in many regions of Iran. The sustainability of urban and rural settlements has relied on aqueducts, and they have also been used for energy production. The presence of aqueducts has decreased the salinity of the land and improved its quality. These roles showcase the importance of the aqueduct as an irrigation, production, social, and economic system in many parts of Iran [Figure 2]. [4,5]

THE PURPOSE OF THE ARTICLE

In this article, we explore the significance of the native structure of the aqueduct (qanat) in social cooperation and the creation of permanent settlements in Iran, where land plays an integral role. Our aim is to preserve the traditional methods of water resource management and align cultural and social institutions to maximize the potential of these structures. We investigate the role of local knowledge of aqueducts and related water structures in sustainable development through an analytical-descriptive approach. To provide context, we examine theories surrounding indigenous knowledge before delving into the role of the water structure of the aqueduct as a sustainable way of extracting water. We also analyze the impact of the water mill and reservoir on traditional water management and their influence on social customs and cultures over time. Our findings demonstrate that indigenous knowledge of aqueducts is the most sustainable method of extracting underground water. It requires group cooperation for its protection, management, and exploitation. Water storage and water mills are the most significant water structures that facilitate the optimal use of water near the aqueducts and complete the circle of social cooperation, architecture, and

Figure 2: Aqueduct (qanat) repairing and reconstructing plus rural women work and Carpet weaving by them and establishing a solar water heating beside of this aqueduct (qanat) in Binabad village, 70 km distance to Birjand, south east of Iran. This caused positive effects in economic conditions of rural people, development tourism, and increasing reverse migration in this region (pictures by author, spring 2021).

the formation of social customs and cultures, often linked to religious beliefs. Despite the shift in water exploitation policies through wells, leading to many abandoned and dried aqueducts, we emphasize the importance of preserving these structures. The restoration and reconstruction of aqueducts, the creation of underground dams and above-ground storage tanks, and the insurance of watermen, among other government support for watermen, will be effective in preserving social and cultural structures and the traditions of the general good. We advocate for the promotion and academic development of the watermanship profession with modern facilities and tools while preserving traditional ways of exploiting aqueducts. Finally, we encourage changing attitudes toward the aqueduct, accepting it as the best method of extracting underground water, and using other extraction methods to cover its weaknesses for optimal use of water.

RESEARCH METHODS

The present study utilized qualitative methodology and rural participatory assessment techniques, including interviews with key informants, field observations, the formation of focus groups, and the

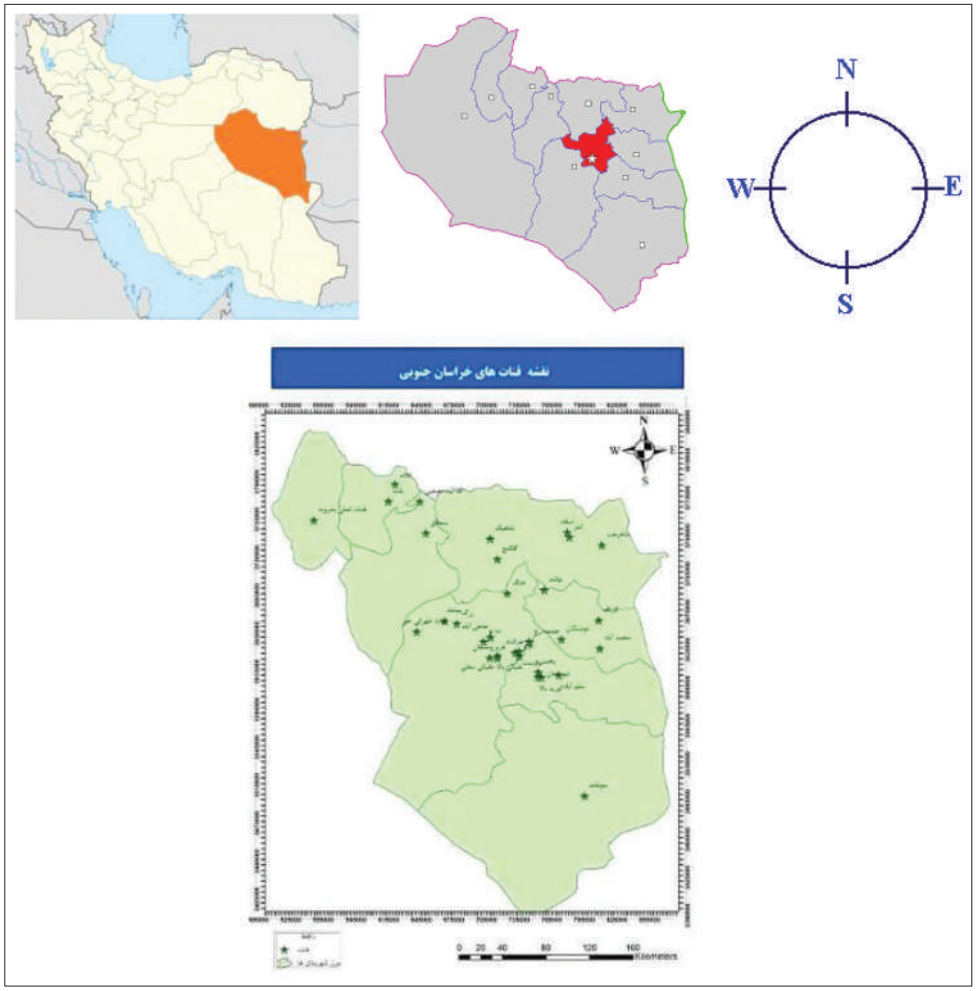

Figure 3: Maps of main locations of doing this research, (left map- Location of South Khorasan Province in east of Iran, Coordinates: 32.8653°N 59.2164°E), and Birjand city center of South Khorasan province and beside borders of Afghanistan (right map), plus maps of locations of aqueducts (qanats) in the South Khorasan Province in east of Iran (At a map scale of 1:1000000)[4,7]

preparation of checklists. The selection of studied aqueducts was done using a purposeful sampling method and with the consultation of a top expert on aqueducts in South Khorasan Province, east of Iran (Figure 3). It is important to note that the generalization of the results to other aqueducts in the province is not the goal of this study. The primary aim is to gather the opinions of villagers and farmers in South Khorasan province on the restoration and reconstruction of the aqueducts of their villages, which have been suffering from continuous droughts for almost two decades. The restoration and reconstruction of these aqueducts have provided hope and encouragement and have helped keep life alive in South Khorasan province, east of Iran.[4]

Qualitative methodology has gained attention from researchers and sociologists in rural development studies. These methods aim to put villagers at the center, to understand rural culture, and to actively involve them in the study implementation process. Given that aqueducts are the primary lifeline of villages in South Khorasan province and nearly half of the province's population lives in these villages, the present study was conducted based on the sustainable livelihood approach, which is one of the most widely accepted theories in rural development that prioritizes rural people. The study examined the five assets (financial, human, social, natural, and physical) of aqueduct users before and after the restoration and reconstruction of aqueducts.

A SHORT OVERVIEW OF SALAMABAD AQUEDUCT VILLAGE

Salamabad Aqueduct Village is situated in Salem Abad, a rural area that is part of the central city of

Figure 4: Various phases of Koling, installing Kol, repairing and reconstructing of aqueducts (qanats) repairing and reconstructing in Salamabad Aqueduct Village and other queducts (qanats) in rural regions in the South Khorasan Province in east of Iran. Plus cultivating Barberry shrubs (Berberis vulgaris) that are drought resistant plants and favorable for dried conditions of this region. (two last pictures) (pictures by author, 2015–2021) [8]

Sarbisheh. The primary occupations in this village are agriculture and animal husbandry. The village is home to three aqueducts, namely Aqueduct Salem Abad (Aqueduct Main Village), Tabran, and Ali Burned. The Aqueduct is located in the central part of Sarbisheh city and in the Momen Abad district.[4,6]

Actions Taken to Restore and Reconstruct the Salamabad Aqueduct

In 2017, the Salamabad Aqueduct, located in Khordad, was subject to restoration and renovation. The Director of Agricultural Jihad in Sarbisheh reported that the project cost 297 million Toman and that the validity of the restoration was ensured. As a result of the efforts, the flow of Dubai Water increased from 15 L/S to 20 L/s. The restoration project took a year, from June 20, 2016 to June 20, 2017. The need for the project arose after the aqueduct was destroyed due to flooding caused by heavy rains in March 2014 and April 2015. A section of the old water flow path measuring 700 m was damaged, with 150 m being completely settled. The resulting disruption to the flow of water from the aqueduct had a significant impact on agriculture and animal husbandry in the area. After a thorough field visit to the aqueduct and the site of flood damage, an excavator was used to immediately reopen the 150-m path. Water flow was restored to ensure minimal disruption to the local economy. After conducting field and expert investigations, it was decided to dig a new aqueduct starting from the location of the Mazhar aqueduct, adjacent to the old gallery of the aqueduct. During the visit, the respected supervisor was able to address queries related to the change in direction of the aqueduct, mapping, and alignment. The new aqueduct will be 520 m long, with two passes. The first pass will be 1–4 m deep and 1.30–2 m wide,

while the second pass will be 4–9 m deep and 2 m wide at the bottom and 8 m wide at the top to ensure optimal water flow. This direction was chosen to align with the existing bridge and to avoid potential dangers to Maghnian (skilled workers for building and repairing aqueducts) and workers (Figure 4).

To prevent water from deviating from the new aqueduct, a dry elementary school aqueduct was drilled with attention to detail. A concrete block with dimensions of 40 cm in length, 20 cm in width, and 20 cm in height was used to construct a tiny back wall hanging 50 cm thick. The wall hanging was then covered with rock derm and concrete, 20 cm high, and armed with rebar grade 8 that was 80 m long. This plan was accepted to ensure proper water flow and avoid any potential issues.[5,6]

Koling and Installing Kol

Installation and Construction of Kol and the Culvert Road: The culvert road spanning 520 m from the end of the concrete block road underwent floor

Figure 5: *Continued*

Figure 5: Visiting of author from rural regions in South Khorasan and their aqueducts (qanats) repairing and reconstructing plus dried aqueducts (qanats) that caused migration local people from their villages to cities and urban regions (Establishing a pool for storage aqueduct water in foothills for utilizing by poor villagers and their herds. With author presence in Derakhte Toot village, 180 km. distance to Birjand, center of South Khorasan province, Autumn 2017. Plus, Noferest village, 40 km. distance to Birjand, center of South Khorasan province, and its aqueduct and a pool for storage aqueduct water and villagers with their gardens and cultivating rose for extracting rosewater etc. Spring 2016. Plus, establishing an irrigation canal for transferring aqueduct water to farms of villagers, in about 20 km distance from Birjand, center of South Khorasan Province, 2011 and 2017. Plus, a dried aqueduct and its two empty water storage pools in Bidokht village and its dried trees and empty of population rural region because of continuous and long run droughts in last two decades, five km distance from Birjand, 22 last pictures, January 11, 2018) (Pictures by author, 2011–2021) [8]

screeding, culling, and leveling around the culverts, followed by the tying of the culling path. To expedite and improve the quality of lime supply, a 30 cm-thick layer of 150 kg of lime was applied under and around the kuls using a tractor shovel. The culling was done vertically and level with cement culling, meeting a specification of 75 cm width, 1.2 cm height, and a grade 3 wire with 300 kg of cement.

Effects of Rebuilding the Aqueduct of Salam Abad Village: Social Effects Participation Rate: Participation by village people is necessary for self-reliance in agricultural production, and management of agricultural water resources is a primary manifestation of village participation. In the restoration and reconstruction of the Salamabad village aqueduct, the owners of the aqueduct participated through self-help, collecting a total of 300 million Rials, equivalent to 30 million Tomans. Agriculture and horticulture activities under the name of the company are carried out in Aqueduct Salamabad, of which 50% of the shares belong to the Awqaf Administration (an organization that is responsible for welfare works and affairs for poor people in Iran) (Figure 4).

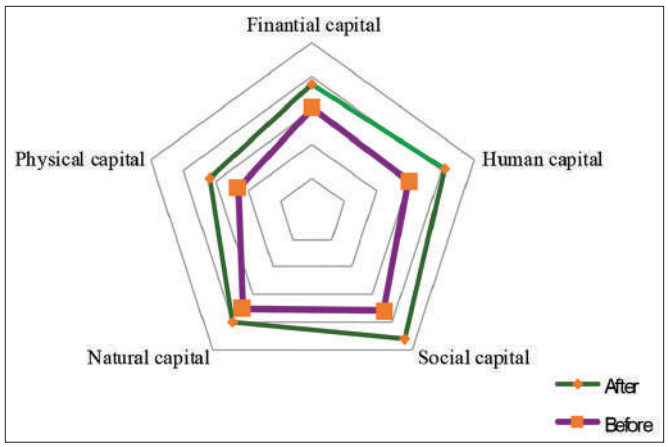

Figure 6: Comparison of different rural capitals before and after of restoration of Salamabad abundant

Aqueduct Salamabad comprises 1800 cups of water, and the irrigation circuit is 7.5, irrigating every 60 cups for 6 h. Satisfaction Level of Farmers: Satisfaction is categorized into internal and external satisfaction. The level of external satisfaction of villagers is primarily affected by the fulfillment of their needs and desires. In Salam Abad village, the restoration and reconstruction of the aqueduct led to an increase in water supply, which had a direct impact on the expansion of horticulture and agriculture, resulting in an overall increase in satisfaction with the performance of the Agricultural Jihad. Desire to Return to the Village: Despite the increase in water supply, the population of Salamabad village has not been directly affected in terms of villagers desiring to return to the village. The primary reason for the increase in the village's population is its proximity to Sarbisheh. Psychological Effects on the Residents of the Village: The aqueduct management is carried out by the company, and the number of farmers owning the aqueduct is limited. The psychological effect among the aqueduct partners is an increase in happiness and joy from the increase in water supply. Other psychological effects, such as creativity, innovation, and an increase in effectiveness and efficiency, are not as evident. Reduction of Conflicts: Conflicts on irrigation management do not exist among the partners of Aqueduct Salamabad, as agricultural activity in the village is carried out by the company, and only a few partners conduct horticulture activities separately. Social Trust: The restoration and reconstruction of the Salamabad aqueduct have doubled the trust of the local people in the government, leading to strengthened social interaction between the villagers and the government in Salamabad village. Institutional trust in the restoration and reconstruction is clearer and bolder because the destruction of the aqueduct affected both the endowment administration and the 25 farmers under the supervision of the Agriculture and Horticulture Company (Figure 4).[5-7]

The institutional trust in the restoration and reconstruction discussions is now more evident and prominent. The recent flooding had caused the destruction of the aqueduct, which disrupted its water supply. After the experts from the Jihad Agricultural Department of Sarbisheh assessed the situation and allocated funds for restoration and reconstruction, priority was given to this project.

Social Cohesion

In many cases, villagers require group cohesion to obtain production resources, particularly agricultural water. In Salam Abad village, the management of agricultural land is under the company's supervision, with only a small number of villagers as its members. Despite this, there was cohesion and unity among the partners of the aqueduct, which has helped to justify the experts of the Jihad Agricultural Organization's restoration and reconstruction of the Salamabad aqueduct. Furthermore, this cohesion has increased their power of influence. The increased water supply from the aqueduct has led to peaceful co-existence between the owners and new residents, resulting in an increase in the yield of agricultural and garden crops and, subsequently, an increase in the income of the aqueduct owners. Since piped water is available in Salamabad village, the restoration and reconstruction of the aqueduct have helped to reduce the gap between agricultural and non-agricultural incomes, making a significant impact on the peaceful lives of the two groups with each other.[7]

Willingness to Stay in the Village

The quality of local services is a critical factor in influencing the desire to stay in the village. As Salam Abad village is located near Sarbisheh city and its residents have access to urban welfare services, the desire to stay in the village is very high. The restoration and reconstruction of the aqueduct have

directly impacted the villagers and the partners of the aqueduct who are involved in agricultural activities and have led to an increase in their desire to stay. Other residents who rely on animal husbandry are also the main beneficiaries of the increase in the aqueduct's water flow, along with the company. Increased irrigation has led to various benefits for both groups.

Social Trust

The Agricultural Jihad Organization's prompt response to the restoration and reconstruction of the Salamabad aqueduct has earned the trust of the local community, doubling their confidence in the government. The prioritization of this project has strengthened the relationship between the villagers and the government, with the endowment administration holding half of the share of the aqueduct and 25 farmers supervised by the Agriculture and Horticulture Company. The institutional trust in the restoration and reconstruction process was clear, as the destruction of the aqueduct by flooding disrupted its water supply. However, after the Agricultural Jihad Department of Sarbisheh's experts visited and examined the site, the Agricultural Jihad Organization allocated funds for the restoration and reconstruction, leading to a successful outcome.

Social Cohesion

Villagers often require group cohesion to acquire resources for production, such as agricultural water. In Salamabad village, the management of agricultural land is supervised by the company, of which only a small number of villagers are members. However, cohesion and unity among the partners of the aqueduct led to their increased influence in justifying the restoration and reconstruction of the Salamabad aqueduct by experts of the Agricultural Jihad Organization. The increase in water supply has allowed the owners to live peacefully with new residents, resulting in a boost in the yield of agricultural and garden crops and increased income for the aqueduct owners. The restoration and reconstruction of the aqueduct have also narrowed the gap between agricultural and non-agricultural incomes, benefiting both groups in Salamabad village.

Desire to Stay in the Village

One of the critical factors that affects willingness to stay in the village is the quality of local services. Salam Abad village is located near Sarbisheh city, and its residents have access to urban welfare services, making them highly desirous of staying in the village. The restoration and reconstruction of the aqueduct have had a direct impact on the villagers and partners of the aqueduct, who engage in agricultural activities, as well as on other residents who depend on animal husbandry. With the increase in water flow, the residents benefit from better irrigation and increased agricultural productivity.[7]

Effects on Financial Capital of Users

The economic value of the aqueduct water share in Salem Abad village has increased by 40% due to the repair and reconstruction of the aqueduct, which has led to an increase in water supply. The price per cup of water has increased from 20 million riyals (2 million Tomans) to 30 million riyals (3 million Tomans). The performance of crops has also significantly improved, with an increase in the yield of wheat and barley from 42 to 82 tons. Fodder production has also increased with the increase in aqueduct irrigation.[7]

Creation of Employment Opportunities in the Village: The proximity of Salam Abad village to Sarbisheh city has attracted many people from far and near villages to migrate and settle permanently in the village. The majority of these residents have found jobs in the service and industry sectors, such as tile work, plastering, mechanics, and masonry. Aqueduct Salamabad, under the supervision of the company, has created employment opportunities through agricultural and horticultural activities.

Increasing the Income Level of Villagers

Agriculture is the main source of livelihood in rural areas. Salamabad village is considered one of the tourist villages in the province due to its high population, proximity to the city center, basic infrastructure, and diversified livelihoods. Better management of arable land and aqueduct water has directly impacted productivity and reduced costs,

thereby increasing the income of farmers who are members of the company. The increase in the water level of the aqueduct has led to the cultivation of 12 ha of barberry gardens and a recently completed rose garden, which will significantly increase incomes from agriculture and horticulture.

Livelihood Diversity

The main livelihoods in Salamabad village are service and industrial professions, such as plastering, building paint, and stonework. The increase in aqueduct irrigation has led to tree planting on 25 ha of land, creating additional sources of income. Namdmali, a tourist attraction in the village, engages most families, particularly girls.
Effects on Natural Capital.

Water Flow and Quantity of the Aqueduct

Prior to restoration and reconstruction efforts, the watering rate of the Aqueduct in Salam Abad village was around 15 L/s. After the restoration and reconstruction, the water flow increased by 25 l/s. The local trustees report that the water level of the aqueduct has increased nearly twofold after the destructive floods of 2014 and 2015.

Water Quality of the Aqueduct

The Salamabad Aqueduct's water is sweet, and the restoration and reconstruction measures have significantly reduced water pollution. The aqueduct is now free of the carcasses and droppings of birds and other animals, resulting in clean and unpolluted water.
Natural landscape of the region: The increase in water flow, along with the increase in rainfall during autumn and winter, has resulted in a greener landscape in the village during spring and summer. The growing population of the village has also boosted the outlook of the village.

Tourism in the Village

Salamabad village is a popular tourist destination, particularly during various religious holidays. The restoration and reconstruction of the aqueduct and the subsequent increase in water flow have enticed families of villagers to return to their hometowns with enthusiasm for vacation. Additionally, the village is known for its art of felt weaving and is a popular destination for foreign tourists.

Effects on Physical Assets

Gardens under cultivation

The increase in water flow from the aqueduct has led to the company adding 12 ha of gardens to their agricultural lands, focusing on barberry and rose gardens. In addition, some aqueduct owners have planted trees separately by purchasing water shares from the company.[7]

Crops under cultivation

Aqueduct Salamabad is primarily used for the integrated cultivation of crops such as wheat, barley, and corn. The increased water flow has expanded the area under cultivation for agricultural crops.

Cultivation diversity

Due to the increased water flow, the village has been able to cultivate summer crops such as carrots, turnips, onions, and garlic in addition to the traditional wheat, barley, and corn crops. In addition, other aqueducts in Salamabad village, under the supervision of the endowment department, have between 7 and 8 farmers.

Animal husbandry

The prosperity of animal husbandry in Salam Abad village can be attributed to the management of agricultural land by the company and the presence of green pastures. The village now has several herds of light livestock, with approximately 4000 light livestock in total.

Effects on Human Capital in Salamabad Sarbisheh Village

Over the past 5 years, Salamabad Sarbisheh village has become a popular destination for immigrants in South Khorasan province, with almost half of its population of over 1000 people having migrated to the village during this period. This is mainly due

to its proximity to Sarbisheh city and the economic growth of service businesses in the village, as well as the development of felt weaving, which attracts many tourists and provides a good source of income for households. The increase in the irrigation of the aqueduct has also had a direct impact on the village's development, with the creation of new side jobs being a major factor in attracting immigrants.

The village's workforce is mainly involved in animal husbandry and service jobs, as mechanized agriculture and horticulture activities are carried out by the company. However, the local trustees have pointed out that the Salamabad aqueduct is still in need of repair, with the water level likely to increase once the work is completed (Figure 5).

PENTAGON DIAGRAM ANALYSIS OF LIVELIHOOD COMPONENTS IN SALAMABAD SARBISHEH VILLAGE

A pentagonal diagram analysis was carried out to investigate the effects of restoration and reconstruction of the Salamabad aqueduct on the livelihood of its users and residents. Five components, namely human, social, financial, natural, and physical, were analyzed based on indicators measured during interviews with villagers and local trusts. Compared to 5 years ago, the restoration and reconstruction of the aqueduct have had a positive impact on the social, human, physical, financial, and natural livelihoods of the village residents (Figure 6).

Salamabad Sarbisheh village is a popular tourist destination in South Khorasan province, with many domestic and foreign visitors attracted to its felt weaving profession. Its location, 3 km away from Sarbisheh city, also provides suitable living facilities and infrastructure. The village's agriculture is carried out by a company, and half of the aqueduct's share belongs to the endowment administration. The restoration and reconstruction of the aqueduct have increased the productivity of available water and improved the management of agricultural lands. This has had a double impact on the social dimension, with the level of satisfaction with the measures taken in relation to the aqueduct, positive psychological effects, and the stability of the population in the village all increasing significantly. Trust in government institutions, particularly the Agricultural Jihad Organization, has also been established among the villagers and local trustees.[7]

CONCLUSION

South Khorasan province is one of the driest and deprived regions of the country, and its also has many qanats from ancient times until today. The majority of Iran's land is located in the dry and semi-dry regions and in the belt of the world's deserts. Therefore, dryness and water scarcity are inherent features of Iran's central plateau, and access to sustainable water resources has been the most important challenge for the residents of this region. The ancient Iranians invented qanats, a suitable way to access water based on respect for the environment and harmony with nature, which became the source of a brilliant civilization in the Iranian plateau, referred to as the "kariz civilization" in some sources. The present research results have shown that the implementation of conservation and restoration operations has had a significant positive impact on the livelihood and lives of rural households in this province. Therefore, in order to accelerate these actions, the following suggestions are proposed for the implementation of various programs and plans:

1. Providing infrastructure and financial support to secure the necessary credits for the preservation and reconstruction of the canals in the province.

Most of the canals in South Khorasan province are usually located on the banks of rivers and are always at risk of flood damage. Therefore, for the prevention of such incidents, reconstruction and fundamental maintenance of canal well piles and preventive factors such as coastal walls and structures are required, which necessitates a significant and long-term budget. However, crisis management studies and analyses have shown that it is possible to implement preventive measures for the canals in the province.

2. Attention to the education of operators and upgrading their knowledge and skills in sustainable management of canal water resources.

Undoubtedly, no change or progress can be achieved without a strong foundation. In order to take steps

towards the transformation of canal approaches, it is essential to pay attention to the education and upgrading of the knowledge and skills of the main operators, who are mostly rural residents. Optimized management and utilization of underground water resources in canals can be the focus of education and promotion of new irrigation methods. This can be achieved through the development of a comprehensive short-term and long-term national educational and promotional program on canals and groundwater resources. In this regard, the following issues are of utmost importance:

- The possibility of establishing an independent department for canal water resources, especially in large cities and water-scarce and desert areas of the country, to preserve these environmentally friendly structures with a focus on canal maintenance and reconstruction, education and promotion of conservation culture among rural communities and canal operators, and research in the field of canals.
- Holding specialized exhibitions on canals and their achievements in various social, economic, and tourism sectors.
- Practical and applied training for rural residents and canal operators with a focus on developing the cultivation of compatible crops in the province that require less water and are more profitable, such as pistachios, rapeseed, and saffron.
- Practical and applied training in the correct selection of irrigation management for farmland is needed so that the implementation of modern and scientific irrigation methods (such as drip, rain, and pressure irrigation) in the rural fragmented land ownership system will not only conserve water but also increase the cultivated land.
- Networking and establishing effective communication between experts and canal operators in canal-rich provinces of the country to promote effective education, coordination, and information exchange among them and provide necessary and practical skills.

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