Economic evaluation of small dams in rain-fed region of Pothwar Plateau, Pakistan

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Abstract: The Small Dams Organization has constructed 55 small dams in the rain-fed region of Pothwar Plateau, Punjab in Pakistan. A study was conducted on the Pothwar Plateau during 2019 to investigate the economic importance of small dams in the region, using Khasala and Jawa dams as the case study. The study tasks included: (i) a broad evaluation based on the performance of small dams in Pothwar Plateau, and to analyze the economic benefits of small dams to farming communities; (ii) a comparative analysis of the Khasala and Jawa dams on the Pothwar Plateau to identify the factors that influence agriculture production on irrigated (I) and non-irrigated (NI) farms in the area; and (iii) identification of key issues in order to identify potential options to improve agriculture production on the Pothwar Plateau. Data was collected through field observations, questionnaires, key informant interviews, and formal and informal discussions with farmers and was collated and reviewed quantitatively and qualitatively. It was found that the minimum water pricing is the basic reason for wastage and excessive water consumption. The cost of collecting water-charges from farmers is greater than the water-charges which are received. This has resulted in delayed maintenance of the irrigation systems which exacerbates water losses. It was also found from the survey of farmers of irrigated land and non-irrigated land that irrigation increases wheat yield.

ABOUT THE AUTHOR

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PUBLIC INTEREST STATEMENT

Agriculture remains Pakistan’s most important economic sector. Its contribution to GDP has gradually declined to 19.3% over the last few decades, but there is still a lot of potential in the sector. Climate change, pest attacks, water scarcity, and other factors have restricted agriculture production from reaching its full potential. Because agriculture consumes the most water, efficient water usage is a critical prerequisite for its long-term sustainability. In this regard, Small Dams Organization has constructed 55 small dams in the rain-fed region of Pothwar Plateau, Pakistan. Proper planning and management of small dams may increase the sustainable agriculture in Pakistan. Small dams are significantly contributing towards economy, environment, local climate, recreational activities and crop production. Water losses through seepage, unlined channels and old irrigational methods are most critical in developing world. Considering the overall positive environmental impacts, construction of small dams must be promoted.
by 15%, maize yield by 42%, vegetable yield by 41–44% and fodder yield by 60%. The availability of wells on non-irrigated farms means that these farmers could access timely irrigation, otherwise, their productivity gap would be greater if they were forced to rely on rainfall only. Issues of concern which were identified included: (i) illegal diversion of irrigation water by influential farmers; (ii) inadequate maintenance of irrigations systems and (iii) inefficient on-farm irrigation practices which contributed to a total irrigation efficiency in the irrigated areas of less than 30%; (iv) water rights and a water rotation systems are not implemented in the study area and (v) there is no water user association to deal with the water channels in the region which leads to clashes between users over the water distribution. A number of strategies that should be implemented to enhance agriculture production and efficient use of water resources are also identified.

**Subjects:** Agriculture & Environmental Sciences; Environment & Economics; Research Methods in Environmental Studies

**Keywords:** irrigated; non-irrigated; small dams; water resources; Pothwar Plateau; Pakistan

### 1. Introduction

Pakistan's population is 207.8 million and the rate of population growth is 2.1% (PBS (Pakistan Bureau of Statistics), 2017), it is expected to reach 227 million by 2025. While agriculture contributes 19.3% to Pakistan's Gross Domestic Product (GDP), it represents 38.5% of the employment of the national labor force. It remains a backward economic sector, nevertheless, agriculture is a mainstay of economic development and poverty alleviation. Agriculture output in the 2019–20 period has increased. The agriculture sector recorded a strong growth of 2.67%, considerably higher than the 0.58% growth, which was achieved in the preceding year. During 2019–20, the total water available for Kharif (summer) season crops was recorded as 80,423 million cubic meters (MCM) which was an increase of about 9.4% over the 73,515 MCM available to the Kharif season crops in 2018. During the Rabi (winter) season in 2019–20, the total water availability was recorded as 36,018 MCM, an increase of 17.7% compared to the Rabi season in 2018–19, but still 19.8% less than the normal water availability of 44,899 MCM (GOP, 2019-20).

Pakistan has an arid or sub-arid climate having an average rainfall of 240 millimeters (mm), mainly during the monsoon season (July-September) (Briscoe et al., 2006; Farooq et al., 2007). According to the benchmark water scarcity indicator (the Faulken Mark Indicators), the assessed per-capita access to water was around 900 m³ per person in 2017. This positions Pakistan at the “high water stress” level (Parry, 2017; Haq et al., 2018). If the same conditions persist, the country will hit an absolute water scarcity border by 2025 (Ahmed, 2007; Ashraf, 2016).

The entire land area of Pakistan is 79.61 million hectares (Mha) which include 29.4 Mha of cultivated land of which, 15.4 Mha is irrigated, 5.2 Mha is under rain-fed farming and the remaining 8.8 Mha area is wasteland or unproductive and requires more water for irrigation. The agriculture sector of Pakistan depends entirely on irrigation and over 95% of the country’s water is consumed for agriculture. It is estimated that around 40% of the water is wasted in the communal water channels and that 20%-25% of the irrigation water is lost during flood irrigation due to irregular farmlands and roughly prepared agriculture fields. Pakistan depends on the Indus Basin Water System (IBWS), the largest contiguous water system throughout the world, for the basic safety of its food production and the distribution of water for all sectors of the economy (PIPIP, 2012). Pakistan's water demand ratio is 74% and the pressure on freshwater reserves resulting from irrigation is 69.85% (Frenken & Gillet, 2012). The water productivity of irrigation for cereal crops in Pakistan is merely 0.13 kg/m³, viz one-third of India (0.39 kg/m³) and one-
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sixth of China (0.82 kg/m²) (GOP, 2013–14; PASP, 2015). In contrast to Pakistan’s reliance on irrigation, almost 80% of world agriculture is based on rain-fed farming (Wani et al., 2009).

Around 11,000 MCM of water is lost annually due to surface run-off in the rain-fed areas. If 50% of this run-off is conserved in small or mini-dams, then half the water-storage capacity of Tarbela Dam (the largest dam in Pakistan) could be retained. Punjab is the most populous province of Pakistan and contains an important part of the Indus Basin Irrigation System (IBIS). In northwest Punjab, there is a substantial tract of highland known as the Pothwar Plateau (Table 1). This area has an undulated terrain where agriculture is fully dependent on rainfall or groundwater extraction. This area has great potential for the construction of small dams (Siddiqui et al., 2011) which are less than 12 meters (m) high or that impound less than 1.2 MCM of water. These dams are constructed after undergoing a full feasibility assessment. Designers and supervision consultants are hired by the Small Dams Organization of Punjab (SDOP) and contractors are awarded construction works. A nominal staff is posted for the operations and management of the dam and water-channel structure (Majeed et al., 2010).

To date, the Punjab Government has built fifty-five (55) small dams in the Pothwar region and around eight (8) dams are under construction (Afzal & Mohsin, 2017). In addition to providing water for irrigation, small dams have multiple indirect effects, such as recharge of aquifers, local and community water supply, reduction of soil erosion, controlling floods in hilly and flat areas, supporting fish farming and for recreation purposes (Ejaz et al., 2012).

These small dams are also subject to several considerations including, low water transmission and practical efficiencies, the loss of the storage capacity due to sedimentation, increased vegetative evapotranspiration losses, surface water evaporation and seepage. Due to the absence of salinity and groundwater issues, a favorable climate for high-value crops and proximity to markets, this area could further increase its share of agriculture production using highly efficient trickle or bubbler systems (Siddiqui et al., 2011).

Water is an important mineral that occurs in nature and its regulation requires additional observation in the rain-fed region (Ali et al., 2011). There is a vast attempt for SDOP to construct further small dams in the rain-fed area to conserve 0.43 million hectare meters (MHM) of run-off water that infiltrates and flows into the Indus River and the Jhelum River without providing benefits (Khan et al., 2011). The annual run-off water in the Pothwar plateau is 0.43 MHM, of which 15% (0.06 MHM) is captured by small dams and nearly 85% (0.37 MHM) is lost. This indicates that a large volume of water is not harvested and can be captured by constructing small dams in the region.

Farmers in the Ambo district, Ethiopia began to extend their crop rotation annually, improved their income and consumption level significantly, and expanded their agriculture systems after the implementation of the Indris irrigation system. Therefore, access to irrigation is an important service to improve agriculture production and small farmers’ income (Bacha et al., 2011). In the case of the Gediz Basin irrigation schemes, Turkey (Yercan et al., 2004) the efficiency of the irrigation systems increased significantly after being shifted to a Water Users Association (WUA). The maintenance costs declined while system revenues were improved. Water distribution in all irrigation systems increased considerably. The financial performance of the irrigation schemes improved in Turkey (Cakmak et al., 2010). The household income increased because of efficient cropping and greater crop production which increased employment on irrigated farms as compared to rain-fed farmers.

To alleviate poverty in the area, irrigation should be implemented among other policies such as equal land allocation, consolidated water-resources governance, provision of unbiased and sufficient land distribution or underground water, advanced methods of cultivation and efficient techniques of cultivation, a switch to valuable market-based crops (Hussain & Hanjra, 2004). There is a positive relationship between irrigation and agricultural output. Historically, the use of water has not been at the optimal level, water supplied to the crops was not sufficient for their requirements and a lot of water was wasted. The high cost of pumped water forced the water
resources governance association to use deficit irrigation and reduce water wastage. In Ethiopia, Derib et al. (2011) recommended that there should be night-repository systems, optimum irrigation timelines, and opportunities for peasants to learn water efficient practices at the Blue Nile.

Ashraf et al. (2007) examined the impacts of small dams on agricultural production and groundwater development in the Pothwar Plateau. The Khasala, Jawa and Dhok Sanday Mar small dams were evaluated. The study was compared conditions before and the construction of the dams. The landholdings, agriculture yield and crop intensity all increased after the dam’s construction. Due to greater water availability, there was a switch of cropping patterns from conventional to market-oriented crops. The groundwater level has increased and has reached levels where it is feasible to extract groundwater which has increased the number of wells that have been dug. Traditional irrigation techniques remain prevalent. If water distribution and its use are well managed, then more areas could be irrigated with the same investment in infrastructure. Ashraf et al. (2007) proposed that an embedded framework be launched in the operating area for the efficient utilization of water supply with advanced infrastructure. Khan et al. (2011) evaluated six small dams which included four small dams from the Rawalpindi district (Khasala and Jawa were included) and two small dams from the Attock district. This research was designed to evaluate the impact of mini-dams on the socioeconomic progress of farmers residing in the rural community on the Pothwar Plateau. The study was based on interviews with dam staff and farmers. It was shown that the dams were positive and provided benefits to the farmers, which was apparent from a huge increase in farmers’ income and their level of satisfaction. There is a viable choice to build more small dams on the Pothwar Plateau to capture run-off water and to convert wasteland into high-income generating farms. In 2017 Afzal & Mohsin studied the water accessibility of small dams (Khasala and Jawa) in the Pothwar region. The study conducted interviews with farmers, SDOP staff and village headmen. It concluded that the study area has the potential to increase agriculture production but water shortage is the major constraint in the Pothwar plateau which causes low agriculture yield. Farmers face difficulties in terms of water availability due to inadequate water management services. Water supply is not equitable and water theft is a common practice due to the failure of the water rotation (warabandi) system. The water distribution channels were not working appropriately and periodic inspection is needed to repair the water channels. Therefore, there is a need to improve water management services in the area to enhance agriculture production. The study area is suited to agriculture production as farmers can sell their crops and produce in the Islamabad market and could increase output if there was a regular supply of water. Farmers in the study area have more land available for cultivation but hesitate to cultivate the additional land due to the limited water supply.

Although studies have been conducted by many authors, this area is still insufficiently explored. There is a need to identify basic constraints on low-land and water efficiency to identify promising strategies to strengthen the production of agriculture. The study tasks included:

- A broad evaluation based on the performance of small dams in Pothwar Plateau, and an analysis of the economic benefits of small dams to farming communities;
- A comparative analysis of the Khasala and Jawa dams on the Pothwar Plateau to identify the factors that influence agriculture production on irrigated and non-irrigated farms in the area; and
- Identification of key issues for potential strategies to improve agriculture production on the Pothwar Plateau.

2. Materials and methods

2.1. General characteristics of the study area

The two small dams which were studied were the Khasala and Jawa dams situated in the Pothwar Plateau (Figure 1). The Khasala dam is located on a stream known as Khasala Kas and it is 27 km from Rawalpindi city. It is located at latitude 33°20’ North and longitude 72°58’ East. The elevation of the watershed varies between 381 m and 427 m above sea level. The Jawa dam is located
35 km from Rawalpindi at 33°26’ North latitude and 72°56’ East longitude. The elevation of this watershed varies between 380 m and 506 m. The coldest month in the study area is January where the mean lowest and mean highest temperature range from 3°C to 16°C respectively. The warmest month is June having 40°C as a mean highest temperature and 24°C as a mean lowest temperature. In the monsoon season, there is high rainfall of 200 mm to 220 mm. While the mean annual rainfall that occurs in the Pothwar Plateau is 968 mm, it varies spatially from 400 mm in the northeast of the plateau to 1800 mm in the southeast of a plateau. The texture of the soil ranges from sandy to silty clay. These dams were mainly built for irrigation and groundwater recharge. Table 2 compares the main features of the Khasala and Jawa dams.

Figure 1. Location of Khasala and Jawa Dams.

Source: Small Dams Organization, Islamabad, Pakistan

Table 2
2.2. Research plan
A cross-sectional data collection method was used to obtain information on the existing and past conditions in the study area because it is a more efficient and reliable method. It was also convenient and appropriate to adopt data collection techniques based on interviews, questionnaires, focus group discussions (FGD), document analysis and field observations. Most of the research consisted of the same cross-sectional data collection methods reported by (Kahn et al., 2000; Rani et al., 2003). Both qualitative (field observations, key informant interviews and focus

| Description                          | Khasala Dam                      | Jawa Dam                      |
|--------------------------------------|----------------------------------|-------------------------------|
| Name                                 | Rawalpindi Division/Pothwar Plateau | Rawalpindi Division/Pothwar Plateau |
| Location                             | Northern Punjab including districts of Rawalpindi, Chakwal, Attock and Jhelum. | Northern Punjab including districts of Rawalpindi, Chakwal, Attock and Jhelum. |
| Area                                 | 22,500 km²                       | 22,500 km²                   |
| Population                           | 10.01 million                    | 10.01 million                |
| Villages                              | 2,600                            | 2,600                        |
| Topography                           | Hilly, Uneven with steep slopes  | Hilly, Uneven with steep slopes |
| Annual rainfall                       | 400 mm-1400 mm                   | 400 mm-1400 mm               |
| Major Rivers                         | Jhelum River and Indus River     | Jhelum River and Indus River |
| Run-off                              | 0.43 million hectare meters (MHM) = 43,000 GL | 0.43 million hectare meters (MHM) = 43,000 GL |
| Water capture in small dams          | 0.06 (15%) million hectare meters (MHM) = 6,000 GL | 0.06 (15%) million hectare meters (MHM) = 6,000 GL |

Source: Small Dams Organization, Islamabad, Pakistan.

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| Description                          | Khasala Dam                      | Jawa Dam                      |
|--------------------------------------|----------------------------------|-------------------------------|
| Location                             | Rawalpindi                       | Rawalpindi                    |
| Controlling division                 | SDO, Islamabad                   | SDO, Islamabad               |
| Year of construction                 | 1985                             | 1994                          |
| Type of dam                          | Concrete gravity dam             | Zoned earth dam               |
| Height (m)                           | 19                               | 25                            |
| Length (m)                           | 124                              | 143                           |
| Spillway crest length (m)            | 40                               | 110                           |
| Mean annual runoff (MCM)             | 4.17                             | 1.07                          |
| Gross reservoir capacity (MCM)       | 2.98                             | 1.94                          |
| Live storage capacity (MCM)          | 1.85                             | 1.11                          |
| Dead storage capacity (MCM)          | 1.13                             | 0.83                          |
| Life of the project                  | Calculated (years)               | 175                           | 65 |
| Adapting (years)                     | 50                               | 50                            |
| Catchment area (km²)                 | 25.4                             | 9                             |
| Gross command area (ha)              | 648                              | 324                           |
| Cultivable Command area (ha)         | 506                              | 323.89                        |
| Crop intensity                       | 140%                             | 100%                          |
| Length of irrigation channels (m)    | 3,415                            | 7,164                         |
| Capacity of irrigation sluice (L/s)  | 170                              | 142                           |
| Total cost of the project (USD million) | 0.28                          | 0.34                          |
| Annual recurring cost (USD/yr)       | 2,400                            | 4,000                         |

Source: Small Dams Organization, Islamabad, Pakistan.
group discussions) and quantitative data collection tools (secondary data, questionnaires) were implemented.

2.3. Sampling techniques and sample size determination

To determine the sampling size of respondents in the area, a multistage sampling technique was used. During the first phase, the Rawalpindi district was carefully chosen purposively due to the agriculture in the district, the presence of small dams, and the recommendations of agricultural experts of the Rawalpindi district. In the second stage, the Khasala and Jawa dams were also purposively selected from the district. The household heads were chosen from (I) and (NI) areas within the catchments of the small dams. The sample households were selected proportionally for each dam. In this regard, the sample population was divided into two strata, (I) and (NI) using stratified random sampling, arranged alphabetically for random tables and then a suitable sample size was determined. For every selected sample size of beneficiaries (farmers of irrigated land), proportional sample sizes of farmers on non-irrigated land were selected. The total number of (I) households for the Khasala dam was 268 from the three villages of Khasala Khurd, Khasala Kalan and Adiala) and for the Jawa dam was 245 in the five villages of Sangral, Sood, Bodial, Manial and Dhalla. The total number of (NI) households for two small dams were 91 and 82, respectively.

The Taro formula (Eq 1) was used to select the sample household (Taro, 1967);

\[
n = \frac{N}{1 + N(e)^2}
\]  

where: \( n \) = sample size: required no. of samples for each small dam; \( N \) = population size: total no. of household heads for both small dams; \( e \) = confidence level (0.05 (95%) level of precision); and \( \sum N \) = entire households for each of the two small dam catchments.

\[
n = \frac{686}{1 + 686 (0.05)^2} = 686/2.715 = 253
\]

The required number of households samples from each small dam (\( n \)) were computed using Eq 2 as mentioned below:

\[
n_1 = \frac{N_1(n)}{\sum N}
\]

(I): \( n_1 = 513 \times 253/686 = 189 \)

(NI): \( n_2 = 173 \times 253/686 = 64 \)

I (Khasala): \( 268 \times 189/513 = 99 \)

I (Jawa): \( 245 \times 189/513 = 90 \)

(NI) (Khasala): \( 91 \times 64/173 = 34 \)

(NI) (Jawa): \( 82 \times 64/173 = 30 \)

The proportional sampling tool was adopted to determine the whole sample size. Consequently, 189 (I) and 64 (NI) from overall 253 household samples were chosen respectively. Furthermore, 99 and 90 household heads from irrigated farms (Khasala and Jawa), 34 and 30 from non-irrigated farms (Khasala and Jawa) were selected respectively (Table 3). An overview of the sampling framework is also presented in Figure 2.
2.4. **Data collection tools**

A standard household survey was carried out to collect quantitative data. In this context, a questionnaire was designed under the supervision of researchers and dam personnel. The quantitative data was collected from the heads of households. To check the accuracy, a pre-test was carried out for some randomly chosen households in the study area. Based on the respon-

| Table 3. Sample household heads (HHs) collected from (I) and (NI) farmers |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|------------------|
| Small Dams | Sample Irrigators | Sample Non-Irrigators | Total Sample HHs |
| Male (M) | Female (F) | Total (T) | Male (M) | Female (F) | Total (T) | HHs |
| Khasala Dam | 67 | 32 | 99 | 25 | 9 | 34 | 133 |
| Jawa Dam | 68 | 22 | 90 | 22 | 8 | 30 | 120 |
| Total | 135 | 54 | 189 | 47 | 17 | 64 | 253 |

Source: Field survey results

**Figure 2. Detailed sampling framework.**
dent’s opinions, modifications and changes were incorporated into the survey. The questionnaires were then distributed to the (I) and (NI) sample households.

2.5. Data collection from Small Dams Organization, Islamabad
The data collected from the Small Dams Organization, Islamabad, Pakistan included:

- Adopted PC-1 reports,
- A complete list of small dams in the Pothwar Plateau,
- Dams inflow-outflow data,
- Data on water charges (Aabiana), and
- An index plan of SDO.

2.6. Data review
The data collected through field observations, questionnaires, key informant interviews, formal and informal discussions were collated and reviewed quantitatively and qualitatively. The gathered data were analyzed using the Statistical Package for Social Science (SPSS). The quantitative data were initially documented and then collated in a spreadsheet. General statistical techniques including averages, percentages and standard deviations were obtained. To study the social and economic influence of small dams on (I) and (NI) households in the study area, comparative analyses were performed using the Un-paired sample t-test to evaluate the economics of small dams in the rain-fed region. A t-test was applied for the comparison between (I) and (NI) households in terms of relevant continuous variables (Bacha et al., 2011).

3. Results and discussion

3.1. Social, economic and demographic characteristics of the household heads
As disclosed in Table 4, the majority of heads of households were males (72%). There was a larger number of males as compared to females involved in irrigation activities which confirms the results from the previous research which found that the main occupation of male farmers was rural food production (Afzal & Mohsin, 2017; Ashraf et al., 2004). The age of respondents in the region varied from 18 years to 75 years with an average age of 45 years.

Education is a possible factor in the household’s choice when implementing technologies because it creates awareness and promotes modernism and development. Around 12.6% of all respondents had not attended school and were uneducated, while only 30.4% of all respondents attended up to the middle level. Those who had completed secondary education only comprised 25.3% of the respondents. It was difficult to find specialized graduates in the field. Only 4.3% of farmers had studied at the bachelor level. An interesting point that emerges from Table 4 is the comparable variation in education levels among (I) and (NI) households. While educated farmers are believed to be more aware of technology, utilization and hazards it was found that education level was not a measure of the willingness to participate in irrigation.

It is also observed that 77.9% of the respondents were married. The number of unmarried and widowed households was 18.2% and 4.0% respectively. As indicated in Table 4, the distribution of household size was virtually the same for (I) and (NI) households which was the same result reported by other studies such as (Ashraf et al., 2004, 2007).

3.2. Dam Inflow-outflow
The SDO, Department of Irrigation, Islamabad, supplied inflow and outflow data for the Khasala and Jawa dams from 2013 to 2019. The catchments of the two selected dams have a great spatiotemporal variation in rainfall. The water distributed for irrigation purposes mainly comes from the live storage of the dams. The dam’s administration releases the water according to the requirements of the farmers and is depends on the availability of water. The dam inflows depend entirely on the rainfall pattern in the
Table 4. Respondents’ age, gender, education, marital status and household size

| Characteristics of HHs | Irrigation HHs | Non-Irrigation HHs | Total Sample HHs |
|-----------------------|---------------|-------------------|-----------------|
|                       | No            | No                | No              |
| Age                   |               |                   |                 |
| 10–20 Years           | 4             | 3                 | 7               |
| 20–30                 | 5             | 4                 | 9               |
| 30–40                 | 15            | 8                 | 23              |
| 40–50                 | 148           | 41                | 189             |
| 50–60                 | 12            | 5                 | 17              |
| 60–70                 | 3             | 2                 | 5               |
| 70–80                 | 2             | 1                 | 3               |
| Total                 | 189           | 64                | 253             |

| Gender                |               |                   |                 |
|                       |               |                   |                 |
| Male                  | 135           | 47                | 182             |
| Female                | 54            | 17                | 71              |
| Total                 | 189           | 64                | 253             |

| Education             |               |                   |                 |
|                       |               |                   |                 |
| Illiterate            | 27            | 5                 | 32              |
| Quranic Education     | 11            | -                 | 11              |
| Primary               | 23            | 8                 | 31              |
| Middle                | 53            | 24                | 77              |
| Matric                | 45            | 19                | 64              |
| Intermediate          | 23            | 4                 | 27              |
| Bachelors             | 7             | 4                 | 11              |
| Masters               | -             | -                 | -               |
| Other                 | -             | -                 | -               |
| Total                 | 189           | 64                | 253             |

(Continued)
| Characteristics of HHS | Irrigation HHs | Non-Irrigation HHs | Total Sample HHs |
|------------------------|---------------|-------------------|------------------|
| **Marital status**     |               |                   |                  |
| Married                | 146           | 77.2%             | 197              | 77.9%           |
| Unmarried              | 35            | 18.5%             | 46               | 18.2%           |
| Divorced               | -             | -                 | -                | -               |
| Widowed                | 8             | 4.2%              | 10               | 4.0%            |
| **Total**              | 189           | 100.0%            | 253              | 100.0%          |
| **Household Size**     |               |                   |                  |
| (persons)              |               |                   |                  |
| 1-2                    | -             | -                 | -                | -               |
| 3-4                    | 17            | 9.0%              | 7                | 10.9%           | 24              | 9.5%            |
| 5-6                    | 38            | 20.1%             | 11               | 17.2%           | 49              | 19.4%           |
| 7-8                    | 83            | 43.9%             | 28               | 43.8%           | 111             | 43.9%           |
| >8                     | 51            | 27.0%             | 18               | 28.1%           | 69              | 27.3%           |
| **Total**              | 189           | 100.0%            | 64               | 100.0%          | 253             | 100.0%          |

Source: Field survey results
The Khasala dam was intended to provide 2.75 MCM of water for irrigation and can irrigate 708 ha of land annually. Figure 3. compares the annual inflow and outflow for the Khasala dam for the period 2013–2019. In the period 2013–2019, 57.9 MCM was captured and released for irrigation from the total inflow of 118.7 MCM. The maximum inflow was captured in 2016 and 2017. The Khasala dam also supplies water in the Kharif season when farmer water demand is high. Figure 4. provides the average monthly inflow-outflow at the Khasala dam. The rainfall data that occurred in the region were not available, but existing inflow data demonstrates the monthly rainfall pattern at Khasala dam. Mostly, rainfall occurs during the monsoon season and the extreme inflows in the months of July–September. The peak outflow occurs in July and September. The water distribution channel is closed in times of heavy rainfall across the region. In April, May and June’s demand is higher for water in the Kharif season.

Figure 3. Annual inflow-outflow at Khasala Dam.

Source: Small Dams Organization, Islamabad, Pakistan

Figure 4. Average monthly inflow-outflow at Khasala Dam.

Source: Small Dams Organization, Islamabad, Pakistan

Figure 5. shows the inflows-outflows at the Jawa dam. From 2013 to 2015, the outflow requirement was greater than the inflows due to the lower rainfall in the region and inflated water demands. During the 2013–2015 period, the inflow was 3.8 MCM and the outflow was
9.4 MCM. The maximum outflow was released in 2013 and 2015. From 2016–2019, the inflow level shows a steady increase and the outflow level shows a decreasing trend due to the increase in rainfall and lower water demands. The inflow was 28.2 MCM and outflow was 4.8 MCM. The maximum inflow was captured in 2017 and 2019. Figure 6. presents the average monthly inflows-outflows at the Jawa dam. The outflow was high in all months except July-September. Due to the monsoon season, the rainfall in the same months has been greater. There is a significant contribution of inflow-outflow for irrigation in the monsoon season due to more rainfall. Water requirements are high when there is a minimum or low rainfall that exists in the summer season or the last three months of the year. The Jawa dam was constructed on a perennial stream where it receives a persistent and steady flow of water if limited rainfall occurs in the region.

3.3. Water pricing (Aabiana)
Farmers currently follow the season-oriented valuing system in the vicinity of dams which was implemented by SDO. Before 2003, water pricing was according to the irrigated area and crops grown in the region (Ashraf et al., 2007). The water charges were 1.40 USD per ha and 0.80 USD per ha during the Kharif and Rabi seasons respectively. The Kharif season always cost farmers more
than the Rabi season due to water requirements. From 2008 to 2019, water charges data were obtained from the SDO, Islamabad. It represents the total cost incurred in both seasons annually. Table 5 indicates the water charges that are received annually and increased gradually over time with the irrigated area. The water charges received during 2018–19 were 299 USD and 359 USD at Khasala and Jawa respectively, which were approximately eight and eleven times smaller than the operational and maintenance cost of Khasala and Jawa dams (Table 2). The minimum water charges received were 51 USD in 2004–2005 and the maximum water charges received in 2013–14 were 507 USD from the Khasala dam. Similarly, at the Jawa dam, the minimum water charges received in 2007–08 were 54 USD and the maximum water charges received in 2013–14 were 493 USD. The water charges received from 2004 to 2012 were 790 USD and 981 USD at Khasala and Jawa dams respectively which are low compared to the operational and maintenance costs. However, from 2013–19, the water charges received increased to 1,979 USD and 2,544 USD at Khasala and Jawa dams respectively, which is close to the operational and maintenance costs of the dams. The average water charges collected annually from 2004 to 2019 were 185 USD and 235 USD from both dams. The data clearly shows that farmers are increasing their cultivated lands and receiving more water. The command area covers 506 ha and 323 ha of land with an average of 0.70 USD and 0.95 USD per farmer water cost at Khasala and Jawa dams respectively.

Table 5. Collection of water charges from Khasala and Jawa Dams

| No. of Years | Water Charges (USD/year) | Khasala dam | Jawa dam |
|--------------|--------------------------|-------------|----------|
| 2004–05      |                          | 51          | 93       |
| 2005–06      |                          | 84          | 57       |
| 2006–07      |                          | 52          | 82       |
| 2007–08      |                          | 97          | 54       |
| 2008–09      |                          | 121         | 62       |
| 2009–10      |                          | 116         | 223      |
| 2010–11      |                          | 125         | 191      |
| 2011–12      |                          | 144         | 219      |
| 2012–13      |                          | 186         | 354      |
| 2013–14      |                          | 507         | 493      |
| 2014–15      |                          | 215         | 296      |
| 2015–16      |                          | 235         | 311      |
| 2016–17      |                          | 257         | 373      |
| 2017–18      |                          | 280         | 358      |
| 2018–19      |                          | 299         | 359      |
| Average      |                          | **185**     | **235**  |

Source: Small Dams Organization, Islamabad, Pakistan.

The minimum water pricing is the basic reason for wastage and excessive water consumption. Canal water irrigation is provided to farmers nearly free of charge, i.e., 2.20 USD per ha (0.80 USD for Rabi crops and 1.40 USD for Kharif crops) expressed as water charges. This charge corresponds to the cost of around 4 kg of wheat prevailing in the market. In practical terms, irrigation water is cheap and nearly free in comparison to diesel tube-well water, which costs around 95 USD/ha for wheat. Water prices have not been revised for many decades. The cost of collecting water charges from farmers is greater than the water charges which are received. This has resulted in delayed maintenance of the irrigation systems which exacerbates water losses. Hence, a reasonable water pricing system needs to be implemented (Qureshi & Ashraf, 2019).
3.4. Landholdings of household heads

Abbas et al. (2012), categorized their respondents into three categories i.e., small, medium and large farmers. Farmers with landholdings of less than 5 ha were referred as small farmers, medium-sized farmers own 5 ha but less than 10 ha of land, and farmers with more than 10 ha of land were classified as large farmers. While most farmers at Khasala and Jawa dams have less than 5 ha of land, the survey also found that some farmers have more than 10 ha of land. During the survey, it was also found that some landowners owned their orchards and used dam water to irrigate them. Large farmers also present near the Jawa dam and have tube wells for irrigation. Both landowners and large farmers are well known in the region due to their limited numbers. The land-holdings and cultivated lands of the household heads were evaluated by using an unpaired t-test in SPSS. The null and alternate hypotheses were formulated and then the data was analyzed for the significance level. The drawn hypotheses related to the t-test were:

H₀: d = 0 (There is no difference between the two means)

H₁: d ≠ 0 (There is a significant difference between the two means)

The alternate hypothesis is accepted and the null hypothesis is rejected if the probability value is smaller than the significance value (P < 0.05), similarly, the alternate hypothesis is rejected and the null hypothesis is accepted if the probability value is more than the significance value (P > 0.05).

The outcomes for land-holdings and cultivated lands are shown in Table 6. The statistical values include farmer categories, sample size, standard deviation, population-mean, standard error mean, etc. Two types of farmers were included named as (I) and (NI) farmers. A total of 253 farmers were included in the sample size, 189 farmers with irrigation (I) and 64 farmers without irrigation (NI). The population means to show that the mean of (I) and (NI) farmers are around 2.20 and 1.50 ha, respectively. The difference in the mean is 0.70 ha among the farmers’ land.

Most of the studies are based on a 5% or 0.05 significance level (Senzanje et al., 2008). Column T indicates the calculated or observed value. The number related to the degree of freedom is 251. The significance (2 tails) value indicates the two-sided probability having a numeral value of 0.00 which is smaller than 0.05. Therefore, we accept the alternate hypothesis and reject the null hypothesis because outcomes are significant and the population means are different. The conclusion shows a significant difference among the (I) and (NI) farmers-owned lands. Thus, the unpaired t-test provides a statistically reliable difference among the mean number of (I) farmers with (M = 2.20, S = 0.44) and (NI) with (M = 1.50, S = 0.38), t (251) = 11.44, P = 0.00, α = 0.05.

Similarly, the cultivated lands in Table 6 shows that the population mean of (I) and (NI) farmers are 1.68 and 1.01 ha, respectively. The difference of mean is 0.67 ha. The unpaired t-test provides a statistically dependable difference between the average number of (I) farmers with (M = 1.68, S = 0.50) and (NI) with (M = 1.01, S = 0.56), t (251) = 8.90, P = 0.00, α = 0.05. It is concluded that about 24% and 33% more land could be cultivated in (I) and (NI) areas of Khasala and Jawa dams respectively.

3.5. Cropping pattern

Before these dams were built, the farmers in the region had to rely on rainwater. The main crops were wheat, cereals and vegetables. Wheat and vegetables were the major cash crops of the area and some other crops were also grown. Because of these cash crops, the economic status of the area is better than the other areas present at the same locality (Afzal & Mohsin, 2017; Ashraf et al., 2004). After the dams were constructed, the cultivation pattern changed from crops of low value to high-value crops although wheat is the staple crop that is cultivated near both dams throughout the Rabi season.
| Small Dams | Un-paired Comparison | N  | Mean | Std. Deviation | Std. Error Mean | Mean Difference | Std. Error Difference | T    | Df  | Sig. (2-tailed) |
|------------|----------------------|----|------|---------------|-----------------|----------------|----------------------|------|-----|----------------|
|            | Household Landholdings (ha) |    |      |               |                 |                |                      |      |     |                 |
| Khasala & Jawa | Irrigators            | 189 | 2.20 | 0.44         | 0.03            | 0.70           | 0.06                 | 11.44| 251 | 0.00            |
|              | Non-irrigators        | 64  | 1.50 | 0.38         | 0.05            |                |                      |      |     |                 |
|            | Household Cultivated Landholdings (ha) |    |      |               |                 |                |                      |      |     |                 |
| Khasala & Jawa | Irrigators            | 189 | 1.68 | 0.50         | 0.04            | 0.67           | 0.08                 | 8.90 | 251 | 0.00            |
|              | Non-irrigators        | 64  | 1.01 | 0.56         | 0.07            |                |                      |      |     |                 |

Source: Unpaired t-test results
The farmers cultivate wheat as a staple food, maize for livestock feed or household purposes, vegetables to be sold in the market or own use and (maize, millet, sorghum, taramira (Eruca sativa)) as livestock feed. The vegetables such as round gourd, ash gourd, bottle gourd, bitter gourd, capsicum, okra, cucumber, taro (arbi), zucchini and green chili are grown in the Kharif season. During the Rabi season, vegetables like turnip, coriander, radish, mustard and spinach are grown. Some farmers even grow vegetables during the off-season and earn more income. The major crop in the Rabi season is wheat and is cultivated on each farm. Wheat is rarely put on the market and instead farmers usually prefer to cultivate vegetables because of easy access and good returns from the markets in Rawalpindi and Islamabad.

3.6. Crop yields

The calculated yield of different crops in the areas (I) and (NI) of Khasala and Jawa dams are set out in Table 7. This includes the total crop production (tonnes), the total crop area (ha) and an average yield of crops in tonnes/ha. The average yield of wheat, maize, Rabi vegetables, Kharif vegetables, Rabi and Kharif fodders in the Khasala and Jawa (I) areas were 2.72, 2.20, 6.43, 6.25, 1.60 and 1.60 tonnes/ha compared to 2.36, 1.55, 4.55, 4.35, 1.00 and 1.00 tonnes/ha in the (NI) areas of the Khasala and Jawa dams. Table 7 discloses that irrigation increases wheat yield by 15%, maize yield by 42%, vegetable yield by 41–44% and fodder yield by 60%. The availability of wells in the (NI) region means that these farmers can access timely irrigation, otherwise, their productivity gap would be greater if they were forced to rely on rainfall only. In the (I) area, farmers complain about the water cut-off at the tail-end of the water channel which ultimately leads to low crop production in the same location. Hussain & Hanjra continued to address this issue in 2004 as less water is available, low-quality water is used towards the end of the tail, and crop yields are lower. In ten irrigated areas in Pakistan, an average wheat yield of 1.7 to 3.4 tonnes/ha at the head of the irrigation system, but 1.2 to 2.9 tonnes/ha at the tail of the system were found. In these areas, more than 3.3 tonnes/ha of wheat have been cultivated in rain-fed situations (Ashraf & Mian, 1979; Kazmi & Rosul, 2009), which shows more potential for improving agriculture production. Xie et al. (2014) concluded that small-scale irrigation schemes have the potential to increase agriculture production by at least 50% and eventually the generated income benefits small farmers.

3.7. Income of household heads from agriculture

### Table 7. Yield calculations at Khasala and Jawa Dams by crop

| Seasonal Crop      | Production (tonnes) | Area (ha) | Yield (tonnes/ha) |
|--------------------|---------------------|-----------|-------------------|
|                    | I    | NI    | I    | NI    | I   | NI   |
| Wheat              | 3.02 | 1.72  | 1.11 | 0.73  | 2.72| 2.36 |
| Maize              | 0.44 | 0.28  | 0.20 | 0.18  | 2.20| 1.55 |
| Rabi Vegetables    | 2.57 | 0.91  | 0.40 | 0.20  | 6.43| 4.55 |
| Kharif Vegetables  | 8.19 | 3.26  | 1.31 | 0.75  | 6.25| 4.35 |
| Rabi fodder        | 0.27 | 0.08  | 0.17 | 0.08  | 1.60| 1.00 |
| Kharif fodder      | 0.27 | 0.08  | 0.17 | 0.08  | 1.60| 1.00 |

Source: Field survey results

Irrigated farmer revenue at Khasala and Jawa dams was 2,466 USD as compared to 1,803 USD for (NI) farmers in the Rabi season. Similarly, (I) farmers earn 2,201 USD and (NI) farmers earn 1,508 USD during the Kharif season at Khasala and Jawa dams. Farmers make more profit growing vegetables or cash crops in the Rabi season. Farmers can only produce cash crops or market-oriented crops through a reliable water supply, which reduces poverty in the region. The educational status, assets available, medical services, other facilities and household heads age are the
main elements that contribute to the depth, severity and incidence of poverty (Amin & Afzal, 2018). The depth, severity and incidence of poverty are considerably smaller in agricultural households with access to irrigation water. Poverty is strongly related to educational status, family size, expense on upgraded inputs, effective credit availability and agriculture extension services. Therefore, the availability of irrigation is merely one of the essential services that are needed to raise the agriculture productivity and income of small farmers (Bacha et al., 2011). The farmers in the region are not sure about the exact or confirmed income through agriculture because their income depends on seasonal conditions. In a good season, when the climate favors agriculture there is less pest infestation, the selling prices of the crops in the market are reasonable and in the case of desirable agro-products farmers can achieve an income of more than 6,286 USD/ha per season (Ashraf et al., 2004).

Table 8 provides the statistical values of (I) and (NI) farmer incomes in the Rabi season. Column T indicates the calculated or observed value. The number related to the degree of freedom is 251. The significance (2 tails) value indicates the two-sided probability having a numeral value of 0.00 which is smaller than 0.05. Therefore, we accept the alternate hypothesis and reject the null hypothesis because outcomes are significant and the population means are different. The conclusion shows a significant difference among the incomes of (I) and (NI) farmers. Thus, an unpaired t-test provides a statistically reliable difference among the mean number of (I) farmers with \( M = 2466, \ S = 425.18 \) and (NI) with \( M = 1803, \ S = 310.87 \), \( t \) \( (251) = 11.47, P = 0.00, \alpha = 0.05 \). Similarly, the income of farmers of the Kharif season in Table 8 shows that the population means of farmers (I) and (NI) are 2,201 USD and 1,508 USD respectively. The mean difference between farmers’ incomes is 693 USD. The unpaired t-test provides a statistically dependable difference between the average number of (I) farmers with \( M = 2201, \ S = 379.47 \) and (NI) with \( M = 1508, \ S = 259.99 \), \( t \) \( (251) = 13.56, P = 0.00, \alpha = 0.05 \).

3.8. Livestock
Over the years, the livestock subsector has overtaken the crops subsector as the largest contributor to agricultural added value. It currently contributes 60.56% of the total agricultural volume and 11.69% of GDP with the growth rate at 2.58% in the period 2019–20. The addition of gross value in livestock increased from 8.61 USD billion (2018–19) to 8.82 USD billion (2019–20), an increase of 2.5% as compared to last year. The significance of livestock production can be seen not only as a source of foreign exchange income which contributes about 3.1% of the total exports but also as a source of income to 35%-40% or 8 million of rural households. It ensures food security in the form of proteins from animal production (GOP, 2019–20). Irrigated farmers have a high potential for animal feed from both (I) and (NI) areas because the water is accessible through the irrigation channels and there is no need to sell animals for food (Table 9). Consequently, each (I) household has a large number of comparatively high-value animals and can earn more income from livestock production. Some households produce milk, particularly in the Jawa dam area, and have more livestock than in Khasala. In contrast to (I), (NI) does not have sufficient feed resources. The FGD also pointed out that (NI) cattle are necessarily sold for food consumption due to the lack of sufficient food supply and because it is mainly obtained through rain-fed farming. Consequently, every (NI) household had a small, poor-quality farm animal population. Pack animals play a vital role in the region under rough terrain and unequal division of the area. Peasants use pack animals to move their crops from farmlands to agricultural roads.

3.9. Lack of agricultural extension services
Many promising land and water governance methods have been established over time. Although, these practices have not been able to use by stakeholders, primarily because of (i) the collaboration gap among the research and development organizations, (ii) the little or zero priorities of agricultural extension departments to provide irrigation guidance services, and (iii) the poor performance of extension staff. A group of irrigation development professionals could be formed at provincial agricultural extension departments. These professionals would be familiar with modern irrigation management practices and could introduce these practices to farmers.
Table 8. Farmer's income at Khasala and Jawa Dams by season

| Un-paired Comparison | N   | Mean | Std. Deviation | Std. Error Mean | Mean Difference | Std. Error Difference | T    | Df  | Sig. (2-tailed) |
|----------------------|-----|------|----------------|-----------------|-----------------|------------------------|------|-----|----------------|
| Rabi                 |     |      |                |                 |                 |                        |      |     |                |
| Irrigators           | 189 | 2,466| 425.18         | 30.93           | 663             | 57.79                  | 11.47| 251 | 0.00           |
| Non-irrigators       | 64  | 1,803| 310.87         | 38.86           |                 |                        |      |     |                |
| Kharif               |     |      |                |                 |                 |                        |      |     |                |
| Irrigators           | 189 | 2,201| 379.47         | 27.6            | 693             | 51.09                  | 13.56| 251 | 0.00           |
| Non-irrigators       | 64  | 1,508| 259.99         | 32.49           |                 |                        |      |     |                |

Source: Field survey results
Likewise, collaboration at the top level between agencies for water conservation, provision and supervision of services need to be improved (Qureshi & Ashraf, 2019).

Farmers in the study area have problems with agricultural advisory services. Farmers are not aware of the different crop varieties, cultivation methods, accurate doses of fertilizers, farming practices, spraying of pesticides, the number of applications of irrigation water required and the state's agricultural policy, etc. Mostly, peasants have complaints regarding pesticide sprays distributed in the region. Farmers reported that the agricultural advisers did not provide enough information about their prevailing issues. As a result of less education or a lack of information, farmers continue to rely on the same traditional technologies. Moreover, farmers also reported that the agriculture department rarely meets with farmers to provide information related to agriculture production and their answer to their queries. The agricultural advisory department, namely the Directorate General Agriculture (Extension and Adaptive Research) under AGRI PUNJAB (Agriculture Department, Government of Punjab, Pakistan) is charged with providing agricultural advisory services in Punjab. Their responsibilities include preparation and conducting training through village-level training programs for farmers, setting up field schools for farmers, introducing new technologies, monitoring field inputs and supplying good-quality seeds. There is a great need for agricultural advisory services in the study area to help farmers to achieve greater returns.

Rehman et al. (2013) concluded that improved agronomic practices and water management, updated seed varieties and the dissemination of farming knowledge to farmers through extension services can boost the efficiency of land and water production. Agricultural extension services should motivate farmers to establish associations of water users to adopt advanced irrigation and cultural practices, introduce cash crops, use water effectively and improve resilience in an area.

Table 9. Livestock production at Khasala and Jawa dams

| Livestock | Khasala Dam | Jawa Dam | Total |
|-----------|-------------|----------|-------|
|           | I | NI | I | NI | I | NI |
| Cattle    |   |   |   |   |   |   |
| Ox        | 29 | 10 | 26 | 9 | 55 | 19 |
| Bull      | 55 | 11 | 119 | 31 | 174 | 42 |
| Cow       | 162 | 38 | 234 | 68 | 396 | 106 |
| Buffalo   | 75 | 18 | 169 | 52 | 244 | 70 |
| Calf      | 79 | 19 | 114 | 33 | 193 | 52 |
| Heifer    | 57 | 13 | 82 | 24 | 139 | 37 |
| Pack animals |   |   |   |   |   |   |
| Camel     | - | - | 11 | 2 | 11 | 2 |
| Horse     | 8 | - | 7 | 1 | 15 | 1 |
| Donkey    | 52 | 25 | 25 | 6 | 77 | 31 |
| Mule      | 16 | 8 | 7 | 2 | 23 | 10 |
| Other     |   |   |   |   |   |   |
| Sheep     | - | - | - | - | - | - |
| Goat      | 147 | 30 | 263 | 71 | 410 | 101 |
| Total livestock unit (TLU) | 680 | 172 | 1057 | 299 | 1737 | 471 |
| Average   | 7 | 5 | 12 | 10 | 9 | 7 |

Source: Field survey results
In the study area, it was noted that agriculture extension services were limited and that On-farm Water Management (OFWM) services were also restricted. The SDO, OFWM and agriculture extension departments need to improve their operations including maintenance of water channels to stop disputes among farmers, to implement a proper water rotation system and to introduce advanced agronomic and irrigation practices.

4. Issues of concern in the study area

4.1. Water-diversions
An issue of concern is influential farmers at both dams diverting water when it was not their turn. Peasants at the tail of the irrigation system rarely get enough water for their farms. Afzal and Mohsin (2017) identified the main reason behind underdeveloped irrigated areas was water diversion by influential farmers without permission. These types of practices not only re-direct water from intended recipients but also diminishes the return on the huge investment in water-channel construction. Downstream of these diversions most of the water channels remain dry in the season. This happens because of the absence of weekly inspection programs and unsatisfactory performance of field staff to ensure that water is distributed equally and to monitor the sudden loss of water from channels through proper investigation.

4.2. Insufficient maintenance of channels
If channels are not properly managed, then water overflows the channels due to sand deposition and shrubs. The channels in the study area are damaged at different locations and the cleaning of the channels is not carried out regularly which cuts the water distributed to downstream farmers. Due to inadequate maintenance of the irrigation infrastructure, between 33% and 65% of the water is lost during transit (Kahlown & Kemper, 2004). To achieve long-term returns from the investment in these small dams, proper maintenance and repair of water channels are necessary. Transmission losses in canals and water channels are 25% and 30% respectively. The losses represent around 25%-40% of the water applied on fields. It is estimated that the total irrigation efficiency in the irrigated areas does not exceed 30%. This wasted water could be utilized for agricultural development. Under the supervision of water user associations, a water cleaning and maintenance program must be launched. The water channels must be free of vegetation and silt so that the water can be distributed to the growers throughout the system (Ashraf et al., 2007).

4.3. Inappropriate field channels
Farmers mostly adopt flood irrigation because of the low price and accessibility of water and the limited information on more efficient practices. Farm field water channels are fully earthen, poorly designed and not well constructed. A significant volume of water is lost as a consequence of undulating farmlands.

4.4. Absence of water user associations (WUAs)
Water rights and water rotation systems are not implemented in the study area. There is no water user association to deal with the water channels in the region. Because of the absence of WUAs, we observed too many clashes between the users over the water distribution. Ashraf et al. (2007) emphasized the requirements of supportable WUAs that would sustain their water channels with efficient use of water through enhanced system supervision.

5. Conclusions and policy recommendations
The Small Dams Organization has constructed 55 small dams in the rain-fed region of Pothwar Plateau, Punjab in Pakistan with a further 8 dams are under construction. A study was conducted in the Rawalpindi district of Pothwar Plateau during 2019 to investigate the economic importance of small dams in the region, using Khasala and Jawa dams as the case study.

The study tasks included:
• A broad evaluation based on the performance of small dams in Pothwar Plateau, and an analysis of the economic benefits of small dams to farming communities.
• A comparative analysis of the Khasala and Jawa dams on the Pothwar Plateau to identify the factors that influence agriculture production on irrigated and non-irrigated farms in the area.
• Identification of key issues for potential strategies to improve agriculture production on the Pothwar Plateau.

Data was collected through field observations, questionnaires, key informant interviews, and formal and informal discussions with farmers and was collated and reviewed quantitatively and qualitatively.

It was found that the minimum water pricing is the basic reason for wastage and excessive water consumption. Canal water irrigation is provided to farmers nearly free of charge, i.e., at 2.20 USD per ha (0.80 USD for Rabi crops and 1.40 USD for Kharif crops) expressed as water charges. This charge corresponds to the cost of around 4 kg of wheat prevailing in the market. In practical terms, irrigation water is cheap and nearly free in comparison to diesel tube-well water, which costs around 95 USD/ha for wheat. Water prices have not been revised for many decades. The cost of collecting water charges from farmers is greater than the water charges which are received. This has resulted in delayed maintenance of the irrigation systems which exacerbates water losses. Hence, a reasonable water pricing system needs to be implemented.

It was also found from the survey of farmers of irrigated land and non-irrigated land that irrigation increases wheat yield by 15%, maize yield by 42%, vegetable yield by 41–44% and fodder yield by 60%. The availability of wells on non-irrigated farms means that these farmers could access timely irrigation, otherwise, their productivity gap would be greater if they were forced to rely on rainfall only.

It was also found that influential farmers at both dams were diverting water when it was not their turn. Peasants at the tail of the irrigation system rarely get enough water for their farms. These diversions not only re-direct water from intended recipients but also diminishes the return on the huge investment in water-channel construction.

If channels are not properly managed, then water overflows the channels due to sand deposition and vegetation. The channels in the study area were found to be damaged at different locations and the cleaning of the channels is not carried out regularly which cuts the water distributed to downstream farmers. Transmission losses in canals and water channels represent around 25%-40% of the water applied on fields. It was estimated that the total irrigation efficiency in the irrigated areas does not exceed 30%.

It was also found that water rights and water rotation systems are not implemented in the study area. There is no water user association to deal with the water channels in the region. Because of the absence of a water-user association, too many clashes were observed between users over the water distribution.

It was concluded that the following strategies should be implemented to enhance agriculture production and efficient use of water resources:

(1) An influential public awareness program should be implemented through media and the extension division of the provincial Department of Agriculture. The awareness campaign must include saving water during domestic and other uses;
(2) There needs to be a water-rotation system (warabandi) and regular surveys to maintain channels;
(3) The consolidation of fragmented holdings in rain-fed areas helps the farmers to manage their lands more efficiently with cropping patterns switched to drought-resistant crops having less water requirements as well as alternate farming systems;

(4) The pricing system for water consumption for domestic, industrial and agricultural purposes should be revised and efficiently applied;

(5) Immediate actions should be carried out to reduce wastage of water from water channels and on the farmlands; and

(6) Collaboration needs to be improved at the planning or policy levels between the authorities responsible for water conservation, water availability and water governance on the one hand and water users on the other. Only by the collaborative effort of water user associations, SDO, and the agriculture extension department will farmers-livelihood in the region be improved.

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