Pakistan Economic and Social Review
Volume 61, No. 2 (Winter 2023), pp. 181-236

ASSESSING INEQUITY IN KAREZ AND TUBEWELL WATER DISTRIBUTION IN BALOCHISTAN USING LORENZ CURVE

TAHIR SIKANDER RAHIM*

Abstract. In Balochistan groundwater is major source of irrigation, because of the shortage of substitute sources of irrigation. Karezes are the most effective, efficient, and economic sources for irrigation in nature which are diminishing due to increasing pumping amid large number of tubewells. This study aims to find the causes of Karez system decline, constraints, and opportunities in Karez irrigation system rehabilitation. It also aims to assess quity difference between Karez and tubewell in terms of access of communities to water. Focus group discussions was held in both villages of district Pishin, Khushab and Malikyar. This study uses the economic approach of Gini coefficient and Lorenz curve to measure the equity between the Karez and tubewell water distribution. This study concludes that Karezes are more equitable than tubewells in terms of access to water. However, they have not remained any more efficient, economic, and effective, sources of water for irrigation than tubewells due to decline in Karez water amid mass installation of tubewells and exploitation of groundwater. Moreover, climate changes in the shape of less precipitation, rising temperatures, evapotranspiration, and other factors such as population growth and urbanization have further aggravated the situation. This study recommends the dams construction, harvesting of low delta crops, use of modern irrigation approaches, on farm water management, regularization of groundwater pumping through tubewells.

*The author is Manager Programs and Additional Manager CARE (Centre of Academic Research and Enhancement) Alhamd Islamic University, Quetta – Pakistan.

Corresponding author's e-mail: economist.tahir@gmail.com

Keywords: Karez, tubewell, equity, Gini coefficient, Lorenz curve, Balochistan

I. INTRODUCTION

An important role is played by water in the economy of world. Utilization of water includes the extraction of energy and mineral resources from earth. It is used to refine petroleum, chemicals, steel, and mill papers. It is also used to produce unlimited other products in form of foods and beverages that decorate the supermarket shelves. Water is used to cool the generators and drive the turbines which generate electricity. Water is important to sustain the habitat and fish stock which are necessary for commercial fishing industry. Oceans, rivers and lakes give natural highways for the commercial navigation. It can be said that each and every sector of the economy is influenced by water directly or indirectly.

Around 70 % of the freshwater that is consumed by humans in the agriculture sector (Baroni et al., 2007). One of the major sectors of economy of Pakistan is agriculture which plays a key role by 18.9 % contribution in the GDP and 42.3 % contribution in the labor force (Pakistan Economic Survey 2019-20). It is a vital origin of foreign exchange earnings & enhances growth in other sectors. As per 6th Population and Housing Census of Pakistan that was conducted in 2017, the fifth most populous country of the world is Pakistan with population of 211.17 million with the population density of 265 persons per Km2. The country population is growing at the rate of 1.9 % per yearlong which is demanding to increase the agricultural production at least with the same proportion if not greater than that (Pakistan Economic Survey 2019-20).

In Balochistan ground water is prime source for the irrigation purposes, because of shortage of substitute sources of irrigation. The policy option for sustaining and enhancing irrigation in Balochistan, the tubewells are increasing in number which support the rich and wealthy sector of the society having no benefits and incentives for the poor and underdeveloped sector of society.

After the green revolution in 1960's, groundwater pumping grew and become fundamental source of irrigation and a substitute and supplementary supply of irrigation in Pakistan. In today's era above than

50% of overall irrigation needs are completed by groundwater extraction in the Pakistan (Watto et al., 2016). Currently, with reference to groundwater consumption, Pakistan is third largest country with almost 9 % of the international groundwater pulled out by greater than one million tubewells within the whole country (Watto and Mugera.,2014). Recently, 1.2 million tubewells with private ownership are functional within the country, around 85% are installed in the Punjab, 6.4% in the Sindh, 3.8% in the Khyber-Pakhtunkhwa, and 4.8% in the Balochistan. In Pakistan, aggregate groundwater extraction consists of almost 60 billion cubic meters (Ashraf & Hasan, 2021).

For centuries, all available resources of water have been used for irrigation in Balochistan province, these resources are not enough to fulfill the requirements of crops which is affecting the development of land resources. In total domain of 34.7 million ha, over 18.5 million ha are communicated as used, out of which 1.7 million ha are utilized for cultivation. The residents of Balochistan had been dependent on natural sources of water such as springs, rivers, streams and Karezes. In all of these, the Karezes are the most tenacious and persistent; remining sources are seasonal which depend on climate (Chaudhary, 1990).

The tubewells diffusion is inserting traditional communal fashions and methods of power and authority in societies under tension and stress with, in the places, replacing them by noting the power of the large farmers. The transition from *Karez* to *tubewell* irrigation contains not only negative and adverse consequences for the social equity *but also* the environmental health & quality (Mustafa & Qazi, 2008). Irrigation by *Karez* is not only practical but also an environmental, social, and economic necessity as compared to tubewlls (Mustafa & Qazi, 2007).

With the passage of time, the Karezes numbers declined and tubewells were installed as an alternate irrigation source. Due to tubewells, the proportion of accessible population to the irrigation water declined and agriculture sector became the ownership of few individual tubewell owners who could afford to install tubewells (Steenbergen et al., 2015). As a result, the economic life of villages got disturbed and migration increased from villages to cities. The decline in irrigation, shrink of agricultural sector, low standard of life, less economic and social development has forced to carry out this study to provide a clear and helpful conclusion about the inequity caused by transition from Karez irrigation to tubewell irrigation.

Karez system, present in Balochistan, is spirited and vibrant example of the ancient approach that is still alive and functional though on small scale as water management source for the community in the arid landscape. Karezes are the most effective, efficient, and economic sources for irrigation in nature which are decreasing due to increasing the number of tubewells. In such situation, dams can be the new hope for the rehabilitation of Karezes by being the source of charging the Karezes and maintaining & storing the water level.

In this study, the approach of Gini Coefficient (GC) and Lorenz Curve (LC) with graphs & charts, will be used. The collected data on above given parameters will be used to draw Lorenz Curve and to find Gini Coefficient. Gini Coefficient and Lorenz curve are commonly used in economics for income inequality and other economics variables like effects of increasing and decreasing incomes on classified and categorized income distributions.

Significance of Research

Keeping in view the importance of this ecologically sustainable system of irrigation, this study helps to investigate the opportunities and constraints in the renovation of Karez. This study also investigates the causes of decline of Karez irrigation systems. Moreover, the inequity in Karez and tubewell water distribution is also being investigated. This study focuses on the groundwater-dependent areas of the Balochistan province and little work had been done in past, this research and study contributes valuable knowledge. Moreover, farmer's perceptions are also recorded. Further, this study helps in designing the appropriate policy interventions from the findings those are valuable for policy makers, academicians, and other stakeholders.

Statement of the Problem

The number of tubewells is increasing day to day to fulfill the needs for irrigation, drinking and other purposes. Being capital intensive, access to tubewells is mostly skewed towards rich and wealthy people. Due to this, the ownership and use of irrigation became the ownership of richer people who constitute a smaller proportion of the farming communities. Karezes were the prime source of irrigation, drinking and domestic use in mainly part of the world and available at comparatively smaller cost. Due to Karezes, water is available to large proportion of community as compared to tubewells. This study will find out the equity in the distribution of Karez and tubewell water in Balochistan.

Research Questions:

- What are the causes of decline of Karez irrigation system?
- What are the constraints in Karez irrigation system rehabilitation?
- What opportunities exist for Karez irrigation system rehabilitation?
- Has inequality in water distribution increased due to transition from Karez irrigation to tubewell?

Research Objectives:

Following are objectives of this research.

- To study causes of decline of Karez irrigation system
- To discover the constraints in Karez irrigation system rehabilitation
- To explore the opportunities of Karez irrigation system rehabilitation
- To find the inequity caused by transition from Karez to tubewell.

II. LITERATURE REVIEW

Karez is an underpass tunnel through which groundwater is transferred to the selected and desired areas by gravity (Khan & Nawaz, 1995). A Qanat or Karez is a fairly, gently and softly sloping underground channel for the transportation of water from a water well or an aquifer to the surface for drinking and irrigation (Wilson & Andrew, 2008).

It is an underpass tunnel, that taps subsurface water well or aquifer following the slope of an alluvial fan. Normally, Karezes are situated beneath the high hills adjacent to virgin land and fertile levelled (Farooqi & Rehman, 1998). Karez or qanat is a type of sub-terrane an aqueduct or water drain i.e., belowground canal-engineered to accumulate and gather groundwater and connect it through a fairly, gently and softly sloping underground duct to surface canals that provide the water for agriculture lands (Lightfoot, 1996). Karez is a technology which brings ground water to the surface through tunnel. In this whole process, no mechanical lift or pump is used. Only gravity brings it from underground reservoir (Farooqi & Rehman, 1998).

Karezes are built as the series of well-like and vertical (top to bottom) shafts, which are connected by fairly, gently and softly sloping tunnels. Karezes efficiently deliver the large quantity of subterranean water to surface without having any necessity for the pumping. Water drains with the help of gravity, typically from a high or upland aquifer, work with destination that is lower than the source. Karezes allow the water for the transportation over wide and long distances in the hot and dry weathers without having much water loss in form of evaporation (Andreas et al. 2016).

It is common and general for the Karez to begin beneath the foothills of hills and mountains, wherever the water table is nearest and closest to surface. From this source, Karez tunnel slopes gently and fairly downward, converging slowly by having the steeper slope of land surface above, & finally the water flows out above the ground at which two points or levels meet. To build connection between agricultural or populated area and the aquifer, Karezes often extend for the far and long distances (Kheirabadi, 1991).

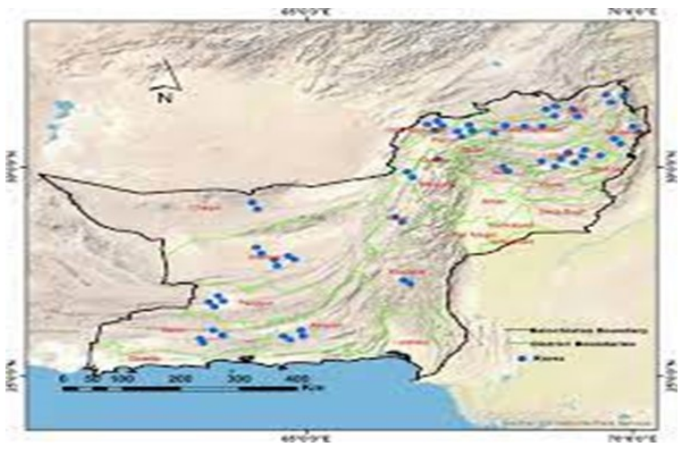
In some situations, water from the Karez is kept in the reservoir for storage, typically with the night flow stored for the daytime use. Example of traditional Persian qanat-fed reservoir used for the drinking water is an Anbar. Karez system contains advantage of being resistant and persistent to the natural disasters like floods and earthquakes, and to severe and deliberate the destruction in the war. Additionally, it is nearly insensitive by having no response to the levels of precipitation, delivering a flow with only gradual variations from wet to dry years. From sustainability point of view, Karezes are functioned and powered by gravity only, and therefore have low maintenance and operational costs once built. Karezes transfer freshwater from the mountain plateau to the lower-lying plains with saltier soil. It assists to prevent desertification and control soil salinity (Nasiri & Mafakheri, 2015).

The Karez value is positively belonged to volume, regularity and quality of the flow of water. A large proportion of the population of Iran and all other arid countries situated in Asia and North Africa depended on water obtained from Karezes historically; the areas of population corresponded closely and nearly to areas where the Karezes are possible. Though it was very expensive to build a Karez, its long-term value added to community, and thereby to the groups which invested in constructing and maintaining it, was considerable (Kheirabadi, 1991).

The technology of Karez irrigation was built and developed in both areas, arid and semi-arid, from western China & India through Middle East into the North Africa. It was believed that this technology was started in the 1st millennium BC in the Persia from where knowledge had travelled eastward and westward along with Silk Route, throughout Muslim world, reaching in Xinjiang at China during Han dynasty (206 BC – 24 AD) and in the Balochistan somewhat earlier (UNESCO., 2021).

FIGURE 1

Karezes in Balochistan



Karez is not only sustainable environmentally but also having no additional energy need and, therefore, has very low life cycle maintenance & operational costs. The Karez are such properties which are maintained and owned by the community having shares in it based on "shabanas", 24-hour cycles. Karez, depending upon its size, consists of 18 to 32 shabanas which are divided among its shareholders, with individuals having claims of water shares from few minutes to a week. The shareholder, also termed as shareeq, is awarded and entitled to standing of a country as gentleman in community and influences the collective decisions by sitting in the jirga. (UNESCO., 2016).

KAREZ IRRIGATION SYSTEM AS SOCIAL INSTITUTION

Farooqi & Rehman (1998) discussed importance of social set up in successful operation of Karez system. They mentioned those factors which were necessary for proper functioning of Karez system following aspirations, motivations and opinions of shareholders, community leadership, tribal values, nature of social participation (cooperation and conflicts), and role played by government functionaries. They suggested that fair understandings of the above-mentioned elements could assist to set up a suitable program for efficient function of the Karez.

Abudu et al. (2011) stated that Karez may be considered as global heritage due to its role for enhancing social and cultural diversity. But now-a-days Karez system is facing many hurdles due to widespread use of tubewells for irrigation and other purposes and it declined the ground water resources. Moreover, natural disasters and socio-economic changes in societies significantly affect the efficiency and maintenance of Karez system all over the world. Furthermore, most of time the protection of Karez system may not be considered in public policy, laws, and regulation. Therefore, Karezes have been vanished and abandoned with in last few decades.

Kahlown and Hamilton (1994) described that Karez system faces deficiency of skill labors for proper maintenance because in past, the labors came from Afghanistan but due to long wars, the society became totally disrupt and labors joined other sources of income. Secondly, seepage of water during conveyance is also high. These problems convert the Karez system into a water source that is high-cost intensive as compared to other sources of irrigation, for example Tubewell irrigation. Therefore, efforts are required to cope with labor demand and high seepage loss because it will improve the efficiency of the Karez system.

Lightfoot (1996) stated that in late 14th century, 300 channels brought to the surface in Tafilalt basin situated in Morocco, out of which, more than 75 of the chains provided water throughout year to the ancient city called "Sijilmassa" and few of them continued to irrigate the northern orchids and oasis till early 1970s'. But due to deficiency of water supply and unsustainable practices of irrigation have intensely declined ground water tables and when the groundwater level was declined, then Khettara became dried. The repercussions of this loss were that local people lose the control over water resource and as result, a sustainable way of irrigation was abandoned.

BRSP (2004) discussed the causes of decline and constraints in the rehabilitation of Karezes. The major causes were flood, drought, earthquake, commercial irrigation, and the high growth of tubewells and the constraints in the rehabilitation process were high volume of damage, high community share, unsure water availability and conflict on water rights.

CAUSES OF DECLINE OF KAREZ IRRIGATION SYSTEM

Due to large numbers of tubewells installations and these tubewells have adversely affected the Karez and spring systems in Balochistan. Drying of Karez systems in Balochistan produced various socio-economic and Environment impacts in the region. In 2001, Balochistan government developed a law1 to regulate and functionate the groundwater resources (Halcrow-ACE, 2003). However, the provincial government was not succeeded to impose this law due to political pressures. In addition to this, other issue in management of the groundwater was that not a single body was responsible for regulating whole and entire resource (Negri., 1989).

Durrani at el. (2017) conducted a study to observe the long-term variability in climate and its effects and impacts on groundwater level of Quetta alluvial. They used precipitation and temperature data from 1946 to 2015. The analysis of annual precipitation shows the declining trends at all gauging stations. The analysis shows the facts that groundwater has regularly declined because of variability in rain fall. Furthermore, the

[1] Balochistan Groundwater Rights Administration Ordinance, 1978

study identifies that there is direct correlation between groundwater depletion & number of tubewells increases. So, the groundwater level has declined with increase the number of tubewells in Quetta alluvial.

Karim and Nawaz (1995) stated that the tubewell was commonly blamed for depletion of Karezes but some time it is not justified from the facts because first, they tap deep seated ground water and depth of mother well isn't so deep, so most of mother wells remain unaffected and secondly, Karezes were depleted in those places where the installation of tubewells were prohibited. So, there were some other factors which were also responsible for depletion of Karez in which socio-economic changes occurred in society of Balochistan and income of the people rose due to increase remittances from gulf states especially in southern part of the province and they invested more in sectors like transport and business and their agricultural dependence had declined. The interest of rich people to run Karez has faded, and small farmers could not afford Karez maintenance. And now-a-days shareholders either depend on government grants and other agencies for maintenance or neglect the process due to lack of capital.

Rehman (1981) studied that due to hardship in construction, difficulty to sustain and maintain, and limited scope, Karez irrigation system had a vital and integral element of agricultural lands in Balochistan province of the Pakistan for last 2500 years, if not earlier. This irrigation system is fairly defined, adjusted and maintained with political & social institutions of Balochistan & synchronizes with local economies. Hussain at el. (2008) identified some issues related to Karez declination. Some of major factors for deterioration of Karez were introduction and wide spread of tubewells, deficiency of the skilled labors for the construction and the maintenance of the Karezes, conflict among shareholders and tribal disputes, lack of adequate polices and Karez has lost importance due of its inability to use it for intensive agriculture.

Rehman (1981) reported that there were political, social, and economic changes occurred in Balochistan which also affected the traditional Karez system. The number of tubewells were growing fast (Qureshi at el., 2009), as a result they were rapidly substituting the Karez irrigation. During the time of only two decades, the area under tubewell irrigation extended by approximately 33.8% in the Balochistan province. Due to increase in tubewells, Karezes are decreasing in number. For example, in Quetta-Pishin district, 178 number of Karezes were present in 1902 but it decreased to 64 in 1974. Therefore, due to excessive and high pumping of the water through tubewells installed in or near alluvial fans, water supply in the Karezes is falling. The falling water table could not be completely recharged by inadequate quantity of rain.

EQUITY AND KAREZ IRRIGATION SYSTEM

Mustafa and Qazi (2007) described the transition of Karez towards tubewell with its impacts and also analyzed that whether the Karez irrigation is anachronism or viable irrigation system. They explained the causes of expansion of tubewells which are flat rate electricity charges, cheap Afghan labors and drought episode in late 1990’s. Moreover, the government promotes the tubewells through soft loans and introduction of high value and more water demanding fruits especially apples and in addition, due to demonstration effect of western technologies, government considered Karez as a wasteful management system because it flows throughout the year and water is needed in only summer season. But study shows that Karez is social enterprise which has its own management, water distribution and conflict resolution mechanism. It ensures more equity in water distribution and small farmers are more benefited from this mode of irrigation and the community want to rehabilitate the social capital and they are trying it by itself and in some places the village community enforced the Harim[2] rule to save the Karez but the government priorities seem different than community aspirations. Furthermore, the Karez is not practically related to the expertise available with government. All in all, Karez isn’t only an anachronism but also a reasonable, viable and suitable irrigation approach. The Karez system destruction leads not only economic & environmental repercussions but also negative social consequences as well. In Balochistan, Groundwater management shows that transition of Karez towards tubewell was neither inevitable nor necessarily more advantageous but the result of deliberate policy options by government (Mustafa & Qazi., 2007).

---

[2] Female

Bell et al. (2016) stated that improved and better water supply allows a greater number of the farmers that may improve equity. However, if benefits aren't equitably distributed, then possibility exists that those farmers having least access to canal irrigation (e.g., those toward the tail end of the canal or the distributary) may be worse off, paying higher water-use fees yet not reaping any of the advantages of the improved and developed infrastructure, which are instead captured by those farmers nearer to the head.

It can be termed that such approach of water access, use & distribution is nearly and widely connected to community identity and social developed structures. Though Karez system is not only expensive to build but also it is a long-term value added to community. That's why, group who invested in constructing and maintaining the Karez, is considerable and important. (UNESCO., 2016).

Khair et al. (2019) revealed that majority of the farmers trust that the groundwater is a bottleneck resource. There are few chances to get evidence to show that this can lead to use in decision making for sustainable groundwater within these communities. By having no equity and effective intervention, groundwater resources will highly affect the consequences and attributes of human behavior related to the common pool resources shown in Hardin's (1968) seminal 'Tragedy of the Commons' paper.

CONSTRAINTS IN THE PROCESS OF KAREZ RENOVATION

Mustafa & Qazi (2008) discussed some constraints in rehabilitation of Karez system like many Karezes are dried due to large numbers of tubewells installation which ultimately decreased the water table and water supply for Karez, moving sand dunes impacted the mother well & vertical wells needed regular maintenance, there is deficiency of skill labors who can construct and do maintenance work, very less support from private and public sections in building the skills of technicians through utilization of feasible technology. So, hardly government is doing anything for Karez improvement and there is hardly any developmental and research activity in the province for betterment of Karez system. Therefore, we must save the Karez because it isn't only a hydrological & engineering wonder, but also the social phenomenon that remained in last millenniums despite climate changes, socioeconomic development & environment circumstances.

Steenberger & Oliemans (2002) described the groundwater resource management in Pakistan. They stated the groundwater issues and policy in Pakistan. Moreover, they described that the government promoted tubewells in Indus plain to control waterlogging and salinity. The purpose of promoting tubewells in Balochistan was agriculture development and Karez was considered as source which waste the water because it flows throughout the year. But the groundwater level is declined and many Karezes are dried due to large number of tubewells installation. Therefore, they stated that a policy should be made to regulate the groundwater resources but first it should be defined which authority would monitor and formulate policy for this subject whether it come in federal or provincial domain and another issue is the participation of local people because no policy would succeeded without the assistance of local people and organizations and finally, they proposed that price of groundwater needs to determine in such a way that it reflects the scarcity of water and every user would use it with care.

Ahmed & Farooq (2006) stated that fresh water is scarce in the world and the world population is growing day by day. So, there is need to find alternative ways to fulfill water requirement of the growing masses. Pakistan is having serious and notable shortage in both surface and ground water sources. Furthermore, the groundwater is decreasing with an alarming rate, especially in arid and semi- arid conditions. So, there is an urgent requirement to protect these areas by doing proper groundwater management and in this way the water could be provided to the deprived societies of Pakistan.

Qureshi at el. (2010) further stated that direct management of underground water for cropping could not prove to be effective and fruitful in Pakistan.in Pakistan. Therefore, there should introduced the indirect management ways to resolve the issue. Similarly, there is no authentic information available on groundwater availability, quality, abstraction, and other key variables which are necessary for proper working of groundwater management. So, keeping in view of scarcity of ground water, the government should introduce the resource conservation technologies like drip irrigation & artificially recharge aquifers that is the most suitable and effective method of establishing the balance between recharge & discharge mechanisms. Furthermore, the policy, dealing with providing the subsidies on tubewell electricity, requires to be disclosed and more efforts should be taken to aware farmers about groundwater issues and taken into the confidence to implement the suitable policy to tackle the problem of groundwater.

Mustafa & Qazi (2008) compared Karez versus tubewell irrigation and analyzed pump, sprinkler and tidal technology which is more socially acceptable and practically sustainable in arid condition of Balochistan province. They concluded that replacement of the Karez with tubewell irrigation isn't occurred by natural evolution but as result of deliberately policy decision by the government. secondly, this transition leads to social inequity and environmental quality degradation. Furthermore, it snatches the power from communal mode of small farmers and hand over to compensatory mode of farmers working at large scale. Each of these perceptions has vital and large impacts for long-term socially and ecologically sustainable and persistent development in Baluchistan.

Ameur at el. (2017) stated that the socio-economic inequalities rose in the Saiss plain of Morocco when government privatize and subsidized the agricultural sector. The objective of this program was agricultural and rural development. So, new investors and lessee entered in the market, and they installed large numbers of tubewells in the area and exploited the ground water resources, but local people (often small farmers) were unable to invest in ground water-based agriculture due lack of financial resources. Therefore, large investors earned huge profits and small farmers were deprived from it and it rose inequalities in income in rural areas and ground water resources were depleted due to over exploitation of ground water. So, the policy of privatization only benefited the large investors and aim of rural development could not achieved.

Mekki at el. (2017) describes causes of ground water mitigation and degradation responses in the Haouaria region situated in Tunisia. Government policy about tubewells can be divided into two phases. In phase one which was extended from 1970 to 1990. In this period, the policy was to promote the tubewells growth to alleviate poverty. So, government gave subsidies on installation and electrical charges for tubewells users. The numbers of tubewells rose abruptly, and it caused the declining of ground water level. Then government realized the issue of ground water declination and addressed the issue by changing the policy of supply side to demand side management, promotion of water saving technology, water harvesting and recharge infrastructure. With development of tubewells, more water intensive crops would be grown which created more pressure on ground water resources. Government announced a law “water code” to address ground water degradation issue but it did not mitigate the issue due to many flaws. Therefore, collective action is required from government, water users and private sector for protection of ground water resources.

Khair at el. (2015) investigated the previous policy of government on groundwater management. They argued that the historical groundwater policies were designed to increase the agriculture yield and reducing poverty, without analyzing the side effect on groundwater reservoirs. The groundwater table became dramatically declined as result of mass installation of tubewells because many subsidies were given on installation of tubewell. Then extraction of water became uncontrol due to having no property rights, ineffective governance, and electricity subsidy policies and these were the main causes of groundwater decline in Baluchistan. So, they proposed that the policy of cheap electricity should be revised in order to mitigate the groundwater declining issue.

OPPORTUNITIES FOR THE REHABILITATION OF KAREZ IRRIGATION SYSTEM

Groundwater is prime and vital to the agro-pastoralist and sedentary agriculture, and in Balochistan, Karez system has been present like the linchpin of groundwater tapping technology for more than a millennium (Mustafa, 2014). Junaid (2020) suggested that the renewed interest in the Karez for constant and sustainable irrigated agriculture in arid regions has few merits and farmers may participate in such efforts if the adequate institutional support is extended. Mehwish (2017) suggested that to rehabilitate the Karez system to develop as social institution Karezes ought to be highly considered as historic symbol and cultural heritage because Karez system has lost its need and primacy as a source and tool of irrigation and domestic water. Mehwish (2019) examined farmers’ enthusiasm towards technologies like subsidized installation system of tubewells from the reliable supplier who could award warranties not only on the system's service but also on the extra parts and train the participating farmers in four south-western districts of the Pakistan.

A hurdle or barrier which stops the flow of water and underground canals and streams is called a dam. It can be said that water reservoirs are created by constructing dams which suppress floods and provide water for all activities like human consumption, irrigation, industrial utilization, navigability, and aquaculture. Hydropower is mostly used in the conjunction with the dams to produce electricity. The dam can be utilized not only for collecting water but also for storing the water that can be desirably and evenly divided among locations. The dams normally serve the basic and primary purpose of storing and retaining water, while all other structures like floodgates or levees (also known as dikes) are used to prevent and manage water flow into specific land regions. In Jordon, Jawa dam is the earliest known dam is, dating to almost 3,000 BC. By building dams across the streams of Karezes, the short life of Karezes will be increased and this practice has not only good and economic effects but also accepted by the court of law (Khan and Nawaz., 1995). Dams can be utilized to store rainwater that can be used for Karezes when needed (Chaudhary., 1990).

Nasiri & Mafakheri (2015) stated that Karezes are sustainable source of water supply because it conserves the aquifers and it has low evaporation losses but now-a-days qanats are facing many challenges and issues such as declining of ground water, drought, deficiency of skill labors and traditional techniques for the construction and the maintenance of Kazres. So, the protection of Karezes requires serious efforts from community and government. These are as follows, if natural recharge of aquifer is limited then artificial tools like underground dams, artificial pool etc might be incorporated. For instance, water table linked with Jandaq Karez in Iran is assisted and supported by underground dam (Abdin,2006). Moreover, periodic maintenance and fair allocation of water rights are also important for proper operation of qanats.

Memon et al. (2017) took in depth interviews to assess the factors which shows that some communities are willing to rehabilitate their Karezes while others are not. They stated that the trust among the shareholders is key factor for rehabilitation , collection funds and operation & maintenance but the huge number of tubewells created uncertainty among shareholders for revival of Karezes .Furthermore, the government has nothing done for protection of the groundwater reservoirs and she still continues to give flat subsidy on electricity charges of tube -wells which destroyed ground water reservoirs of the province by excess pumping (Mustafa & Qazi,2008) and this problem could not solve only by making delay action dams , because the recharge is less than extraction of ground water. Mustaf and Qazi (2008) explained that a minor change could be made in water rights of the community and a little portion of water should be given to an outside organization for Karez maintenance which can use modern technology like gravity driven micro-drip fed for irrigation purposes by conserving groundwater.

Abudu at el. (2011) stated that proper use of Karezes is one of the most efficient way for groundwater sustainability. So, Karez system in arid regions can be protected by combining Karez system with the modern irrigation approaches and techniques which may improve the efficiency of the Karez system for meeting the growing demands of society. The community can increase its income with the help of Karezes by promoting tourism in these regions because Karezes have historical and cultural importance. Finally, establishment of local data base in Karez region could be used for further studies to improve Karez systems.

Kahlown and Hamilton (1994) discussed the design and construction of Karez system, water rights, the institute which manage and maintain the system and briefly discuss the physical interaction between Karez and tubewells and they mentioned the problems which the system is facing e.g., the growth of tubewells technology. They suggested that the challenge is to develop such institutional arrangements which control the placement and number tubewells in Karez areas and bring technological innovation which improve the efficiency of Karez system like lining of tunnels, covering the access wells, and bringing an increase the recharge of water in vicinity and surroundings of Karez mother wells. So, these improvements may establish the system more competitive than other sources of irrigation.

Hussain at el. (2008) explained that Karez still can play vital role in semi-arid and arid environment of Pakistan, Iran, Afghanistan, and Saudi Arabia. In Turbat district, government revived 200 Karezes in recent years with collaboration of NRSP and NGO's. So available evidence suggests that Karez could be revitalized under some favorable conditions which were as follows. consistent underground tunnels, a stable groundwater, clear water-use rights, strong social cohesion in community, willingness, and commitment for providing funds and services for Karez rehabilitation and its O&M. All-in-all, they proposed some actions for protection of Karezes, doing some legislative measures for controlling of wide spread of tubewells and introducing modern irrigation methods with traditional practices for the growth of high valued crops to attract farmers attention for care and maintenance of Karezes. Furthermore, small tanks are constructed at terminus points of the Karezes with the concept to restore water that is wasted between the irrigation periods.

Karim & Nawaz (1995) stated that Karez system can be rehabilitated by the water flow which could increase if Karez is clean thoroughly. Sometime boring of mother well could revitalize the Karez because aquifer that is present at few depths might be punctured. The Karez might be revived by boring the new mother well up slop from the existing mother well, it would increase the flow of water. If any mechanism could develop to cap the opening of the shafts, it would stop the sand, filth, and gravel to enter the tunnel of Karez which tend to decrease the flow of water. The delay-action dam may rise the water table. Lining of channels is hard and expensive but it can reduce the seepage and dribble of the water and achieve more water available for the irrigation needs. In winter season, demand for water is very less and if we make some arrangements to preserve this water then it is possible that Karez could be used for irrigation of high value crops. These suggestions will only be feasible and helpful if shareholders are willing in maintaining the Karez.

Mustafa (2007) the following efforts are required for improvement of Karez technology (1) it requires capital investment with some technically improvement in Karez designs for lessening and removal the need for time based periodic maintenance. (2) More research is required in fields of water quality, civil engineering, and hydrological aspects to improve the construction of Karez and its management. (3) Proper ground water mapping is requiring for Karez operations, not only future Karez construction but also future tubewell installation and its regulation. Beside these suggestions, there is well-developed water markets in the province, so both, governmental and non-governmental enterprise can enter in such markets and purchased some share and auction them seasonally. The income derived out of it could be used for both purposes, technical assistance, and loans for the maintenance of Karez. Moreover, the agriculture extensions services will have to review their policy of maximization of output towards resilience and long-lasting productivity. For this purpose, they should encourage, promote, and support water-efficient crops in the province. Furthermore, government must review the policy for subsidized electricity for tubewell installation and operation in Balochistan (Qureshi at el.,2009). In this way, Karez system can be protected and even rehabilitated to provide its social, economic, and environmental benefits to the region.

Ahmed (2007) described that Karez irrigation is natural heritage and a sustainable system for Balochistan province. He further explained the importance, issues, and solution for rehabilitation of the Karez system. Furthermore, he stated that a project was launched by ICARDA for rehabilitation of qanat in Syria in which following criteria was regarded necessary for renovation of Karez. So, the government of the Pakistan and Balochistanwill have to take similar steps for rehabilitation of Karez. The provincial government may declare Karez system as 'Agricultural & Cultural Heritage' and may start a program for initiation R&D works for Karez system. For this purpose, comprehensive research should be conducted for understanding the system, its issues, constraints, and possible opportunities of renovation the system. In addition to it, initiate a similar research program for introducing the water efficient high valued crops, fruits, and vegetables. Similarly, a class of skill labors should produce who can use the modern tools in Karez construction and maintenance.

USE OF LORENZ CURVE & GINI COEFFICIENT

Gini coefficient (GC) and Lorenz curve (LC) are commonly used in economics for income inequality and other economics variables like the impacts of the growing incomes on the classified income distributions. The graphical representation, that illustrates the division of the wealth and the income within population, is termed as Lorenz curve. Lorenz curves can be summarized as the graph of percentiles dealing with population against the cumulative wealth or income of the people below or at that percentile. In addition to this, Gini coefficient is an index consists of single number that is aimed to measure the degree of the inequality in a distribution. In economics, it is mostly used to measure how far a country's income or wealth division deviates or differentiates from the totally equal distribution. Gastwirth (1971) said that Gini coefficient is income-ordered population percentile which shows the cumulative shortfall from the equal part of total income up till each percentile.

Gupta (1984) gave functional form to estimate Lorenz curve. Tille & Lingle (2012) studied histogram-based interpolation of Gini index & Lorenz curve for the grouped data. Kakwani & Podder (1976) determined efficient and effective estimation of Lorenz curve and associated inequality measures from the grouped observations.

Barret & Pendakur (1995) studied asymptotic distribution of generalized Gini indices of the inequality. Roauseau & Hicke (1998) provided graphical representation of evenness. Bishop, Formby & Smith (1991) explained interstate variations in income inequality by using Gini coefficient and Lorenz curve.

Satchell (1987) studied the source & subgroup decomposition inequalities for the Lorenz curve. Matsuyama (2013) provided the endogenous ranking & equilibrium using the Lorenz curve across identical countries, but these concepts are also used in other disciplines, studies, and research. Gini coefficient (GC) and Lorenz curve (LC) have been used for cancer disease to characterize risk predictiveness and etiologic heterogeneity (Audrey & Colin: 1997).

These concepts have also been used for Visualizing exposure-disease association (Llorca, Delgado-Rodriguez: 1999). These theories have facilitated characterizing exposure-disease relation in the human populations (Lee WC: 1999). These concepts have helped to know the limitations of understanding the division of population viral load have been studied with the help of Lorenz curve framework (Alexander: 1999).

The property of Lorenz curve has been studied to characterize the power function distribution of population (Moothathu: 1986). Study of the participation using discrepancy index with the application to ease of higher education in the Italy was made with the help of Lorenz curve (Larcinese: 2008).

III. METHODOLOGY AND THEORETICAL FRAMEWORK

In most areas of Balochistan groundwater is major source of irrigation, due to shortage of any alternative source of irrigation. To agricultural tubewells, the provision of 90 % subsidized electricity encourages farmers for extensive groundwater pumping (Khair, 2013). Available water uses for the irrigation and effect crop choice and causes farmers to transfer from the low delta crop to high valued and expensive crops. The irrigation equity can be expended to enhance crop productivity (Watto and Mugera, 2015).

In this research, philosophy consists of positivism, realism, and objectivism because Karezes are social institutions and ‘the details of the Karezes had been taken to understand the reality or perhaps a reality working behind them’. Remenyi et al, (1998) stressed the necessity of such study. Smircich (1983) noted that objectivists of such study would tend to view the culture as something that exists in real. In this study, approach of Lorenz Curve (LC) & Gini Coefficient(GC) with graphs and charts has been used. The philosophy behind this approach is that the equity level has been determined for the Karez and tubewell water for the reason to find out which source is better for the society and why. The impacts of both, Karez and tubewell, have been studied on the social and economic sectors. For these studies, the selected approaches are the most feasible and best.

DESCRIPTION OF STUDY AREA

This reserach was conducted in Pishin district of Balochistan. Two villages namely, Khushab and Malikyar, with the characteristics of having both, Karezes and tubewell, irrigation system was purposively selected for the research purpose.

Khushab

Khushab is a village in Pishin District, tehsil Karezat that is almost 70 kilometres east the capital city of Balochistan, Quetta and about 8 kilometres away from the small city of Khanozai. It is situated in the northeast of the Pishin. It has the Kakar tribe as the largest proportion of the population. All the residents and the livelihoods are dependent on the agriculture. In early times, farms were irrigated by Karezes, which were the major and prime sources of water in these particular areas. Its coordinates are N67.357E, E30.649N and altitude from sea level is 5600 feet and hydrologically located in sub basin Kuchlak. The population in the village is around 13000 people. Some 50 to 60 % population is related to agriculture, 30 % to business, service, and labor and 10 % to mining. This village has metaled road, basic health unit, veterinary center, and agriculture extension to 20km. Boy's primary, middle and high school are present with girl's primary, middle and high schools. Due to poverty and gender stereotypes, the numbers of females attending school is significantly lower than males. The soil type of village Khushab is clay. Largest farm consists of 35 to 40 acres and smallest far consists of 4 acres. Share of small farms comprises 60 to 65 % of village Khushab. Major crops grown here are apple, tomato, wheat, apricot, and garlic. Major source of water is tubewells. Flood is also used as irrigation method. Total number of tubewells is around 200 having 80 solar and rest are electric. In Khushab, water table depth is 107 meters, bore well depth is 153 meter and decline of water table is 6.1 meter. Streams generated in Khushab are Khorha, Kazey and Manda. It has low precipitation, mass tube-well installation caused by rapid decline of water tables, traditional irrigation techniques decreasing water use efficiency, improper cropping pattern and poor agronomic cultural practices, apple quality is decreasing due to rising temperature, drought, and water stress condition, and an increase of insect and disease pests in horticultural crops. Khushab is the facing the problems of Declining water tables Illegal tube-wells, Orchards being replaced by tomato, garlic, People diverting to business, mining and services, People striving for other livelihood source (mining, business etc.), and Women have no direct role in water management/farming.

Malikyar

Malikyar is a village in Pishin, Pakistan, located 14 km north of Pishin. Its coordinates are 67.057E, 30.692N and altitude from sea level is 5373 feet hydrologically located in sub-basin present in Pishin. The papulation of village Malikyar is around 22000 people. 80 % papulation is related to agriculture, 5 to 10 % to business, 1 to 2 % service, and rest are laborer. This village has metaled road, basic health unit, and veterinary center. Boys' primary, middle and high school are present with girl's primary, middle and high schools. Due to poverty and gender stereotypes, the numbers of females attending school is significantly lower than males. The soil type of village Malikyar is clay and sandy. Largest farm consists of 100 acres and smallest far consists of 3 acres. Share of small farms comprises 65 to 70 % of village Khushab. Major crops grown here are apple, grapes, tomato, and chilies. Major source of water is tubewells. Flood and furrow are also used as irrigation method. Total number of tubewells is around 250 having 40 solar and rest are electric and electric generators are also used in summer at the rate of Rs 1500/Hour. In Malikyar, water table depth is 107 to 122 meters, bore well depth is 183 meter and decline of water table is 9 meters. Streams generated in Khushab are Barshore Lora, Tormurgha Nala and Torasha Manda. It has rapid water decline and tube-wells drying due to excessive pumping and lack of rainfall, apple orchard reduction and water stress conditions, poor irrigation techniques, improper cropping pattern, post-harvest losses and poor packaging of Agri commodities, and Codling moth, borers, powdery and downy mildews. Malikyar is the facing the problems of Rapid decline of water tables, orchards being replaced by tomato, garlic, people diverting to business, mining, and services, dwindling, water drying, loss of main livelihood source, people striving for other livelihood source (mining, business etc.), and women have no direct role in water management/farming.

COLLECTION OF DATA

Both, the primary & the secondary data were utilized for this research.

Primary Data Collection

Focus group discussion (FGD) was conducted in Zarghoon and Malikyar with Agha Muhammad[3], Abdul Rasheed[4], Abdul Sattar[5], Haji

[3] Representative of the area, member of Local Support Organization, Farmer, Konwon wit name Maser.

[4] Deputy Director, Irrigation Department, Govt of Balochistan

[5] Well known farmer of the area

Abdul Baqi[6] and Ghulam Muhammad[7] to get their feedback of various aspects of Karez irrigation.

FGD conducted with the relevant stakeholders to prepare the lists of land and water shareholders in each Karez and tubewell owners. The land holding, water share in Karez and tubewell ownership related information were also collected. The information regarding causes of Karez system decline, and constraints and opportunities in Karez system rehabilitation were also collected.

Secondary Data

Secondary data was used from economic survey of Pakistan, UNESCO reports, irrigation department reports and PRA reports of government of Balochistan.

ECONOMIC APPROACH FOR MEASURING INEQUITY IN ACCESS TO KAREZ AND TUBEWELL WATER

The data about the supply and availability of water from both sources, Karez & Tubewell, obtained through interview from the stakeholders. In this study, Gini Coefficient and Lorenz Curve have been used. The data has been collected in terms of water shares and shareholders for the Karez and tubewells to find Gini Coefficient and draw Lorenz curve. Hence, equity has been found between Karez and tubewell water shares.

The philosophy behind this approach is that the equity level will be determined for the Karez and Tubewell water for the reason to find out which source is more equitable for the community and why. Lorenz curve is the graphical illustration of distribution of the wealth or income in economics. In 1905, Max O. Lorenz developed this for highlighting inequality of distribution of wealth.

Lorenz curve highlights the distribution of income in an economy by plotting the fraction of the population on the x-axis i.e., horizontal axis & the fraction of income on y-axis i.e., vertical axis (after households have

---

[6] Old and notable personality of the area
[7] Farmer

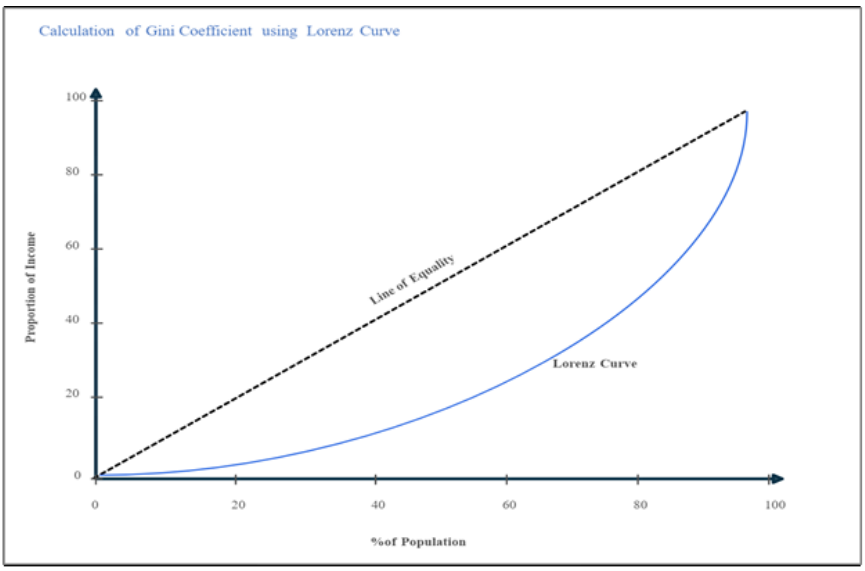
been ranked by their income) in an economy. If Lorenz curve would be closer to 45-degree line, the distribution of income will be more equal.

The curve is a graph disclosing proportion of total wealth or income with the assumption of keeping the bottom x% of people, though it isn't practically true for a finite and very large population. It is mostly used to show the income distribution, where it represents for bottom x% of the households, what percentage (y%) of total income they have. The household's percentage is drawn on the x-axis while income percentage is drawn on the y-axis. It could also be utilized to represent distribution of the assets. In this way, numerous economists think Lorenz Curve to be the tool of measuring the social inequality.

This approach is useful and feasible in describing inequalities not only in studies of biodiversity but also among size of the individuals in ecology by plotting cumulative proportion of the species against cumulative proportion of individuals (Wittebolle, Lieven; et al. (2009). In business modeling, it is too useful as well like in consumer finance, to measure actual percentage y% of delinquencies attributable to x% of people with worst risk scores.

FIGURE 2

A Typical Lorenz Curve



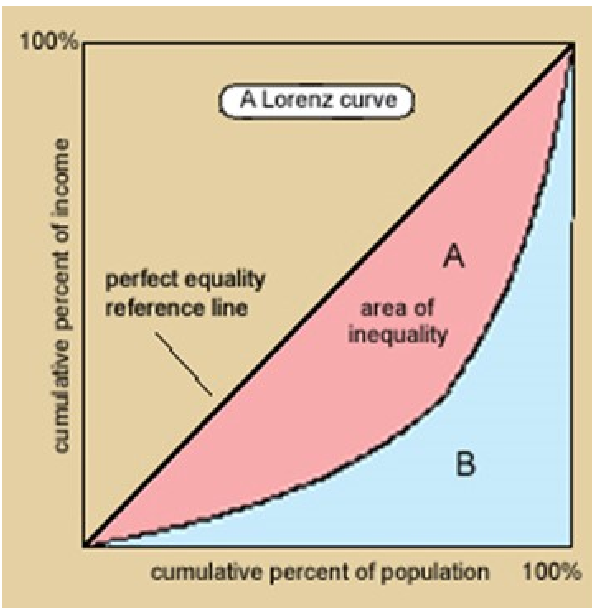
Gini coefficient is termed as Gini ratio or Gini index in economics. It is a tool of measuring statistical dispersion with the objective to show the wealth inequality or income inequality within a group of people or whole nation. Corrado (1912) developed this (Gini Coefficient) who was an Italian statistician and sociologist.

The Gini coefficient explains inequality by calculating the numeric values of frequency distribution like levels of the income. When Gini coefficient is zero, it illustrates perfect equality, where all the values are same (for example, where everyone has same income). When Gini coefficient is one (or 100%), it shows maximum inequality among the values (e.g., for many people where only one person has all the income or the consumption, and all the others have none).

The Gini coefficient is ratio of the area between the line of perfect equality and the observed Lorenz curve to the area between the line of perfect equality and the line of perfect inequality. In the diagram on the right, this is given by the ratio A/(A+B), where A and B are the areas of regions as marked in the diagram.

FIGURE 3

Derivation of the Gini Coefficient and Lorenz Curve



LORENZ CURVE AND GINI COEFFICIENT USE BY PREVIOUS RESEARCHERS

Lorenz curve and Gini coefficient is commonly used in economics for income inequality and other economics variables like impacts of increasing incomes on classified income distributions. For example, Petersen (1986) determined the effects of incomes on papulation through Lorenz Curves and Gini Indices. Stark & Yitzakhi (1988) studied merging populations and Stochastic Dominance through Lorenz curves. Similarly, Lorenz curve was used for the study of distribution of unemployment experiences (Kaliski: 1986); to examine consolidation in New Zealand commercial fishing (Abayomi & Yandle: 2012). Measurement of the regressively of gambling taxes was done by using Lorenz curve vy (Thomas, 1981). Measuring the inequality and the social welfare from any arbitrary distribution was done through Lorenz curve (Beena & Kumaran: 2010). Inequality in plant size or fecundity was described by Lorenz curve (Dammgard & Wiener: 2000). In Italy, the participation of students with an application to case of the higher education was studied with the help of Lorenz curve (Larcinese: 2008). Measuring the regressively of gambling taxes was done by Lorenz curve (Thomas: 1981).

Water is important and essential for life on earth, but the quantity of fresh water is only 2.5 %. Around 99 % of all fresh water is present in the form of underground aquifers (United Nations Environment Program, 2002), and more than quarter of the world's population takes water from these underground water reservoirs in the form of the aquifers. Pakistan's population of over 180 million is dependent on the water because it relies heavily on the agriculture. Agriculture makes a significant contribution (21 percent) to gross domestic production of the country and provides livelihood to more than 43 percent of rural population (Government of Pakistan, 2014), but uses around 95% of country's water. In Pakistan, surface water supply is variable and not constant, specifically for farmers located at the tail end of canals and distributaries in Punjab and Sindh provinces, so the agricultural sector is heavily dependent on underground water. Groundwater is accessed by tubewells, where a pipe is introduced into an underground aquifer, and the water lifted by a pump. Availability of locally made diesel engines and subsidized electricity has increased the number of private tubewells dramatically within the country. Recently, more than 0.8 million private tubewells are operational and functional and 90 percent of these tubewells are used for agriculture in Pakistan (Nangraj, Mangan, Khooharo, Laghari, & Buriro, 2016; Qureshi, McCornick, Qadir, & Aslam, 2008). With this intensity of use there are grave concerns about the sustainability and equity of groundwater use for agriculture (Ashfaq & Ashraf, 2006; Khair, Mustaq, Culas, & Hafeez, 2011; Qureshi, McCornick, Sarwar, & Sharma, 2010). In the world, Pakistan is categorized as one of the most water-scared countries because degradation and depletion of underground water is very high in this country. Pakistan is facing scarcity of per capita water soon (Asian Development Bank, 2016; Rahut, Ali, Imtiaz, Mottaleb, & Erenstein, 2016). In 1947 the availability and ownership of water in terms of per capita was 5650 cubic meters while in 2013 it declines to 990 cubic meters in Pakistan (Government of Pakistan, 2014; Lalzad, 2007). If this decreasing trend remains continuous it will reduce groundwater tables and it is forecasted that per capita availability of groundwater could be decreased to 800 cubic meters by 2020 (Innovateus, 2014; Kahlown & Majeed, 2002).

In Balochistan irrigated agriculture depends on both surface and groundwater resources. The major sources of surface irrigation are the Pat Feeder, Khirther, and Lasbela canals of the Indus Basin Irrigation System (IBIS). Floodwater is another important and major source of surface water which flows through streams. Some 97 percent of area was cultivated under irrigated crops, and only 3 percent was under rainfed/Sailaba[8] farming during 2014-15 (Government of Balochistan, 2015). An estimated 30 percent of floodwater has been utilized for agriculture in the form of storage dams, sailaba diversions, and minor but updated perennial irrigation schemes. In addition to this, Groundwater is also present for irrigated agriculture with the help of Karezes, springs and tubewells. Groundwater irrigates around half of the irrigated area of Balochistan and the main source is tube-wells. The growth of tube-well-led agriculture in Balochistan has caused manifold increase in the agricultural production, but the groundwater resources in many basins of Balochistan are under tremendous pressure. Water tables are decreasing

[8] Rainwater. flood water

sharply with the rate of 2 to 5 meters per annum which is very alarming situation because many areas are running out of water and farmers are losing their source of livelihood.

In most areas of Balochistan groundwater is prime irrigation source due to shortage of any alternative source of irrigation. To agricultural tubewells, the provision of 90% of subsidized electricity encourages farmers for extensive groundwater pumping (Khair, 2013). Water having the equity increases the crops growth and effects crop choice and causes farmers to have a shift from the low delta crop to high valued crops. It not only increases irrigation by production and yields of crops but also increases economic worth. The irrigation equity can be expended to enhance crop productivity (Watto and Mugera., 2015).

THEORETICAL AND CONCEPTUAL FRAMEWORK

Karezes are underpass drains like tunnels and transmits water from the hillside through a main well, called mother well that is connected to the pond, constructed for extraction and use of water, with the series of the wells. Karezes are equitable, sustainable, natural resource, social institution and cultural heritage with low evaporation loss and precipitation rate having easy access. Normally, Karezes are situated beneath the high hills adjacent to virgin land and fertile levelled oasis (Farooqi & Rehman, 1998). Karezes allow water for the transportation over the long distances in hot and dry weather without having much water loss in the form of evaporation (Andreas et al. 2016). The Karez value is positively related to volume, quality, and regularity of flow of the water (Kheirabadi, 1991). Karezes are not merely a source of water but also a social institution and a cultural hertitage. Farooqi & Rehman (1998) discussed importance of social set up in successful operation of Karez system. They mentioned the factors which were necessary for proper functioning of Karez system, these are the aspirations, motivations and opinions of shareholders, community leadership, tribal values, nature of social participation (cooperation and conflicts), and the role played by government functionaries. Abudu et al. (2011) stated that Karez may be considered as global heritage due to its role for enhancing social and cultural diversity. Karez irrigation system is on the verge of complete abolition as highlighted by the following studies. Kahlown and Hamilton

(1994) described that Karez system faces deficiency of skill labors for proper maintenance. Karim and Nawaz (1995) stated that the tubewells are the reason for depletion of Karezes. Rehman (1981) studied that due to hardship in construction, difficulty to maintain, and limited scope, the Karez irrigation system had been a vital and integral element of agricultural lands in Balochistan. Hussain at el. (2008) identified the factors for deterioration of Karez which were introduction and widespread adoption of tubewells, deficiency of skilled labors for construction and maintenance of Karezes, conflict among shareholders and tribal disputes, and lack of adequate polices. Therefore, Karez system has lost its importance due to its inability to be used for intensive agriculture. While Durrani at el. (2017) studied the impact of the long-term variability in climate on the groundwater level of Quetta alluvial. Their analysis of annual precipitation shows the declining trends at all the gauging stations and concludes that groundwater has regularly declined because of variability in rain fall. As the resultant of this, the water levels have been decreased and there is no other source to recharge the underground water levels. In another study Mustafa and Qazi (2007) described the flat rate electricity charges, cheap Afghan labors and droughts, the reasons for Karez irrigation system decline. Mustafa & Qazi (2008) reported the constraints in rehabilitation of Karez system. These are large number of tubewells installation, regular maintenance, deficiency of skill labors, very less support from the private and public sectors in building the skills of technicians through utilization of feasible technology.

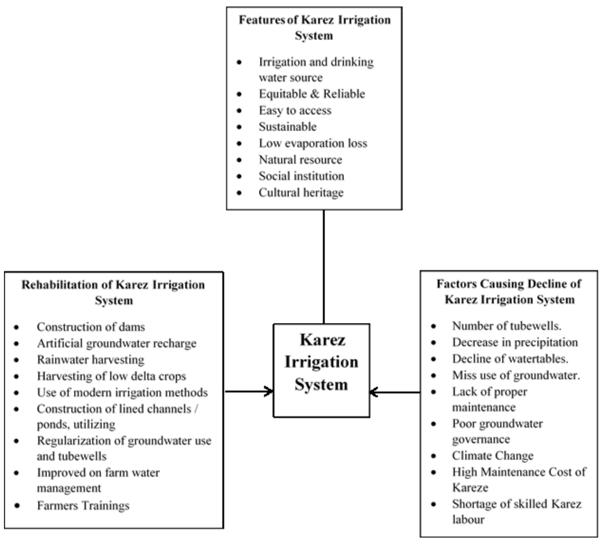
Khair at el. (2015) investigated the previous policy of government on groundwater management by arguing that the historical groundwater policies of subsidized electricity and tubewell development were responsible for groundwater depletion that were originally designed to increase the agriculture yield and reducing poverty. Few studies suggested various suggestions for the rehabilitation of Karez irrigation system. For example, Junaid (2020) suggested that the renewed interest in Karez for sustainable irrigated agriculture in arid regions has some merits and farmers may participate in such efforts if adequate institutional support is extended. Mehwish (2017) suggested that to rehabilitate the Karez system to develop as social institution Karezes ought to be highly considered as historic symbol and cultural heritage.

Nasiri & Mafakheri (2015) stated that Karezes are sustainable source of water supply because it conserves the aquifers, and it has low evaporation losses. Abudu at el. (2011) stated that the proper use of Karezes is one of most efficient way for groundwater sustainability. Hussain at el. (2008) explained that Karez still can play vital role in semi-arid and arid environment of Pakistan. Ahmed (2007) described that Karez irrigation is natural heritage and a sustainable system for B Fig 5 shows the schematic diagram for the relationship between Karez water and tubewell water description the features of Karezes, causes of decline in Karezes, constraints and opportunities for Karezes in relation with the physical, socio-economic and productions factors in Khushab village and Malikyar village of Balochsan, Pakistan.

Figure 4 shows the features of Karez irrigation system and the interaction of various socioeconomic, environmental and physical factors that have been causing Karez rrigation system decline, and the opportunities for its rehabilitation.

FIGURE 4

Karez Irrigation System and the Interaction of Various Socioeconomic, Environmental and Physical Factors



Source: Khair et al., 2013

IV. RESULTS AND DISCUSSION

OCCUPATION OF THE SELECTED COMMUNITIES

The results disclosed in Table 1 shows the occupation features of stakeholders in terms of percentage relating to the research territory i.e., Khushab and Malikyar. The proportion of the population related to the irrigated agriculture in both villages, Khushab and Malikyar, were 13 % and 15 % respectively through irrigated annals-crop[9], vegetables[10] etc while 42 % and 51 % population related to irrigate perennials-orchards[11] respectively in both villages. A considerable proportion of the population in both villages possess dryland farming i.e., 26 % in Khushab and 14 % in Malikyar by depending on unexpected natural sources of irrigation like rain, flood etc. Such drylands are called rainfed, khuskawa, sailaba etc. While it was also reported that some individuals utilize dry_lands for livestock (12 % in Khushab and 14 % in Malikyar). A small proportion of the papulation in both villages, 4 % in Khushab and 3 % in Malikyar, is related to dairy farming[12]. Remaining population of 3 % in both villages is related to other spheres of life like education, health, retails, transportation, community development etc.

TABLE 1

Occupation Sources

Occupation	Khushab	Malikyar
Agriculture (vegetables, Irrigated annals-crops, etc)	13 %	15 %
Agriculture (irrigated perennials- orchards).	42 %	51 %
Dryland (sailaba, khuskawa, rainfed etc)	26 %	14 %
Dryland (Livestock)	12 %	14 %
Dairy farming	4 %	3 %
Other	3 %	3 %

Source: FGD, 2021

[9] Wheat, barley, melons,
[10] Lady fingers, pumpkin, onion, brinjals
[11] Almonds, apples, apricots, grapes, peaches, plums, pomegranate, bananas (Balochistan Agriculture Department Report, 2016-17)
[12] Using milk of cows, goats, sheep, jenny, oxen

Agriculture sector could be called the backbone of these both villages because a massive part of population is related to agriculture directly and indirectly. The agriculture sector is the major source of income, survival, progress, development, and growth for both villages, Khushsab and Malikyar.

SOURCES OF WATER FOR IRRIGATION

The sources of water for irrigation in agricultural dependent villages, Khushab and Malikyar include Tubewell i.e., common, and frequent source for the irrigation in both villages by having around 250 tubewells in Khushab and around 300 tubewells in Malikyar as illustrated in below mentioned Table 2. The registered tubewells are in very small proportion i.e., some 180 registered tubewells in Khushab out of 250 and there were around 230 registered tubwells in Malikyar out of 300 tubewells. The major source of power for these tubewells is electricity in both villages. Minimum 5 to 6 hours per day electricity is available for tubewells in both villages. Now the solar technology is being installed to operate tubewells. Several tubewells are converted into solar from electric source of energy. With the help of solar power, one tubewell can be operated for 8 to 10 hours per day for water extraction in the long days of summer and 5 to 6 hours in short days of winter. There are also alive functional Karezes in the villages. Khushab has only one alive functional Karez with name Zarkoon and while Malikyar has only one alive functional Karez with name Sahibzada.

TABLE 2

Source of Water for Irrigation

Particulars	Khushab	Malikyar
Source of water in village	Tubewells	Tubewells
Number of tubewells	250	300
Source of power of tubewells	Solar (Less), Electricity (Most)	Solar (Less), Electricity (Most)
Existence of alive Karezes	Yes	Yes
Number of alive Karezes	2	1

Source: FGD, 2021

Residents of both villages are declaring Karezes are the best source of irrigation. According to them, Karezes deal with humans like mother.

The water of Karezes is more powerful in terms of minerals than tubewells. For lands, Karez water is required once in ten days while tubewell water is required once in two days. Karez water is effective, efficient, and economic. Karezes have been dried due to climate changes, less rains and absence of dams.

CAUSES OF DECLINE OF KAREZES

Results illustrated in Table 3 show the causes of decline of Karezes in village Khushab and village Malikyar. There are several reasons of decline of Karezes reported by responents. According to residents of villages, the prime reasons of decline of Karezes were decrease in precipitation and climate change. Rainfall is decreasing day by day. As a result of this, the underground water is also decreasing day by day. This situation is leading to decline of the Karezes. Duration of hot weather is expanding, and duration of cold weather is shrinking. Snow has almost disappeared from last three decades. This act has increased the quantity of water evaporation as well. Second key cause of decline of Karezes is the installation of tubewells at very large scale. Installation of tubewells is capital intensive and expensive work, but government is promoting the installation of tubewells through different loan schemes, subsidies, and incentives. Moreover, many NGOs[13] are also promoting and sponsoring the installation of tubewells. Government is not taking effective and efficient actions to save and rehabilitate the Karezes. There is not a single project of any department of the government about the betterment of Karezes in both villages. Dams are the basic requirement for Karezes restoration but there is not a single dam in any of the two villages or in any nearby village. NGOs are also not working to rehabilitate Karezes by taking actions with long lasting effects. They provide service at a small scale with short effect by constructing a small water tank, providing pipes, wires etc. in addition to this, increase in population is also a cause of decline in Karezes. Initially, the population of both villages was in hundreds but now the papulation is in thousands. There is a direct relation between population growth and increase in water demand. As per result, due to urbanization the Karezes have been declined.

---

[13] BRSP, LSO, UNDP

TABLE 3

Ranking of Causes of decline of Karezes

Causes	Khushab	Malikyar
Increased number of tubewells.	II	I
Decrease in precipitation	I	II
Climate change (rising temperature, decreasing precipitation).	III	III
Increase in population	IV	V
Poor groundwater governance	V	IV
Decline of watertables.	VI	VI
Increase in consumption of water for domestic and irrigation.	VII	VII
Availability of modern technology for groundwater extraction	VIII	VIII
No cleaning of Karez.	IX	IX
Lack of public awareness	X	X
Misuse of groundwater.	XI	XI
Lack of proper maintenance of Karez.	XII	XII

Source: FGD, 2021

CONSTRAINTS IN KAREZ IRRIGATION SYSTEM REHABILITATION

Results presented in Table 4 explained the constraints in Karez Irrigation system. The major constraint in Karezes rehabilitation reported by the respondents is decline of water levels which was mainly due to increase in population. Urbanization has led to squeeze the water shares for the shareholders. The other primary constraint reported was the climate change. Global warming has increased the warm days that might have decreased the precipitation.

TABLE 4

Ranking of Constraints in Karez Irrigation System

Constraints	Khushab	Malikyar
Decline of water levels	I	I
Increase in papulation.	II	II
Shares squeezing due to population rise	III	III
Climate Change	IV	IV
Decrease in precipitation	V	V
Community feuds	VI	VI
Smaller flow	VII	VII
Hard to maintain.	VIII	VIII
Ownership rights problem.	IX	IX
Lack of skilled labour	X	X
Expensive to maintain Karez	XI	XI

Source: FGD, 2021

Community is willing to have Karez water again for domestic and irrigation purposes. They reported that Karez rehabilitation was possible. Provided strategies like construction of dams, water tanks, water storage structures etc are built/ adopted to recharge the groundwater and Karez rehabilitation for increasing water.

OPPORTUNITIES FOR KAREZ IRRIGATION SYSTEM

Results disclosed in Table 5 explained the opportunities for Karez irrigation system rehabilitation. The positive element reported by villagers was that few NGOs are involved in the rehabilitation of Karezes by providing pipes, construction of small water tanks and other like activities. On the other hand, government also carries out few projects for the sake of rehabilitation of Karezes at small scale. Dam is the basic need of Karez for recharging point of view especially at the upstream. Both villages, Khushab and Malikyar, have a large land that could be used for rainwater harvest which could play a vital role in generating income, utilizing resources, and enhancing living standard.

TABLE 5

Ranking of opportunities for Karez irrigation system

Opportunities	Khushab	Malikyar
Government and NGOs involvement	I	I
Rainwater harvest	II	II
Construction of dams	III	III

Source: FGD, 2021

All available opportunities should be utilized fully with full of strength for Karez irrigation system.

EQUITY IN WATER DISTRIBUTION UNDER KAREZ AND TUBEWELL IRRIGATION DEPENDENT COMMUNITIES

Village Khushab

Results in Table 6 indicated the equity in water distribution and ownership between Karez water and tubewell water dependent communities in village Khushab. More people have share in Karez water (41 % population) than in tubewell water (24 % population). Karez is more affordable source of water than tubewell because wealthy and rich are likely to afford to dig a tubewell while Karez operation and maintenance cost is shared by the communities as it is a common property resource.

On the other hand, due to large number of tubewells, water supply is dominated in terms of water withdrawals by tubewells as compared to Karez that's why Karezes have limited share in total irrigation water supply than the tubewells and similar is their impact on agriculture and livelihoods.

The water of Khushab Karez is distributed among the shareholders in terms of Maath[14], This distribution of water shares is based on expenses which were incurred on the construction of Karez, land shares and labor efforts on the maintenance and cleanliness of the Karez afterwards. According to the respondents, this distribution of water shares was finalized almost hundred years ago and even now the committee, consists of representatives of the concerned Karez area, are responsible to maintain this distribution and it is practically implemented till yet.

During the last two decades most of the landowners of the area have installed the tubewells and as a result the access to groundwater has increased. Among the tubewell owners, many own two or more than two tubewells. Solar tubewells have further accelerated water pumping and access to groundwater. According to local people, the reasons for the installation of tubewells in area were the increasing water demand amid population growth, dry climate and the resulting reduction in Karezes discharge.

The Gini Coefficient of water distribution from Karez in village Khushab, shown in table 6, is 0.675758 which shows 67.57 % inequity while Gini Coefficient of water distribution from tubewells in village Khushab, shown in table 6, is 0.481818 which shows 48.18 % inequity. The results indicate that tubewell water distribution is not only equitable, but also more water is available for the residents.

[14] Means 12 hours. It can be explained as if someone gets the water for three hours in a math, his total watr shares will be six hours in a day i.e., 24 hours.

Village Malikyar

Results showed in Table 6 indicated the equity in water distribution and ownership between Karez water and tubewell water dependent communities in village Malikyar. More people have share in Karez water (51 % population) than in tubewell water (31 % population). Karez is more affordable source of water than tubewell because wealthy and rich are likely to afford to dig a tubewell while Karez operation and maintenance cost is shared by the communities as it is a common property resource.

In addition to this, due to a very large number of tubewells, supply of water is dominated in terms of water withdrawals by tubewells as compared to Karez that's why Karezes have limited share in total irrigation water supply than the tubewells and similar is their impact on agriculture and livelihoods.

The Karez water of Malikyar is distributed among the shareholders in terms of Mazegar[15] and Paoo[16]. This distribution of water shares is based on expenses which were incurred on the construction of Karez, land shares and labor efforts on the maintenance and cleanliness of the Karez afterwards. According to the respondents, this distribution of water shares was finalized almost hundred years ago and even now the committee, consists of representatives of the concerned Karez area, are responsible to maintain this distribution and it is practically implemented till yet.

During the last two decades most of the landowners of the area have installed the tubewells and as a result the access to groundwater has increased. Among the tubewell owners, many own two or more than two tubewells. Solar tubewells have further accelerated water pumping and access to groundwater. According to local people, the reasons for the installation of tubewells in area were the increasing water demand amid population growth, dry climate and the resulting reduction in Karezes discharge.

---

[15] Means two hours

[16] Means 30 Minutes (two paoo is equal to one hour).

The Gini Coefficient of water distribution from Karez in village Malikyar, shown in Table 7, is 0.627966 which shows 62.79 % inequity while Gini Coefficient of water distribution from tubewells in village Malikyar, shown in table 6, is 0.415556 which shows 41.55 % inequity. The results indicate that tubewell water distribution is not only equitable, but also more water is available for the residents.

In reality and practically, Karezes are more equitable, affordable and reliable as all respondents wish and dream to have Karezes again, but from figures of Lorenz Curves, it can be concluded that Karezes have not remained any more efficient, economic, reliable, effective, accessible, equitable, feasible, better, and organized sources of water for irrigation than tubewells. It is due to decline in Karez water and increase in installation of tubewells. Karezes have been dried with the passage of time due to less precipitation, climate change and urbanization. Dams have neither constructed in any of the villages nor in nearby villages. There was not permanent source of recharging groundwater in any village. NGOs sponsor the installation of the tubewells. Government provide subsidy on the installation of the tubewells. Rich people support the farmers in the installation of the tubewells because of having orchids of valuable fruits like apples, apricots, and grapes to have large share of profit.

TABLE 6

Water Distribution Features under KAREZ and Tubewell Irrigation Dependent Communities

	Khsuhab		**Malikyar**	
Statements	Karez	Tubewell	Karez	Tubewell
Water received in number of hours	6.03	11.03	7.01	9.46
Number of shareholders/owners	33	33	118	101
How much people (%) accessible to water?	41%	24%	51%	31%
Economic source of water.	Yes	No	Yes	No
Only wealthy and rich can afford?	No	Yes	No	Yes
Water supply is limited.	No	Yes	No	Yes
Overall impact on irrigation.	Better	Fair	Better	Fair
Living standard of life has increased.	Yes	No	Yes	No
Reliability is higher	Yes	No	Yes	No

Source: FGD, 2021

The Gini Coefficient of water distribution from Karez in village Khushab, shown in Table 6, is 0.675758 which shows 67.57 % inequity while Gini Coefficient of water distribution from tubewells in village Khushab, shown in table 7, is 0.481818 which shows 48.18 % inequity. Moreover, table 6 also shows the Gini Coefficient of water distribution from Karez in village Malikyar that is 0.627966 which shows 62.79 % inequity while Gini Coefficient of water distribution from tubewells in village Malikyar, shown in table 6, is 0.415556 which shows 41.55 % inequity. The results indicate that tubewell water distribution is not only equitable, but also more water is available for the residents.

TABLE 7

Gini Coefficients

	Khushab		Malikyar	
	Karez	Tubewell	Karez	Tubewell
Area Under The Curve	0.337879	0.240909	0.313983	0.207778
Gini Coefficient	0.675758	0.481818	0.627966	0.415556

The Table 8 shows the quartiles of Khushab village regarding to both, Karez and Tubewell, shares. The obtained data about Karez water shares and tubewell water shares in village Khushab was arranged in quartiles. the first quartile shows 10 shareholders in Karez water and 6 shareholders in tubewell water, second quartile shows 12 shareholders in Karez water and 11 shareholders in tubewell water, third quartile shows 27 shareholders in Karez water and 21 shareholders in tubewell water and forth quartile shows 51 shareholders in Karez water and 62 shareholders in tubewell water.

TABLE 8

Quartiles of Khushab Village

Quartiles	Karez Water Shares	Tubewell Water Shares
0-25	10	06
26-50	12	11
51-75	27	21
75-100	51	62

The deatiled and one sighted explanation of quartile distribution of Karez water shares and quartile distribution of tubewell water shares in village Khushab is shown in Figure 5.

Figure 5

Quartiles Showing Distribution of Karez and Tubewell Water Shares in Village Khushab

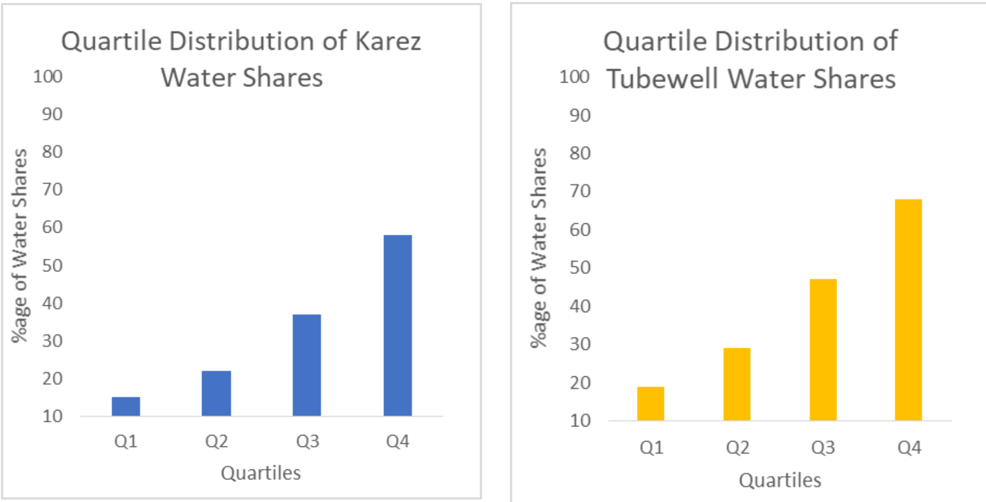


TABLE 9

Quartiles of Malikyar Village

Quartiles	Karez Water Shares	Tubewell Water Shares
0-25	08	03
26-50	12	09
51-75	21	19
76-100	59	68

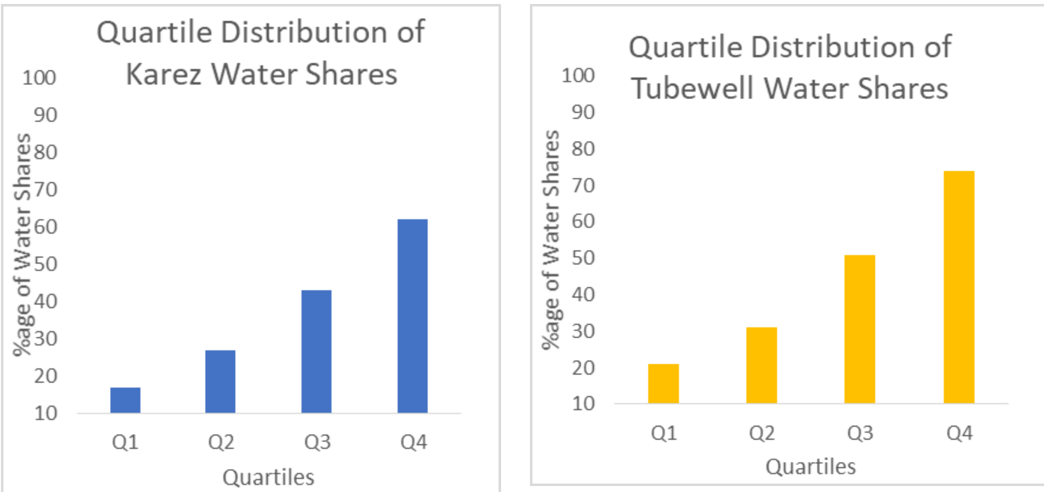
The Table 9 shows the quartiles of Malikyar village regarding to both, Karez and Tubewell, shares. The obtained data about Karez water shares and tubewell water shares in village Malikyar was arranged in quartiles. the first quartile shows 8 shareholders in Karez water and 3 shareholders in tubewell water, second quartile shows 12 shareholders in

Karez water and 9 shareholders in tubewell water, third quartile shows 21 shareholders in Karez water and 19 shareholders in tubewell water and forth quartile shows 59 shareholders in Karez water and 68 shareholders in tubewell water.

The deatiled and one sighted explanation of quartile distribution of Karez water shares and quartile distribution of tubewell water shares in village Malikyar is shown in Figure 6.

Figure 6

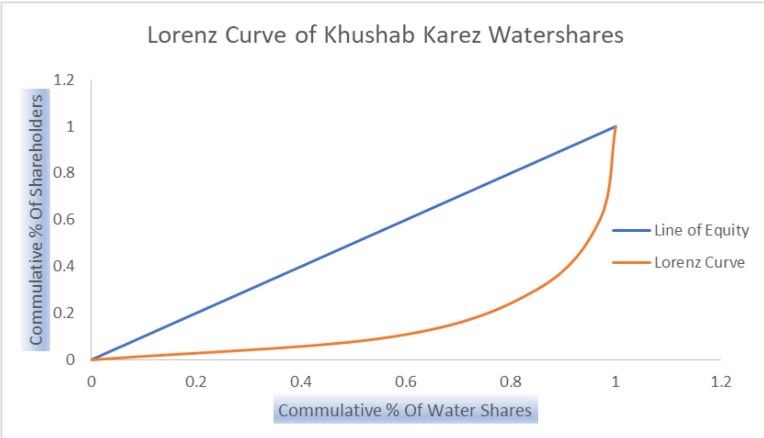
Quartiles Showing Distibtion of Karez and Tubewell Water Shares in Village Malikyar



In village Khushab, the equity among the Karez water shares is shown through the Lorenz curve that is displayed in figure 7. The Lorenz curve is flat by having more area under the curve which shows much inequity in distribution of water from Karezes in village Khushab.

Figure 7

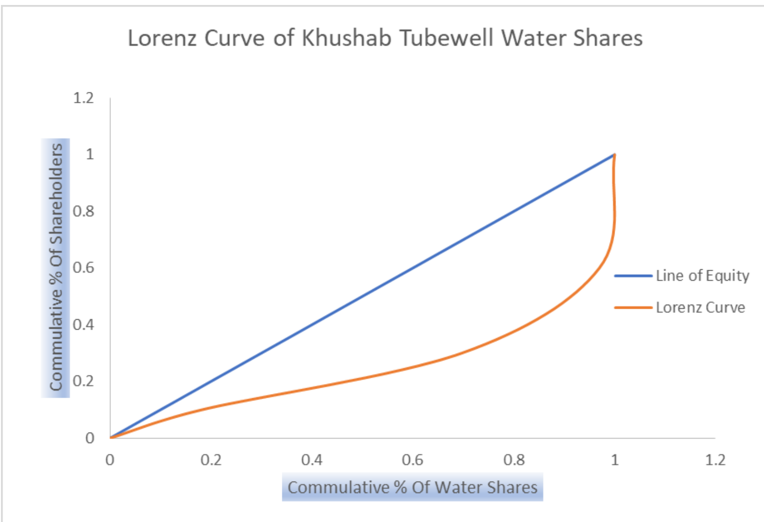
Lorenz Curve Showing Karez Water Shares in Village Khushab



In village Khushab, the equity among the tubewell water shares is shown through the Lorenz curve that is displayed in Figure 8. The Lorenz curve is not much flat by having less area under the curve which shows less inequity in distribution of water from tubewells in village Khushab.

Figure 8

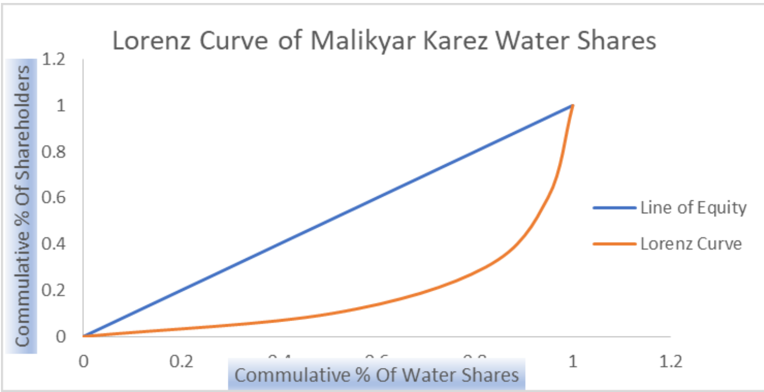
Lorenz Curve showing Tubewell water shares in village Khushab



In village Malikyar, the equity among the Karez water shares is shown through the Lorenz curve that is displayed in Figure 9. The Lorenz curve is flat by having more area under the curve which shows much inequity in distribution of water from Karezes in village Malikyar.

Figure 9

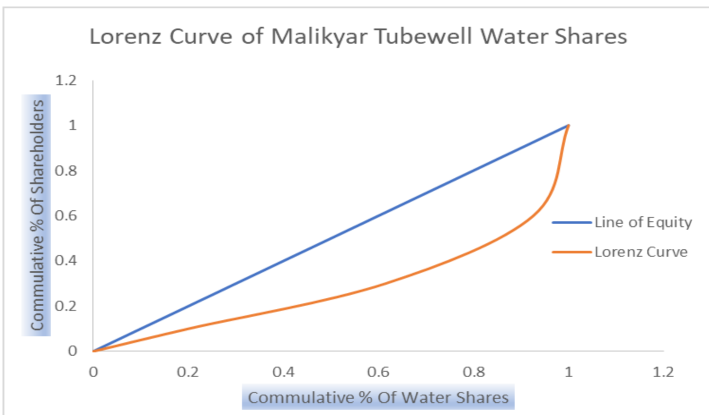
Lorenz Curve Showing Karez Water Shares in Village Malikyar



In village Malikyar, the equity among the tubewell water shares is shown through the Lorenz curve that is displayed in figure 11. The Lorenz curve is not much flat by having less area under the curve which shows less inequity in distribution of water from tubewells in village Malikyar.

Figure 10

Lorenz Curve Showing Tubewell Water Shares in Village Malikyar



DISCUSSION

The equity of Karez & tubewell water distribution are determined by using Lorenz Curve & Gini Coefficient. In addition to this, the descriptive approaches like tables, charts & graphs etc are also used in this study. Halcrow used the same methodology of Lorenz curve and Gini coefficient in BalochistanCommunity Irrigation and Agriculture Project for THAL (1998), ISKALKU (1999), ARAMBAI (2000) and KAN MEHTARZAI (2000). Moreover, ACIAR has also studied the same areas with same concepts to improve the management of groundwater to increase agriculture, livelihoods, and farming in Pakistan by utilizing Participatory Rural Appraisal.

Agriculture sector is the key sector of Khushab and Malikyar villages because a very large part of population is related to agriculture directly or indirectly. The agriculture sector is the primary source of income, survival, progress, development, and growth for both villages, Khushsab and Malikyar. In both villages, there is a substantial area of land, well in excess of available water, which is held as shamlat17. The development of pumped water had complicated the arrangement. Trading of water rights is common and has been going on for a long time. Ownership patterns of land is of little relevance as it is of little vale without water.

Land is substantially in excess of the water available for irrigation and the distribution of land ownership is of little relevance to the water shares. Irrigated area is controlled by water shareholding. There are more landowners than there are water shareholders. Some shareholders had additional share holdings in tubewell water which are very unlikely to have been registered officially. There are large areas of saliba irrigation which are mainly cropped with wheat. Landholders without water shares make use of sailaba and also farm as tenants or sharecroppers of water owners.

To identify shareholders with ownership in both, Karez and tubewell, data was collected from the sample of 87 respondents of Khushab Village and 135 respondents of Milayrar village. The surveys

[17] Land having communal ownership of the community

identified the landlords mostly with perennial crops. 91 % of the total cultivated area was consists of orchards. The number of shareholders is declining quite rapidly in Karezes and that small shareholders are disposing of their shares. This was confirmed by the WUA chairman, who reported that the number of shareholders in Karez water were indeed declining and number of shareholders in tubewell water were increasing.

The farmers are worried for declining the water in Karezes but they can't do anything themselves because of the climate changes. The precipitation has really decreased and the recharging of the Karezes has been on decline. On the other hands, farmers are feeling happy and relaxed by installing tubewells. They are wishing to rehabilitate the Karezes on urgent basis. They are waiting for the government to take seriously and long-lasting projects for the rehabilitation of Karezes.

Farooqi & Rehman (1998) discussed importance of social set up in successful operation of Karez system. They mentioned those factors which were necessary for proper functioning of Karez system following motivation, aspirations, and opinions of shareholders, community leadership, Feudal value and coordination, nature of social participation (cooperation and conflicts), and role of government and non-government functionaries. They suggested that fair understandings of the above-mentioned factors could assist to set up a suitable program for efficient and rapid function of Karez. It can be said that Karezes are social institutions saving tradition, customs, history, and humanity from centuries.

Durrani at el. (2017) conducted a study to observe the variability in climate at long term scale and its effects on level of groundwater in Quetta alluvial. They used the precipitation and temperature data from 1946 to 2015. The analysis of precipitation per annum identifies the decreasing attributes at all the gauging stations. The analysis shows that groundwater has regularly decreased because of variability in rain fall. Furthermore, the study shows that there is direct and positive relationship between groundwater depletion & number of tubewells increases. So, the groundwater level has declined with increase the number of tubewells in Quetta alluvial.it can easily be termed that Karezes have been declined due to less precipitation, increases in population, climate change, and increases in tubewell installation.

The Halcrow (1999) used GC and LC for Balochistan community irrigation and agriculture project on THAL perennial irrigation scheme using the summary of basline and impact survey data 1985 to 1998. In this study, the distribution of water shares as reported at feasibility. The distribution of Karez water was much equitable with Gini of 0.32.

The Halcrow (1999) used GC and LC for Balochistan community irrigation and agriculture project on ISKALKU perennial irrigation scheme. In this study, the distribution of water shares as reported at feasibility. The distribution of Karez water was much equitable with Gini of 0.40.

The Halcrow (2000) used GC and LC for Balochistan community irrigation and agriculture project on ARAMBAI Karezes perennial irrigation scheme using the summary of basline and impact survey data 1989 to 2000. In this study, the distribution of water shares as reported at feasibility. The distribution of Karez water was much equitable with Gini of 0.41.

The Halcrow (2000) used GC and LC for Balochistan community irrigation and agriculture project on KAN MEHTARZAI perennial irrigation scheme using the summary of basline and impact survey data 1985 to 2000. In this study, the distribution of water shares as reported at feasibility. The distribution of Karez water was much equitable with Gini of 0.36.

The Halcrow (1999) used GC and LC for Balochistan community irrigation and agriculture project on KAZHA Karez perennial irrigation scheme. In this study, the distribution of water shares as reported at feasibility. The distribution of Karez water was much equitable with Gini of 0.43.

In this study, data was obtained for the Karez water shares situated in village Khushab. To find the equity, GC and LC methodology was used. The Gini Coefficient of water distribution from Karez in village Khushab is 0.67 which shows 67.57 % inequity. In addition to this, Gini Coefficient of water distribution through tubewells in village Khushab is 0.41 which shows 41.55 % equity. The results indicate that tubewell water distribution is not only equitable, but also more water is available for the residents.

Data was also obtained for the Karez water shares located in village Malikyar. To find the equity, GC and LC methodology was used. The Gini Coefficient of water distribution from Karez in village Malikyar is 0.62 which shows 62.79 % inequity. In addition to this, Gini Coefficient of water distribution through tubewells in village Malikyar is 0.48 which shows 48.18 % equity. The results indicate that tubewell water distribution is not only equitable, but also more water is available for the residents.

With the passage of time and recently, Karezes have not remained equitable due to several reasons and population is focusing on the installation of tubewells. On the other hand, population is wishing for the Karezes to be rehabilitated by comparing them with mother. Karez is the representative of the national heritage. It has saved the livelihood, custom, tradition, language, unity and discipline from last many centuries. People had free and open access to the Karez water that was not only used for irrigation but also for domestic needs and livestock. Residents are dreaming to have Karezes again.

Both villages, Khushab and Malikyar, have low precipitation, mass tube-well installation caused by rapid decline of water tables, traditional irrigation techniques decreasing water use efficiency, improper cropping pattern and poor agronomic cultural practices, apple quality is decreasing due to rising temperature, drought, and water stress condition, and an increase of insect and disease pests in horticultural crops. Both villages, Khushab and Malikyar, are facing the problems of Declining water tables Illegal tube-wells, Orchards being replaced by tomato, garlic, People diverting to business, mining and services, People striving for other livelihood source (mining, business etc.), and Women have no direct role in water management/farming.

V. CONCLUSION AND POLICY RECOMMENDATION

This chapter presents the conclusions on the basis of outcomes found and their policy recommendations to improve the equity between Karez and tubewell water distribution in the villages, Khushab and Malikyar, situated in disticr Pishin of Balochistan. This study also recognizes a number of limitations.

CONCLUSION

This study uses the Gini coefficient and Lorenz curve method to measure the equity between the Karez and tubewell water distribution in Khushab and Malikyar villages of Pishin of Balochistan. Moreover, the demographic and socioeconomic characteristics of the farmers were also studied to examine their relationship with the irrigation strategies. The result indicated that a large share of population depends on irrigation for the survival by getting income to fulfill their expenses. Water is the only source of irrigation that is obtained by different means like Karezes, tubewells, floods, rain etc. Almost three decades ago, Karezes were the primary and key source of irrigation. The Karez water was not only used for irrigation but also for domestic needs and livestock. With the passage of time, Karezes got dried because of climate changes, less precipitation, increase in population and having no recharge structures in forms of dams, tanks etc. to fulfill the requirement of water for irrigation purpose, tubewells were began to install. The number of tubewells got increased with the passage of time.

Major crops grown in villages, Khushab and Malikyar, are apple, tomato, wheat, apricot, grapes, and garlic. Major source of water is tubewells. Flood is also used as irrigation method. Both villages have low precipitation, rapid decline of water tables aimed massive tubewell installation, traditional irrigation techniques, improper cropping pattern, poor agronomic cultural practices, and an increase in insect and disease pests attack on horticultural crops. Both villages, Khushab and Malikyar, are facing the problems of declining water tables, illegal tubewells, orchards being replaced by tomato and garlic, people are diverting to business, mining and services, people striving for other livelihood source (mining, business etc.), and women have no direct role in water management/farming.

In nutshell, it can be concluded that Karezes have not remained any more efficient, economic, reliable, effective, accessible, equitable, feasible, better, and organized sources of water for irrigation than tubewells. It is due to decline in Karez water and increase in installation of tubewells. Karezes have been dried with the passage of time due to less precipitation, climate change and urbanization. Dams have neither constructed in any of the villages nor in nearby villages. There was not permanent source of recharging groundwater in any village. NGOs sponsor the installation of the tubewells. Government provide subsidy on the installation of the tubewells. Rich people support the farmers in the installation of the tubewells because of having orchids of valuable fruits like apples, apricots, and grapes to have large share of profit.

On the other hand, population is wishing for the Karezes to be rehabilitated by comparing them with mother. Karez is the representative of the national heritage. It has saved the livelihood, custom, tradition, language, unity and discipline from last many centuries. People have free and open access to the Karez water that is not only used for irrigation but also for domestic needs and livestock. Residents are dreaming to have Karezes again.

RECOMMENDATIONS

Key recommendations accustomed, regarding estimated results, to improve the equity of water distribution of Karezes and tubewells in villages, Khushab and Malikyar, of district Pishin, Balochistan include the construction of dams, harvesting of low delta crops, use of modern irrigation methods, construction of lined channels / ponds, utilizing techniques of flood protection, regularization of groundwater use and tubewells, reduction in miss use of groundwater, decrease in over extraction of groundwater and training of farmers to keep them updated.

Government of Balochistan, development sector and NGOs need to work together for obtaining the desired and fruitful results.

THE WAY FORWARD

To improve equity in water distribution for irrigation, more research is needed in the following sections.

- Role of construction of dams in distribution of water for irrigation.
- To find out the technical problems regarding the performance of groundwater.
- Environmental impact measurements on the way to find out the social cost (cost on future generations) of groundwater extraction.
- Impact of over-pumping of groundwater on crop productivity, farmers' incomes and annual depletion rate.

REFERENCES

Ashraf., & Hasan. (2021). Groundwater Management in Balochistan, Pakistan: A Case Study of Karez Rehabilitation, World Bank Report, 1-16.

Ameur, F., Kuper, M., Lejars, C., & Dugué, P. (2017). Prosper, survive, or exit: Contrasted fortunes of farmers in the groundwater economy in the Saiss plain (Morocco). Agricultural Water Management, 191, 207-217.

Abudu, S., Cevik, S. Y., Bawazir, S., King, J. P., & Chunliang, C. (2011). Vitality of ancient Karez systems in arid lands: a case study in Turpan region of China. Water History, 3(3), 213-233.

Ahmad, S. (2007). Karez a cultural heritage of natural and agricultural sectors and an interminable system of harvesting groundwater in Balochistan. Water for Balochistan-Policy Brief, 3(14), 1-13.

Abdin, S. (2006). Qanats a unique groundwater management tool in arid regions: The case of Bam region in Iran. International Symposium on Groudwater Sustainability, 2, 1-31.

Apostol, T. M. (2004). The Tunnel of Samos. Engineering and Science, 1, 30–40.

Ajam, M. (2003). Iranian Qanats: a heritage from ancient. Seminar of Qanat in Gonabad.

Ahmad, F., & Farooq, S. (2002). Sustainable management of groundwater in the drylands of Pakistan. Proceedings, 2, 93-101.

Audrey, M., & Colin, B. B. (1997). Using the Lorenz curve to characterize risk predictiveness and etiological heterogeneity. Epidemiology, 27(4), 531-537.

Bell, A. R., P. S. Ward., & Shah, M. A. (2016). Increased water charges improve efficiency and equity in an Irrigation System. Ecology and Society, 21(3), 23.

Baroni, L.; Cenci, L.; Tettamanti, M.; Berati, M. (2007). Evaluating the environmental impact of various dietary patterns combined with different food production systems. European Journal of Clinical Nutrition, 61(2), 279–286.

Barret, F. G., & Pendakur, K. (1995). The asymptotic distribution of the generalized Gini indices of inequality. The Canadian Journal of Economics, 28(4b), 1042-1055.

Bishop, A. J., formby, P. J., & Smith, J. W. (1991). International comparisons of income inequality: tests for Lorenz dominance across nine countries. Economica, 58(232), 461-477.

Bishop, A. J., formby, P. J., & Smith, J. W. (1991). Lorenz dominance and welfare: changes in the U.S. distribution of income 1967-1986. The Review of Economics and Statistics, 73(1), 134-139.

Budd, E.C. (1970). Postwar changes in the size distribution of income in the United States. American Economic Review, 60, 247-260.

Chaudhary. (1990). The adoptation of tubewell technology in Pakistan, The Pakistan Development Review, 29(3), 291-303.

Durrani, I. H., Adnan, S., Ahmad, M., Khair, S. M., & Kakar, E. (2017). Observed long-term climatic variability and its impacts on the ground water level of Quetta alluvial. Iranian Journal of Science and Technology, A, 1-12.

Döring, M. (2003). Wasser für Gadara – 94 km langer antiker Tunnel im Norden Jordaniens entdeckt. Querschnitt, 21, 25-32.

Eltelo, O., & Frigyes, E. (1968). New income inequality measures as efficient tools for causal analysis and planning. Econometrica, 36, 383-396.

Fatima, G., Khan, A. I., & Andreas, B. (2016). Scocio-economic characterization of date palm growers and date value chains in Pakistan. SpringerPlus, 2, 1-13.

Farooqi, A. A., & Rehman, Z. (1998). Social set-up and Karez in Balochistan. WEDC CONFERENCE, 24, 99-101.

Gupta, R. M. (1984). Functional form for estimating the Lorenz curve. Econometrica, 52(5), 1313-1314.

Gastwirth. (1972). The estimation of the Lorenz curve and Gini index. Review of Economics and Statistics 10(2307), 41-63.

Hansen, R. D. (2016). Karez (Qanats) of Turpan, China. Water History, 51-74.

Hosseini, S. A., Shahraki, S. Z., Farhudi, R., Hosseini, S. M., Salari, M., & Pourahmad, A. (2010). Effect of urban sprawl on a traditional water system (Qanat) in the City of Mashhad, NE Iran. Urban Water Journal, 7(5), 309-320.

Hussain, I., Abu-Rizaiza, O. S., Habib, M. A., & Ashfaq, M. (2008). Revitalizing a traditional dryland water supply system: the Karezes in Afghanistan, Iran, Pakistan, and the Kingdom of Saudi Arabia. Water International, 33(3), 333-349.

Hadden, R. L. (2005). Adits, Caves, Karizi-Qanats, and Tunnels in Afghanistan: An Annotated Bibliography. US Army Corps of Engineers, Army Geospatial Center.

Halcrow-ACE. (2003). Exploitation and regulation of fresh groundwater: main report. ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Halcrow-ACE. (2000). Arambai perennial irrigation scheme, Balochistan. Community Irrigation and Agriculture Project, ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Halcrow-ACE. (2000). Kan Mehtarzai perennial irrigation scheme, Balochistan. Community Irrigation and Agriculture Project, ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Halcrow-ACE. (1999). Iskalku perennial irrigation scheme, Balochistan. Community Irrigation and Agriculture Project, ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Halcrow-ACE. (1999). Thal Perennial Irrigation Scheme, Balochistan. Community Irrigation and Agriculture Project, ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Halcrow-ACE. (1998). Kazha perennial irrigation scheme, Balochistan. Community Irrigation and Agriculture Project, ACE Halcrow JV Consultants, Gulberg III, Lahore, Pakistan.

Jogezai, G., Mari, F. M., & Memon, J. A. (2020). Futuristic outlook on traditional Karez systems for sustainable irrigated agriculture in arid Balochistan. Journal of Pure and Applied Agriculture, 5(1), 90-98.

Jann, B. (2016). Estimating Lorenz and concentration curves. The Stata Journal, 16(4), 837-866.

Khair, S., Ashfaq, M., Ali, A., Akhtar, S., Mangan, T., & Allan, C. (2021). Improving groundwater management to enhance agriculture and farming livelihoods in Pakistan: Participatory rural appraisal: starting the co-inquiry into groundwater and livelihoods. Institute for land, Water and Society, 1(148), 1-89.

Khair, S. M., Mushtaq, S., Smith, R. K., & Ostini, J. (2019). Diverse drivers of unsustainable groundwater extraction behavior operate in an unregulated water scarce region. Journal of Environmental Management, 236(15), 340-350.

Khair, S. M., Mushtaq, S., & Reardon-Smith, K. (2015). Groundwater governance in a water-starved country: public policy, farmers' perceptions, and drivers of tubewell adoption in Balochistan, Pakistan. Groundwater, 53(4), 626-637.

Khan, M. F. K., & Nawaz, M. (1995). Karez Irrigation in Pakistan. Geo Journal, 37(1), 91-100

Kahlown, M. A., & Hamilton, J. R. (1994). Status and prospects of Karez irrigation. Journal of the American Water Resources Association, 30(1), 125-134.

Kheirabadi, M. (1991). Iranian cities: formation and Development. Austin University of Texas Press, 145-149.

Kakwani, C. N., & Podder, N. (1976). Efficient estimation of the Lorenz curve and associated inequality measures from grouped observation. Econometrica, 44(1), 137-148.

Lictevout, E., Abellanosa, C., Maass, C., Pérez, N., Gonzalo, Y., & Véronique, L. (2020). Exploration, mapping and characterization of filtration galleries of the Pica Oasis, northern Chile: A contribution to the knowledge of the Pica aquifer. Andean Geology, 47 (3), 529–558.

Larcinese, V. (2008). A discrepancy index for the study of participation with an application to the case of higher education in Italy. Social indicators research, 88(3), 483-496.

Llorca, J., & Delgado-Rodriguez, M. (2000). Visualizing exposure-disease association: the Lorenz curve and Gini index. Med Sci Monit, 8, 193–197.

Lee, C. W. (1997). Characterizing exposure-disease association in human populations using the Lorenz curve and Gini index. Stat Med, 16(7), 729-39.

Lightfoot, D. R. (1996). Moroccan Khettara: Traditional irrigation and progressive desiccation. Geo Forum, 27(2), 261-273.

Memon, J. A., Qudoos, M., & Hussain, A. (2019). Who will think outside the sink? armers‘ willingness to invest in technologies for groundwater sustainability in Pakistan. Environment, Develoment and Sustainability, 12, 51-74.

Memon, J. A., Jogezai, G., Hussain, A., Alizai, M. Q., & Baloch, M. A. (2017). Rehabilitating traditional irrigation systems: Assessing popular support for Karez rehabilitation in Balochistan, Pakistan. Human Ecology, 45(2), 265–275.

Mustafa, D. (2014). The necessity of Karez water systems in Baluchistan. Middle East Institute, Middle East-Asia Project (MAP), 172-194.

Matsuyama, K. (2013). Endogenous ranking and equilibrium Lorenz curve across identical countries. Econometrica, 81(5), 2009-2031.

Mustafa, D., & Qazi, U. M. (2008). Karez versus tubewell irrigation: The comparative social acceptability and practicality of sustainable groundwater development in Balochistan, Pakistan. Contemporary South Asia, 16(2), 171-195.

Mustafa, D., & Qazi, U. M. (2007). Transition from Karez to tubewell irrigation: development, modernization, and social capital in Balochistan, Pakistan. World Development, 35(10), 1796-1813.

Moothathu, K. S. T. (1986). A characterization of power function distribution through a property of the Lorenz curve. The Indian journal of statistics, 48(2), 262-265.

Morgan, J. (1962). The anatomy of income distribution. The Review, 44, 270-282.

Nasiri, F., & Mafakheri, M. S. (2015). Qanat water supply systems: a revisit of sustainability perspectives. Environmental Systems Research, 4(1), 13.

Nair, S. V. (2006). Etymological conduit to the land of qanat. Environment, 1-24.

Negri, D. H. (1989). The common property aquifer as a differential game. Water Resource, 25(1), 9-15.

Petersen, H. G. (1979). Effects of Growing Incomes on Classified Income Distributions, the Derived Lorenz Curves, and Gini Indices, Econometrica, 47(1), 183-198.

Qureshi, A. S., McCornick, P. G., Sarwar, A., & Sharma, B. R. (2010). Challenges and prospects of sustainable groundwater management in the Indus Basin, Pakistan. Water Resources Management, 24(8), 1551-1569.

Rispoli, F. (2010). Unmasking a mystery: the curious case of the Gua Made Green masks. Current World Archaeology, 43, 9-42.

Rousseau, R., & Hecke, V. P. (1998). The Lorenz curve: a graphical representation of evenness. Coenoses, 13(1), 33-38.

Rahman, M. (1981). Ecology of Karez irrigation: a case of Pakistan. Geo Journal, 5(1), 7-15.

Steenbergen. V. F., Kaisarani. B. A., Khan, N. U., & Gohar. S. M. (2015). A case of groundwater depletion in Balochistan, Pakistan: Enter into the void. Journal of Hydrology: Regional Studies, 4(A), 36-47.

Steenbergen, V. F., & Oliemans, W. (2002). A review of policies in groundwater management in Pakistan 1950–2000. Water Policy, 4(4), 323-344.

Steenbergen, V. F. (1995). The frontier problem in incipient groundwater regimes in Balochistan (Pakistan). Human Ecology, 23(1), 53-74.

Satchell, E. S. (1987). Source and subgroup decomposition inequalities for the Lorenz curve. International Economic Review, 28(2), 323-329.

Tille, Y., & Langel, M. (2012). Histogram based interpolation of the Lorenz curve and Gini index for grouped data. The American Statistician, 66(4), 225-231.

Thomas, W. C. (1981). Measuring the Regressivity of Gambling Taxes. National Tax Journal, 34(2), 267-270.

UNESCO. (2021). Karez wells. World Heritage Convention, 5347, 1-6.

UNESCO. (2016). Karez system cultural landscape. World Heritage Convention, 6110, 1-4.

Watto, M. A., & Mugera, A. W. (2016). Wheat farming system performance and irrigation efficiency in Pakistan: a bootstrapped metafrontier approach. International Transactions in Operational Research (2016), 1–21.

Watto, M. A., & Mugera, A. W. (2014). Measuring production and irrigation efficiencies of rice farms: evidence from the Punjab province, Pakistan. Asian Economic Journal, 28(3), 301-322.

Wilson, A. (2008). Hydraulic Engineering and Water Supply. New York: Oxford University Press, 290–293.