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# Climate Change Impact on Groundwater-Based Livelihood in Soan River Basin of Pakistan (South Asia) Based on the Perception of Local Farmers

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**Abstract:** Based on the perceptions of the local farmers, this study aims to assess the effects of socioeconomic factors and climatic change on the groundwater livelihood system, with a particular focus on in situ Persian wheels/dug wells. Farmers' perceptions of climate change and how it is affecting their way of life in the Soan River Basin have also been evaluated to determine the most appropriate adaptive interventions. Information and literature about dug wells was unavailable, which stressed the need to carry out this survey. A structured close-ended questionnaire was designed and administered with as much quantitative data as possible. Random sampling opted for a 5 km buffer zone across the Soan River and its tributaries. Union councils having more than 50% of their area lying in the buffer zone were surveyed, and data was collected. Fifty UCs fell within this criterion, and six dug wells from each Union Council were surveyed. The results of our survey collecting local farmer's perceptions determined that about 70% of respondents agreed about climate change in the Soan Basin of Pakistan, and 62% of farmers reported that climate change severely impacted their livelihood by affecting agricultural productivity and water availability. Ninety-two percent reported summer becoming hot, 72% highlighted that winters are becoming less cold, and 96% reported that average annual rainfall has decreased compared to 10 years before. About 72% of respondents indicated that available water in their dug wells had decreased, and 80% of respondents explained that their crop yield had decreased compared to 10 years before. Sixty percent preferred drip and 35% sprinkler irrigation as efficient water management practices to cope with water shortages. Ninety-five percent of farmers were ready to use solar pumps for irrigation to tame high pumping costs. The study recommends integrating solar pumping with drip and sprinkler irrigation systems to enhance farmers' cropped area and productivity. These vulnerable farmers can enhance their resilience and profitability by adopting high-value agriculture (tunnel farming, off-season vegetables, etc.) instead of conventional crops.

**Keywords:** climate change; groundwater utilization; local farmers' perception; irrigation technologies; Soan River

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**Citation:** Ahmad, B.; Nadeem, M.U.; Liu, T.; Asif, M.; Rizvi, F.F.; Kamran, A.; Virk, Z.T.; Jamil, M.K.; Mustafa, N.; Saeed, S.; et al. Climate Change Impact on Groundwater-Based Livelihood in Soan River Basin of Pakistan (South Asia) Based on the Perception of Local Farmers. *Water* **2023**, *15*, 1287. https://doi.org/10.3390/w15071287

Academic Editors: William Frederick Ritter and Nektarios N. Kourgialas

Received: 2 March 2023
Revised: 21 March 2023
Accepted: 23 March 2023
Published: 24 March 2023

## 1. Introduction

The climate of Pakistan is characterized by hot summers and cold winters and lies in the arid zone. Due to scanty rainfall, different irrigation systems have been used for centuries to combat this aridity issue. The irrigation systems and their patterns vary from region to region due to geographical, social, economic, and political factors [1–4]. Before the Persian wheel method, irrigation was inefficient in south Asia. The use of the Persian Wheel for irrigation has been practiced since the seventh century (A.D.) in South Asia. Canals and Persian wheels or dug wells are the traditional and the very first methods of irrigation in South Asia. Canals have been constructed in the plain landscape with substantial public investments [5,6], and wells have been dug by individual farmers in undulating topography.

Dug wells draw water from a natural or artificial aquifer that is either near sand dams or around ponds but not located inside a riverbed. It can include wells far from a river or wells receiving water from shallow aquifers hydraulically connected to the river. The traditional method of obtaining groundwater in rural areas of the developing world is through hand-dug wells [7]. With knowledge about the shallow water table, a hole is dug for water extraction using pumps or buckets. Owing to suitable geological conditions, dug wells provide a low-tech solution to the challenges of rural water supply and can provide a viable alternative to unhygienic, unprotected water sources [8]. The depth and diameter are the main parameters to be considered during design, impacting the dug wells' performance and efficiency. Dug wells are shallow wells, usually consisting of a depth of several meters or less than 15 m.

Throughout history, dug wells have been constructed by hand, especially before World War II [9,10]. The rate of pumping of the wells changes according to the design of the dug wells, especially with the change in well penetration depth. It implies that in a given aquifer, the yield of the dug wells is less associated with the well-wetted perimeter compared to the hydraulic gradient between the well-water surfaces and surrounding groundwater [10]. Hence, to receive the maximum yield from the dug wells, good penetration depth relating to aquifer characteristics in design parameters should be considered.

In South Asia, dug wells are again in practice with some modifications (GOI, 1962; NAS, 1974). At this time, the dug well has been deepened by digging the formation with the help of the rock drills. In Pakistan, over the last 25 years, dug wells have been improved by integrating different pumps. Such driven sources are diesel or electric, and inexpensive centrifugal or turbine pumps are installed around 1–2 m above the water level. These pumps are locally manufactured in Pakistan and many neighboring countries and are readily available. In the rainfed areas of Pakistan, people are still interested in dug wells. The main reason for using dug wells so far is inexpensive and easy construction, which does not require skilled labor and extensive work. Dug wells are the source of reliable, safe, and hygienic water and involve the transformation of crude holes in the ground into clean water sources [11].

The dug wells in Pakistan, India, Sri Lanka, and Nepal contribute significantly to the rural development of arid areas in South Asia. In Pakistan, about 4600 dug wells have been established with the collaboration and support of ABAD to provide water facilities to rural communities to raise crop productivity. Many dug wells in small villages and towns of Pakistan are constructed and worked for a long time and are considered one of the interventions in the village development program. As reported by Dane in 1898, about 5864 Persian wheels are recorded only in the Swabi area of Pakistan. Most of these dug wells are located along the length of the Indus riverbank, where the water table is higher than the remaining areas [12]. According to the progress report of the ABAD project [13], it has been reviewed that the dug wells are the most promising interventions in the target areas. In Madya Pradesh, India, based on a research survey (NBARD, 1994), dug wells are considered one of the efficient interventions of the integrated rural development program, which helped the rural communities to improve their livelihoods. In Sri Lanka, the Agrowell program was targeted and aimed to support rural communities by promoting dug-well sustainability and development in intermediate and dry regions of the country. This project intended to give profitability to the cropping pattern through the sustainability of dug wells [14].

With the development of more advanced and efficient technology for tube wells, dug wells that have been used for thousands of years are being replaced with tube wells [15]. Such dug wells are no longer constructed due to associated contamination issues, and extraordinary human effort is involved in their construction. With time, old traditional dug wells have been replaced with bore wells.

Currently, the main limitations while using modified traditional Persian wheels or dug wells are high construction cost, maintenance, the fact that they are time-consuming, and low water yield capacity [16–18]. The capacity of the Persian wheel is very low for lifting water from a deep aquifer. Back in time, the operation costs of wheels were minimal, but with time and more modifications, their operational costs are becoming high with low-performance capacity. The continued use of Persian wheels in rural areas is due to preconstructed Persian wheels, lack of technology, inherited traditions affiliated with an agro-pastoralist community (e.g., animals as a symbol of pride, competition), etc. Lately, it has been used in the form of sustainability rather than perseverance [19–21]. The state of agriculture has been subsistence in rainfed areas of dug-wells practice. Dug wells play an essential role in the irrigation sustainability of the regions. With time, there has been a significant change in the agriculture and irrigation system through modernization and mechanization. Likewise, the traditional use of dug wells is being replaced with new, advanced electric- and diesel-operated generators rather than the use of animals as driving forces, and the agro-pastoralist community is also adapting to new technologies [22,23]. Moreover, dug wells are the traditional and sustainable water source in rural areas of many developing countries, including Pakistan. Due to climate change, the quantity and quality of water in dug wells have changed over the last few decades in various regions of the world. For example, in Pakistan, many farmers from the Potohar region observe a decrease in water quality and quantity from dug wells. Based on the literature, an assessment of the water quality of dug wells in Indonesia, including the physical, chemical, and biological factors, or standards of water changes due to climate change, has found that water of dug wells is declared unfit for human use [24]. Water quality and quantity must be tested to maintain the sustainability of dug wells because the dug-well water should not be used directly for drinking, laundry, bathing, and other domestic purposes [11]. A bacteriological assessment of the water quality of dug wells in Bangladesh has declared that the drinking water from dug wells is likely to provide health risks.

Agriculture is the primary source of livelihood for most communities, which are usually dependent on rainwater in rainfed areas, e.g., the Potohar region of Pakistan. Dug wells have been the only water source for many areas of the Potohar region for ages. When water from rains is insufficient to support the crops' productivity, these dug wells are the only ray of hope for these vulnerable farming communities. Due to erratic patterns and changing rainfall patterns, the productivity of the dug wells is declining. Due to technological advances, youngsters feel embarrassed and are reluctant to pull water using animals, including donkeys, through dug wells. Though still operational in some places, these are now considered old-fashioned and outdated options because pumping water through them is uneconomical. Earlier, farmers used them for irrigation of their crops and domestic needs, but now they have almost abandoned this system.

Previously, females used water from dug wells for domestic, animal, and vegetable production, but they have almost abandoned this activity as vegetables are available in every small town. Another aggravating factor is climate change [25–29] (changing rainfall patterns, droughts, etc.), which has caused a lowering of groundwater, affecting recharge rate and yield, ultimately affecting farmers' livelihood by decreasing farm productivity. Using this limited available water resource effectively and efficiently by integrating high-value off-season crops is a promising solution to these problems. This fragile but highly economically valued system got significantly less focus from public investment and researchers' attention in order to modernize these systems. It is an inefficient system that has been prevalent for decades and demands an overall upgrade. Sustainability in subsistence agriculture practices is a rare phenomenon without the help of modern technologies [30]. In Pakistan, water uplifting through the Persian wheel is quite an old method, which needs to be more advanced and economically feasible. So, it is essential to modernize this system to restore livelihood and enhance agriculture productivity on a sustainable basis of dug wells.

Much literature has documented dug wells' potential, scope, and status in many regions, but there is a dearth of literature and knowledge available on the socio-economic significance of these dug wells and associated livelihoods. No such study has been documented showing the climate change impacts on dug wells associated with the livelihoods of farmers of the rainfed area of Pakistan. Databases regarding the availability of dug wells, resource utilization, and water table fluctuation, which is of prime importance for devising adaptation packages and rehabilitation measures for improving these wells, are not available. The current study focuses on discovering the factors affecting the farmers' dug-well yields and associated livelihoods in the face of climate change in the Soan Basin (Potohar region) of Pakistan to devise a suite of viable technologies.

The present study was carried out under the HI-AWARE project to determine the dependence of the farming communities on the traditional dug-well/Persian wheel system for their livelihood. The most crucial objective of the study was to assess climate change impacts on the livelihoods of communities relying on dug wells, resource use, constraints, and opportunities to identify strategies for adaptive interventions and to inform national policymakers and public institutions about the variations in livelihoods across communities that depend on dug wells in order to develop adoption strategies and programs (solar water pumping, high efficiency irrigation system, and advanced agriculture methods). This study provided a basis for the Pakistan Agriculture Research Council to initiate a pilot of climate-smart interventions at selected dug wells for improving agricultural productivity and resilience. Regarding the effects of climate change on farmers' livelihoods dependent on dug wells, the following factors were highly relevant:

- What are these wells' socio-economic significances in the selected study areas?
- What is the behavior of the water table in the region?
- What is the climate change impact on dug wells and associated livelihoods?
- What adaptation and rehabilitation measures can be taken to improve these wells?

Therefore, a survey is conducted to the collect the perceptions of local farmers throughout the Soan River Basin of Pakistan. Conducting a survey to collect farmers' perceptions in response to climate change impacting their livelihoods is important for several reasons:

- Understanding farmers' perspectives: Farmers are on the front lines of climate change, and their perceptions and experiences can provide important insights into the impacts of climate change on agriculture. By conducting a survey, we can better understand their perspectives on climate change, how they perceive its impacts on their livelihoods, and what measures they are taking to adapt to these changes.
- Identifying vulnerabilities and adaptation strategies: Farmers are often the most vulnerable to the impacts of climate change, such as changes in precipitation patterns, increased temperatures, and extreme weather events. By collecting data through a survey, we can identify the specific vulnerabilities faced by farmers and the adaptation strategies they are using to cope with these challenges.
- Informing policy and decision making: The insights gained from a survey can be used to inform policy and decision making related to climate change adaptation in the agriculture sector. For example, policymakers can use survey data to identify the areas where farmers need the most support and to develop targeted interventions that address the specific challenges faced by farmers.
- Tracking changes over time: By conducting a survey at regular intervals, we can track changes in farmers' perceptions and adaptation strategies over time. This can help to identify trends and patterns and to evaluate the effectiveness of interventions and policies aimed at addressing the impacts of climate change on agriculture.

Overall, conducting a survey of farmers' perceptions in response to climate change is an important tool for understanding the impacts of climate change on agriculture and developing effective strategies to support farmers in adapting to these changes. The results of this study will help policymakers and other stakeholders to reduce vulnerability of agricultural communities to the consequences of climate change by highlighting the socio-economic and sociocultural features of local residents in response to changing climate.

## 2. Materials and Methods

### 2.1. Study Areas

Soan Basin is located in the Potohar Plateau, one of Pakistan's highly vulnerable zones as far as climate change is concerned. The Soan River area contains a continental (32–34° N and 72–73° E), subtropical climate with hot summers and moderately cold winters. December has the lowest mean temperature (9 °C), while June has the highest mean temperature (31 °C). In the lowlands, the average annual rainfall is 400 mm, whereas in hilly areas, it is about 1710 mm, with roughly two thirds of the rainfall falling during the monsoon season (June–September). The Soan Basin is one of the significant hydrological units of the Potohar Plateau, having a drainage area of about 11,085 km$^2$, which is nearly 55% of the total Potohar area. The area consists of the districts of Rawalpindi, Islamabad, and parts of Chakwal and Attock having semiarid to subhumid climates with cold winters and hot summers, excluding Murree, which has a humid climate. The average annual rainfall in the area varies from 1800 mm in Murree in the north and 750 mm in Talagang in the south part of the basin. The Soan Basin has an elevation range of 265 to 2274 m and 6842 km$^2$ in size. The average precipitation that the basin receives is 1465 mm of rain annually, with a range of 8 to 18 °C for the mean annual temperature. In the north-eastern (NE) parts of the area, the temperature drops below the freezing point from December to February, whereas in the western parts, the temperature is relatively high in the summer. However, the winter is relatively mild [31]. The salient features of study area are illustrated in Figure 1, and the geographical location of in situ dug wells (sample points) is showed in Figure 2.

The Soan Basin comprises mainly a vast plateau, generally at 300–450 MASL, and a high mountainous belt in the northeast and west, rising to 2200 MASL, having ridges and narrow intervening valleys. The mountains have steep to moderately steep slopes, while the plateau has level to undulating topography, with isolated gullies here and there. The area is subject to active water erosion, and, in places, streams have cut very deep gullies and gorges through the land and rock strata. These rivers and other hill torrents have cut deep valleys and are of little use for irrigation. Agriculture is thus almost entirely dependent on rainfall, and a small area is under irrigation by rainwater harvesting in small and mini dams built across the streams [32].

Local inhabitants of the area consist of 60% rural population mainly deriving their livelihood from agriculture. The main crops of the area include maize (*Zea mays*), barley (*Hordeum vulgare*), masoor (*Lens culinaris*), wheat (*Triticum aestivum*), moong (*Vigna radiate*), sorghum (*Sorghum bicolor*), and fruits such as guava (*Psidium guajava*), olive (*Olea Europaea*), and citrus (*Citrus aurantium*). Water is one of the most limiting factors affecting crop yield (Ashraf, 2004). A monocropping system is practiced in the area, and the existing cropping patterns are wheat-fallow-wheat, wheat-pulses-fallow, and wheat-millet-fallow [33]. Two seasonal rivers, Soan and Haro, flow from the east to the west and flow into the Indus after crossing the region in the north (NRD briefings, 2010). Groundwater occurrence in the area is controlled by its climatic and geological conditions. Precipitation is the ultimate source of groundwater [34]. The rainfed environment has limitations for crop management, but regardless of this issue, the area has enormous potential for crop production to combat food security threats by climate change [3]. The yield and cropping intensity vary significantly year by year depending upon rainfall and soil moisture availability, which gives farmers a tough time when crops demand water [3,34]. To meet water needs, farmers have indigenously developed a system of animal-driven dug wells to irrigate crops.

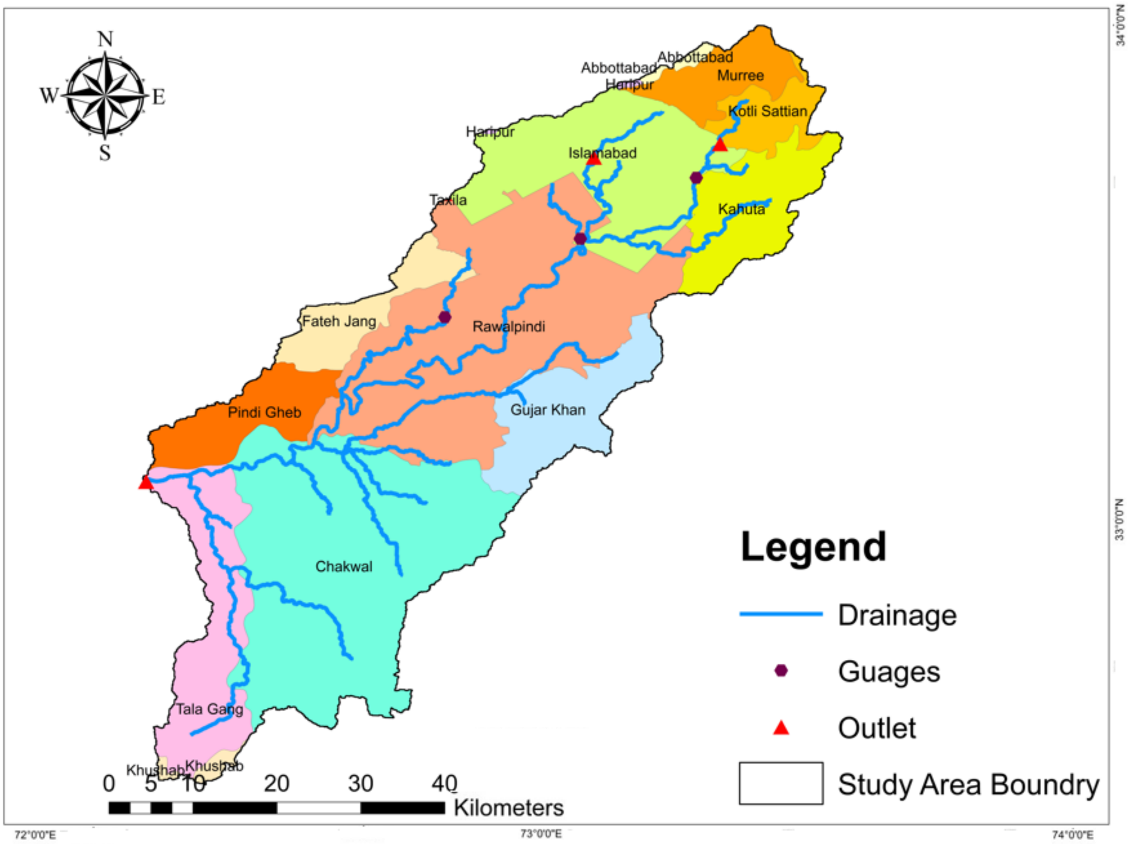


**Figure 1.** Map of the study area.

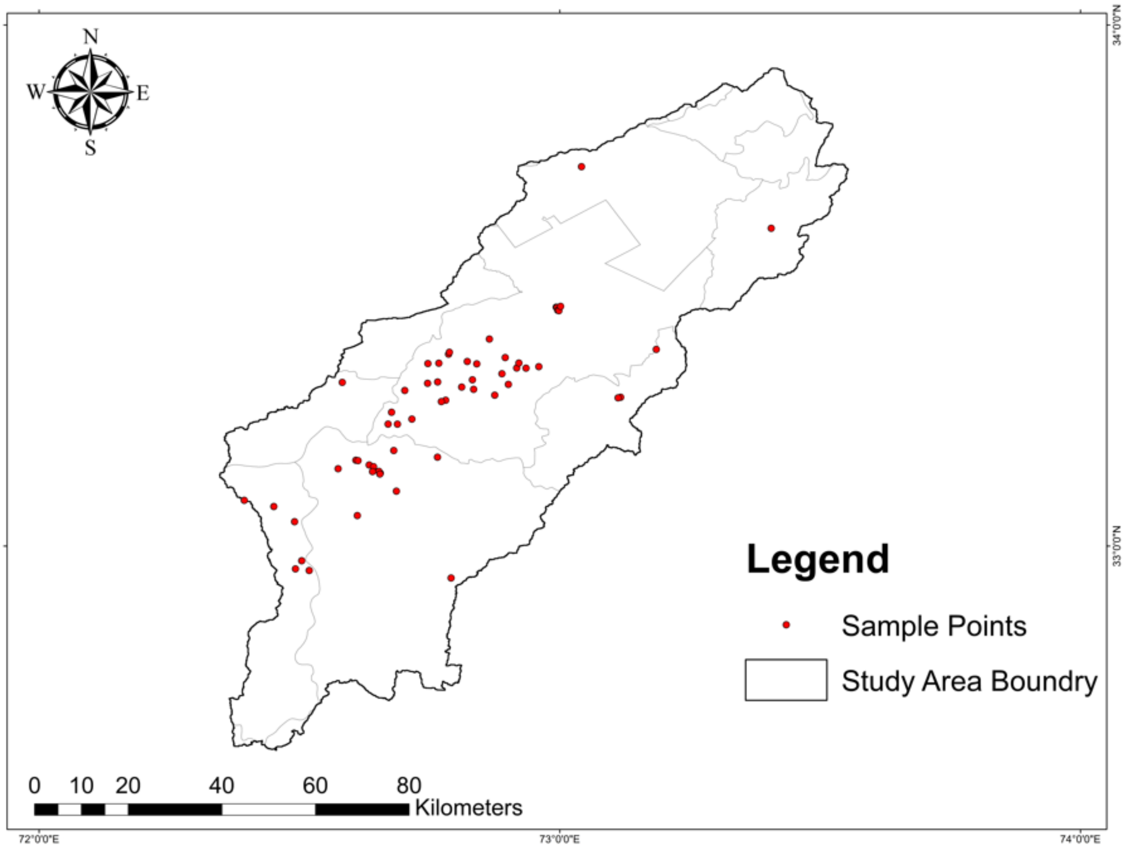


**Figure 2.** Geographical locations of dug wells' sample points.

## 2.2. Climatic Conditions

A few questions regarding people's perception of climate change and its impact on the likelihood of dug wells were asked during the questionnaire-based survey in the current study.

## 2.3. Research Design

The study combines a quantitative assessment of dug-well-dependent farmers' perception of climate change, socio-economic and livelihood vulnerabilities, critical climate stress moments, and response/adaptation measures. Furthermore, for the collection of perceptions, there are 101 union councils (UC) in the study region overall. Three hundred dug wells were going to be surveyed after a 5 km buffer zone was put in place on both sides of the Soan River and its tributaries, as shown in Figure 3. Union councils having more than 50% of their area lying in the buffer zone were surveyed, and data were collected. Fifty UCs fell within this criterion, and six dug wells from each Union Council were surveyed. However, only 70 dug wells could be properly assessed because of numerous limitations (limitation of project funding, human power, limited access to technology, hesitancy to speak up, social desirability bias, lack of farmers, majority of the wells were not in functioning order, and farmer awareness). In order to operationalize the quantitative assessment, a paper-based survey was conducted with about 70 households across different union councils. We attempted to survey all the study area's districts in order to gather accurate data on climate change from local farmers. However, the sample size is still small in number, but Vasileiou et al. [35] concluded that if the population is relatively homogeneous, meaning that there is little variation between individuals, a smaller sample size may be sufficient to accurately represent the population. Figure 4 illustrates the layout of research design. Questionnaire sheet which is used to collect farmer's perception is shown in Table S1 (of supplementary material).

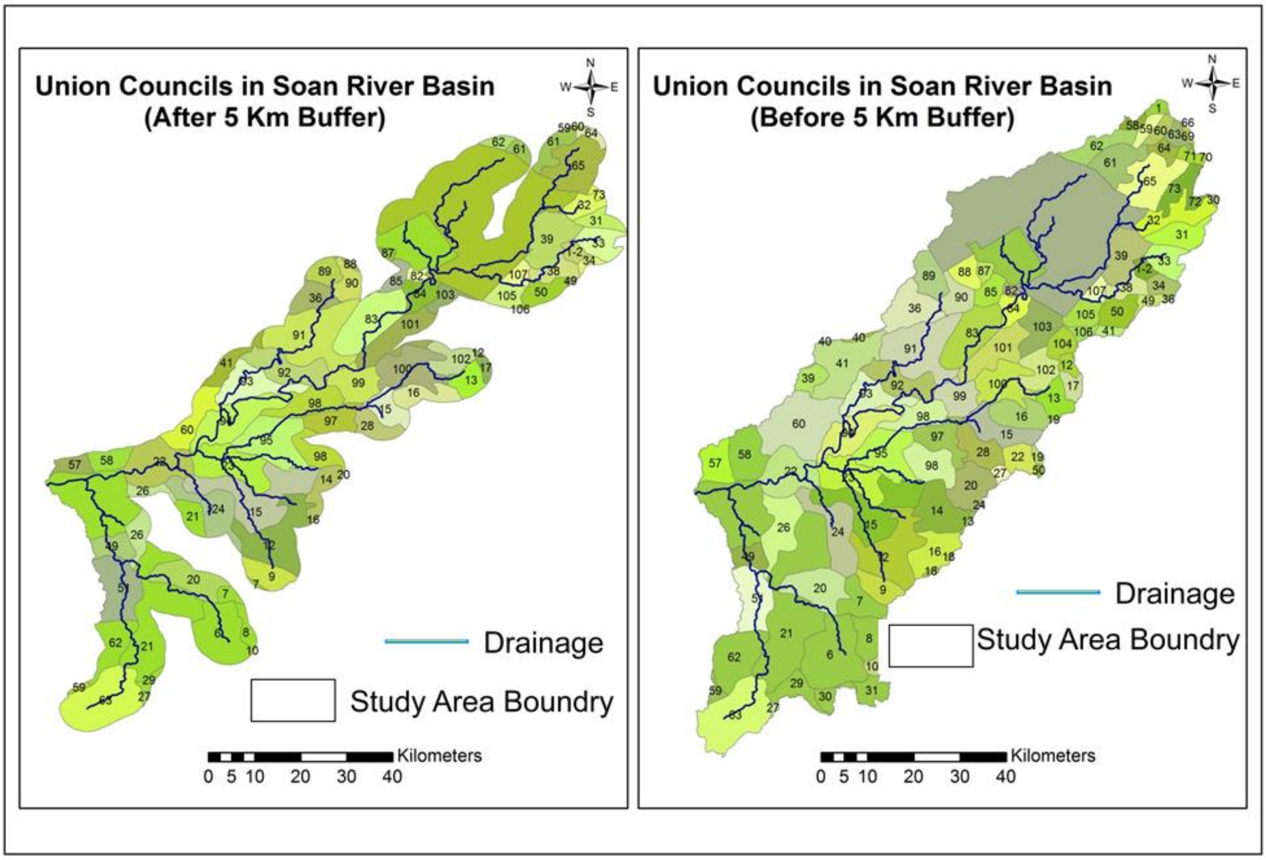


**Figure 3.** Union councils with and without buffer zone.

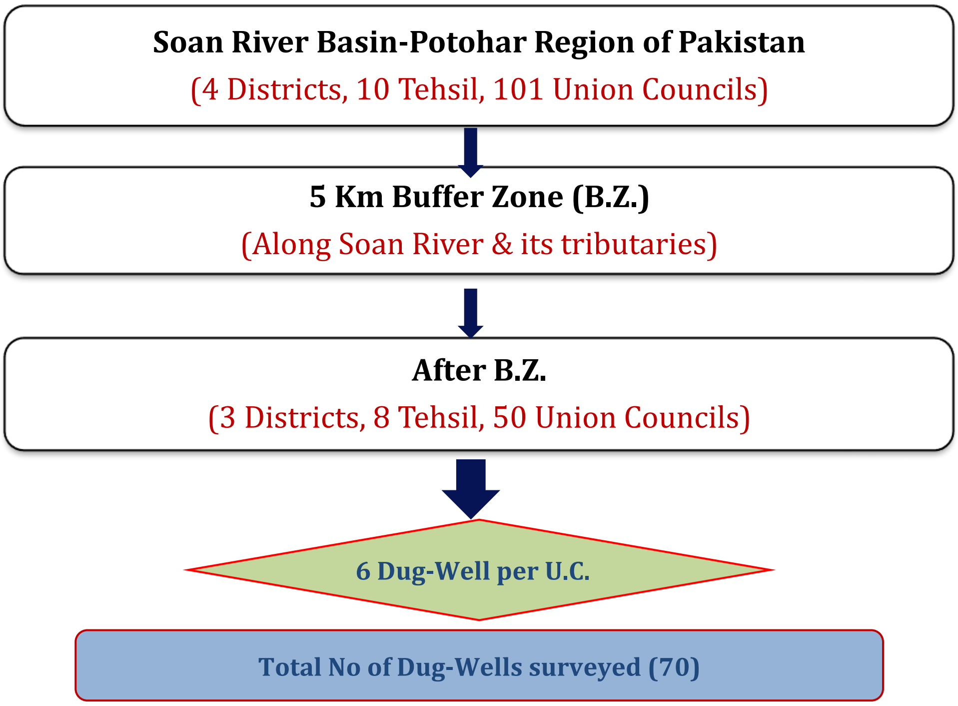


**Figure 4.** Conceptual flow chart of study.

### 2.4. Criteria for Selection of UCs and Numbers of Dug Wells

Soan Basin consists of four districts, ten tehsils, and 101 UCs, as shown in Figure 4. This assessment was made within a 5 km buffer zone along both sides of the Soan River and its tributaries, as these areas may have shallow water tables appropriate for agriculture owing to recharge from the river. Fifty UCs have more than 50% area within a 5 km buffer zone of rivers and tributaries, as shown in Appendix A, Table A1, which fell within this criterion. Six randomly selected dug wells per UC were surveyed through a close-ended paper questionnaire that entails farmers' interviews, as shown in Figure 3. The survey focused on farmers' perceptions of climate change and its impacts on dug-well productivity, livelihood dependence on their dug-well irrigation system, real issues on traditional animal-driven dug-well-based irrigation systems, and how public institutions can support improved agriculture and efficient water management. Union councils having more than 50% of their area lying in the buffer zone were surveyed, and data were collected. Table A1 highlights the tehsil-wise union councils in the buffer zone.

### 2.5. Data Collection Tools

A standardized questionnaire was prepared to collect data from households. Enumerators were trained; the questionnaire was pretested in all strata to make necessary corrections to ensure consistency of questions and smooth data collection. Enumerators were guided to select the respondents, preferably in households with people over 25 years of age, because the questionnaire contains many questions about perceptions of past events, and they were required to recall the situation 5 to 10 years ago. Secondly, if both female and male members (>25 years) were present in the household, it was preferable to interview female members (if involved in agriculture, livestock, and other livelihood activities) to allow their representation in the sampling.

### 2.6. Hydrologic Assessment

Dug-well design-related parameters such as nature of construction (Kacha/Pacca), diameter, depth of well, current water level, etc., were measured on site for each surveyed dug well. These dug wells were mapped through GPS coordinates for future monitoring. Dug-well water potential parameters such as current water level, and minimum and maximum water level in the well were assessed by farmers who included recharge and discharge rate.

## 3. Results and Discussion

### 3.1. Socioeconomic Characteristics in Study Areas

Most households in the study area have a patriarchal structure. It is found that these regions are highly variable in many contexts. Socio-economic indicators of education, agriculture, income, women's empowerment, health, access to basic facilities, and livelihood diversification are highly variable in the Indus Basin.

In Soan Basin, around 80% of households are dependent on agriculture and livestock for their livelihood, as shown in Table 1. The literacy rate is 78% in our survey results. The major crops grown are wheat and maize. People quickly access health, education, electricity, roads, transport facilities, etc.

**Table 1.** Socio-economic features.

| Parameters | Responses % |
|---|---|
| **Household (HH) Head (%)** | |
| Male | 96 |
| Female | 4 |
| **Education status of the HH head (%)** | |
| Illiterate | 10 |
| Primary | 12 |
| Middle | 27 |
| Matriculation | 33 |
| Intermediate | 2 |
| Graduation | 2 |
| Master | 2 |
| Any other | |
| **Number of dependents (%)** | |
| 1 | |
| 2 | 15 |
| 3 | 4 |
| 4 | 8 |
| 5 or more | 73 |

Around 35% of households have access to essential services provided by the government. Women's empowerment is relatively low because of low literacy and social rituals. A significant source of income for farmers (60%) is agriculture, and 100% of respondents' income directly depends upon the dug wells' productivity. About 33% reported a decrease and a 28% an increase in the income from dug wells in the last five years (Table 2).

**Table 2.** Household income.

| Parameters | Responses % |
|---|---|
| **Income Sources** | |
| Agriculture | 60 |
| Nonagriculture | 7 |
| Livestock | 4 |
| Fisheries | 0 |
| Others | 29 |
| **Was there an increase or decrease in the income from (SOURCE) in last five years?** | |
| Increase | 28 |
| Decrease | 33 |
| Fluctuating | 14 |
| No change | 25 |
| **Is your income directly related/dependent upon dug well's productivity?** | |
| Yes | 100 |
| No | |

About 85% of the respondents are landowners, and the rest have land on lease. About 64% of people own less than 5 acres of agricultural land, 30% have an area in the range of 5–10 acres, and the rest have an area greater than 10 acres, as shown in Table 3. Regarding the land size under irrigation, only 6% of respondents have land less than 5 acres, 38% land in the range of 3–10 acres, and 56% have a land size greater than 10 acres. While asking about the fallow land, 38% of people reported an area of less than 1 acre of fallow land, while the same percentage of people reported an area of fallow land of 1–2 acres, and 24% of people claimed the fallow land to be more than 2 acres. The reason for leaving the land fallow is mainly the unavailability of water for agriculture or irrigation purposes, as 88% of the respondents highlighted. According to the responses, 60% of crops are grown on the study area land, 30% of the land consists of vegetables, and 10% of mixed cultivation is practiced. Seventy-one percent of the people have not leveled their land for agricultural purposes.

**Table 3.** Agricultural and other livelihood opportunities.

| Parameters | % Reponses |
|---|---|
| **Status in agricultural landholding** | |
| Landowner | 85 |
| Borrower/tenants/lease | 15 |
| Any other | |
| Size of owned agricultural land (acres) | |
| Less than 5 | 64 |
| 5–10 | 30 |
| Greater than 10 | 6 |
| **What is the status of your land piece?** | |
| One piece | 100 |
| Patches | |
| **Size of your dug-well-dependent land?** | |
| Less than 5 | 64 |
| 5–10 | 30 |
| Greater than 10 | 6 |
| **Size of land under dug-well irrigation?** | |
| Less than 1 acre | 6 |
| Between 1–3 acres | 38 |
| Greater than 3 acres | 56 |
| **How much land left fallow?** | |
| Less than 1 acre | 38 |
| 1.0–2.0 acres | 38 |
| Greater than 2 acres | 24 |
| **Reason for leaving it fallow?** | |
| Not enough water for irrigation | 88 |
| Non fertile land/soil conditions | |
| Uncultivable due to slop | |
| Labor shortage | |
| Other (specify) | 12 |
| **Types of crops grown?** | |
| Crops | 60 |
| Vegetables | 30 |
| Mix (crops and vegetables) | 10 |
| **Have you leveled land?** | |
| Leveled | 29 |
| Not leveled | 71 |

### *3.2. Dug Well Type and Characteristics*

Dug wells are the traditional and still the most widespread practice for obtaining groundwater for domestic, irrigation, and agricultural purposes. Considering the availability, nature, and type of the dug wells, respondents were asked some questions about the characteristics of dug wells operating in their areas. About 96% of the dug wells are of Pucca (lines) type, and the rest are of Kucha (earthen) type, as shown in Table 4. A significant percentage of 97% of dug wells are operational. Considering the design parameters of the dug well, 6% of dug wells have diameters of 0–5 ft, 69% have a diameter between the range of 5–10 ft, and 25% are of 10–15 ft diameter. According to the respondents, 25% claimed that the depth of the dug well varies between 0–25 ft from the ground surface, 65% of the dug wells have a depth that varies between 25–50 ft, and 10% stated a depth of 50–100 ft. About 65% of the wells have current water table depths of the water tble from 0–25 ft from the ground surface, and 35% have 25–50 ft. Based on the survey and questions, 34% of respondents reported that the water of the dug wells is being utilized for drinking purposes and 4% for irrigation, and 62% for people claimed for both purposes.

**Table 4.** Dug well Types and Characterizations.

| Parameters | % Responses |
|---|---|
| **Construction type of dug well** | |
| Pucca | 96 |
| Kacha | 4 |
| **Status of dug-well operations** | |
| Operational | 97 |
| Nonoperational | 3 |
| **Diameter (ft) of the dug well** | |
| 0–5 | 6 |
| 5–10 | 69 |
| 10–15 | 25 |
| **Total depth (ft) of the well from the ground surface** | |
| 0–25 | 25 |
| 25–50 | 65 |
| 50–75 | 10 |
| 75–100 | 0 |
| 100–150 | |
| **Current depth of water table (DW) in feet from the ground** | |
| 0–25 | 65 |
| 25–50 | 35 |
| 50–75 | 0 |
| 75–100 | |
| 100–150 | |
| **Purpose: How this well water is being utilized** | |
| Irrigation | 4 |
| Drinking | 34 |
| Both | 62 |

### *3.3. Water-Lifting System for the Dug Well*

Animal-driven water lifting through the traditional dug well is the oldest method practiced in South Asia. Electrical- and diesel-operated dug wells are also in operation in the study area. The present study asked the people about the traditional Persian wheel and water lifting system. Based on the survey, 59% of the dug wells in the Soan Basin are of traditional Persian wheel type, 24% responded regarding the electrically operated pumps, and the rest are diesel operated, as shown in Table 5. The farmers use donkeys and bullocks to operate the dug well; donkeys operate 82% of the dug wells, 9% are operated by bullocks, and the rest using both systems. Considering the efficiency of the water-lifting system for the dug well, 3% of the respondents responded as better, 42% reported normal, 36% reported poor, and 18% as very poor. The water table from the traditional Persian wheel is 10–20 ft, as reported by 31% of people, and 69% of dug wells have a depth of more than 20 ft. Sixty-five percent of the dug wells are empty for 0–3 h of irrigation operation, 18% for 3–6 h and 17% of wells become empty for more than 6 h of irrigation operation per day. About 91% of respondents observed an increase in recharge rate during the rainy season, and the rest observed decreasing rate. Sixty-two percent of respondents observed a decrease in the discharge rate from the dug well; in the last ten years, 9% of people observed an increased rate, and the rest noticed no change in the discharge rate. About 95% of the respondents claimed this traditional Persian wheel system for dug well is sustainable for their livelihood. For improvement in the dug wells' system operation, 50% of people showed interest in the solar pumping system, 10% were interested in deepening of the well, and 40% were interested in other means. Eight percent of respondents feel embarrassed about using animals to drive the Persian wheel.

**Table 5.** Water-lifting system for dug well.

| Parameters | % Responses |
|---|---|
| Traditional Persian wheel system | 59 |
| Electric operated pump | 24 |
| Diesel operated pump | 17 |
| Solar operated pump | |
| Pulley system | |
| Others | |
| **?** | |
| Donkeys | 82 |
| Bullocks | 9 |
| Both | 9 |
| **No. of bullocks/donkeys required to operate this dug well system?** | |
| 1 | 88 |
| 2 | 12 |
| More | |
| **Does this irrigation system meet your requirements?** | |
| Yes | 84 |
| No | 16 |
| **Efficiency of this traditional Persian wheel irrigation system?** | |
| Better | 3 |
| Normal | 42 |
| Poor | 36 |
| Very poor | 18 |
| Nonfunctional | 0 |
| **Depth in feet (from top) of water lifted by Persian wheel?** | |
| 0–10 | 0 |
| 10–20 | 31 |
| More than 20 | 69 |
| **Time (hrs) of operation for irrigation during which well becomes empty?** | |
| 0–3 | 65 |
| 3–6 | 18 |
| More than 6 | 17 |
| **How many hours do you operate this system daily?** | |
| 0–3 | 41 |
| 3–6 | 56 |
| More than 6 | 3 |
| **Do you observe an increase in the recharge rate during rainy season?** | |
| Increased | 91 |
| Decreased | 9 |
| No change | |
| **Do you observe a change in recharge compared to 10 years before?** | |
| Increase | 9 |
| Decrease | 62 |
| No change | 29 |
| **Is this system sustaining your livelihood?** | |
| Yes | 95 |
| No | 5 |
| **How can we help you in improving your system?** | |
| Solar pump with HEIS | 50 |
| Deepening well | 10 |
| Livelihood | 0 |
| Others | 40 |
| **Do you feel embarrassed by using animals to derive Persian wheel?** | |
| Yes | 80 |
| No | 20 |

### *3.4. Salient Features of Pumps Used to Draw Water from In Situ Dug Wells*

Based on the survey, a few questions on electric- and diesel-operated pumps for water uplifting were asked of the respondents. Considering the power of an electrically operated pump in hp, 22% of pumps have power between 0.5–1.0 hp, 22% of pumps consist of power ranges between 1–2 hp, and 56% of pumps are operated on 2–3 hp power, as shown in Table 6. All respondents using electric pumps preferred less expensive options of water pumping. Focusing on the operational cost of electrically operated pumps, respondents answered: 50% of pumps are operated with less than 8000 Rs./month, and 20% of pumps are operated with 8000–13,000 Rs./month, whereas 30% of pumps are operated with more than 13,000 Rs./month.

**Table 6.** Salient features of electric-operated pumps for water pumping from dug wells.

| Parameters | % Responses |
|---|---|
| **What is the pump power?** | |
| HP | |
| 0.5–1 | 22 |
| 1–2 | 22 |
| 2–3 | 56 |
| **Is this system expensive to pull water from well?** | |
| Yes | 100 |
| No | |
| **What is the operational cost of the system (Rs/month)?** | |
| Less than 8000 | 50 |
| 8000–13,000 | 20 |
| Greater than 13,000 | 30 |
| **Do you need a less expensive option for this activity?** | |
| Yes | 100 |
| No | |

The same questions were asked to the people in the case of diesel-operated pumps for water uplifting from the dug well. Sixty-nine percent of respondents reported the power hp of pumps between 1–10 hp, 25% reported between 10–20%, and 6% of pumps have power of 20–30 hp, as shown in Table 7. Ninety-four percent of people are satisfied with the pumping system for irrigation and drinking requirements, but still, people observe this diesel operated pump system to be expensive. Regarding the operational cost of diesel-operated pumps, 47% of pumps are operated with less than 8000 Rs./month, and 21% of pumps are operated with 8000–13,000 Rs./month, whereas 29% of pumps are operated with more than 13,000 Rs./month.

**Table 7.** Diesel-operated pump for water uplifting from dug wells.

| Parameters | % Responses |
|---|---|
| **What is the pump power?** | |
| HP | |
| 1–10 | 69 |
| 10–20 | 25 |
| 20–30 | 6 |
| **Does this pumping system fulfill your irrigation and drinking requirements?** | |
| Yes | 94 |
| No | 6 |
| **Is this system expensive for pulling water from the well?** | |
| Yes | 100 |
| No | |
| **What is the operational cost of the system (Rs./month)?** | |
| Less than 8000 | 47 |
| 8000–13,000 | 21 |
| Greater than 13,000 | 29 |
| **Do you need a less expensive option for this activity?** | |
| Yes | 100 |
| No | |

All the respondents need to overcome the expense of electric- and diesel-operated pumps and replace them with other sources for the pump operation.

### 3.5. Historical Climate Trends

The climate of the Soan Basin of Pakistan has been adversely changing over the last 30 years [36]. According to the findings, the temperature extremes (frost days FDO, summer days SU25, Tmax. mean, Tmin. mean) are showing a positive trend in all stations, except the trend of frost days in Islamabad and Jhelum. A negative trend is found in the Tmin mean of Murree and the Tmax mean of Mianwali from 1960–2013. Considering the rainfall extremes (consecutive dry days CDD, consecutive wet days CWD, annual total wet days precipitation PCRPTOT, heavy precipitation days when rainfall is 10 mm and 20 mm), is shows a positive trend except for the trends of CDD in Islamabad, PRPTOT of Jhelum, and CWD and CDD of Murree.

### 3.6. Climate Change Perceptions of the Communities

The present study shows that most respondents perceive a change in the climate parameters, including temperature, rainfall, summer and winter severities, and overall climate. The rise in average temperature was reported by 93% of respondents, as shown in Table 8. About 96% claimed a rise in summer temperature (summer becoming hot), whereas 78% indicated a rise in winter temperature (winter becoming hot). About 16% of respondents reported a decrease in winter temperature compared to 10 years ago.

**Table 8.** Perception about climate change and variability.

| Parameters | % Responses |
|---|---|
| **Average temperature compared to 10 years ago (%)?** | |
| Increased | 93 |
| Decreased | 6 |
| No change | 1 |
| Not applicable | |
| **Current summers compared to 10 years ago (%)?** | |
| Increased | 96 |
| Decreased | |
| No change | 4 |
| Not applicable | |
| **Current winters compared to 10 years ago (%)** | |
| Increased (becoming cold) | 78 |
| Decreased (becoming hot) | 16 |
| No change | 6 |
| Not applicable | |
| **Average rainfall compared to 10 years ago (%)?** | |
| Increased | 4 |
| Decreased | 86 |
| No change | 10 |
| Not applicable | |
| **Is climate changing?** | |
| Changing | 99 |
| No change | 1 |
| Not applicable | |
| **How did you realize the climate is changing?** | |
| Personal observation | 69 |
| Ac | 6 |
| Media | 25 |

About 86% of respondents stated a decrease in average rainfall, implying a greater water availability risk than ten years ago. Only 4% reported an increase, whereas 10% felt no change in rainfall from a decade earlier. People understand climate change and its associated vulnerabilities, as evident by 99% of respondents saying yes to a direct question, "Is the climate changing?". About 69% of respondents realize climate change through personal observation, whereas 25% realize it through media.

### 3.7. Perceptions of Climate Change Impacts on Agriculture

The inhabitants of the Soan Basin perceive the climate change around them and report impacts of this change as overall temperatures increase (93%) and rainfall decreases (86%), resulting in declining crop productivity. About 60% of respondents witnessed a reduction, whereas 28% reported no change in crop productivity, as shown in Table 9. About 63.8% of respondents indicated a shortening of crop growing season length, whereas 20% felt no change in season length. About 93% of respondents reported decreased dug wells' associated income due to climate change, and only 7% feel no change in income. According to the survey, the agricultural sector is the most affected sector due to climate change and water resources. About 69% of people witnessed decreased dug-well productivity due to climate change.

**Table 9.** Perception about climate change's impact on agriculture.

| Parameters | % Responses |
|---|---|
| **Crop Productivity (%)?** | |
| Increased | 12 |
| Decreased | 60 |
| No change | 28 |
| Not applicable | 0 |
| **Crop growing seasons changing over time?** | |
| Increased | 20 |
| Decreased | 64 |
| No change | 16 |
| Not applicable | 0 |
| **Effect of CC on cultivation?** | |
| Decrease in yield | 66 |
| Decrease in water supply | 28 |
| No change | 6 |
| Not applicable | 0 |
| **Dug-well livelihood (income) affected by CC?** | |
| Decreased | 93 |
| No change | 7 |
| Not applicable | 0 |
| **Which sector is most affected by climate change?** | |
| Agriculture | 70 |
| Water management | 27 |
| Human health | 3 |
| **Climate change impact on dug well's productivity?** | |
| Increased | 3 |
| Decreased | 69 |
| No change | 28 |

### 3.8. Perceptions of Climate Change Impacts on Water

Climate variability significantly impacts the agriculture and water resources of any region. The increase in average mean temperature and erratic rainfall pattern of the basin is affecting the livelihood of the dug wells. Based on the analysis, about 76% reported a decrease, whereas 24% indicated no change in water availability from dug wells for agriculture, as shown in Table 10. About 72% of respondents reported a decrease in water availability from nearby rivers or streams for agriculture in the face of climate change.

**Table 10.** Perception about climate change's impact on water availability.

| Parameters | % Responses |
|---|---|
| **Water availability for crops (%)?** | |
| Increased | 0 |
| Decreased | 76 |
| No change | 24 |
| **Current water availability in nearby rivers or stream?** | |
| Increased | 3 |
| Decreased | 72 |
| No change | 25 |
| Not applicable | 0 |
| **Have you noticed any change in the quantity of water obtained from your dug well in the face of changing climate?** | |
| Better in quality | 2 |
| Decreased in quality | 44 |
| No change | 54 |
| Not applicable | 0 |
| **Is the changed quality of water of your dug well suitable for agriculture, drinking, or both?** | |
| Both | 100 |
| Agriculture | 0 |
| Water | 0 |
| Not applicable | 0 |

### *3.9. Adaptive Strategies by the Farmers*

One of the study's main objectives was to see whether farmers are aware of climate change impacts and how they are coping with this threat. Farmers were asked questions illustrating adaptive strategies to counter climate change's adverse impacts. About 60% of respondents practice adaptive measures to overcome climate change challenges, as shown in Table 11. Eighty (80) % of respondents think climate-smart interventions can prevent them from being severe victims of climate-change-related problems. Regarding primary coping measures for sustainable water supply, about 56% of the farmers maintain water supplies by deepening their dug wells, 43% manage alternate supplies, and 1% have improved their recharge system. Some households are adopting more than one adaptation measure, and some households are adopting more than 2 to 3 adaptation measures. Sixty percent of farmers preferred drip and 35% sprinklers as efficient water management practices to cope with water shortages and improve production. When these farmers explained solar pumping, overwhelmingly, 95% of farmers were ready to use solar pumps for irrigation.

**Table 11.** Adaptive strategies by the farmers.

| Parameters | % Responses |
|---|---|
| **Are you using some adaptive measures to overcome these challenges?** | |
| Yes | 60 |
| No | 40 |
| **Do you think that climate-smart technology interventions can prevent you from being a severe victim of climate-change-related problems?** | |
| Yes | 80 |
| No change | 20 |
| Not applicable | 0 |
| **Major coping/adaptation practices for sustainable water supply?** | |
| Deepening of dug well | 56 |
| Alternative water supply | 43 |
| Improved recharge system | 1 |
| Construction of additional water storage | |
| **Major coping/adaptation practices in efficient water management?** | |
| Surface irrigation | 5 |
| Drip irrigation | 60 |
| Sprinkler irrigation | 35 |
| Any other | |
| **Major coping/adaptation practices in energy for water pumping?** | |
| Animal-driven water pumping | 2 |
| Diesel pumps | 0 |
| Electric motors | 3 |
| Solar pumps | 95 |
| Any other | |

## 4. Discussion

Climate change is a global issue that significantly impacts vulnerable communities, and people's perceptions of climate change indicate that people are aware of this change around them. It mainly impacts the environment, agriculture, and water resources. The country is prone to climate change with increased periods of droughts and intensive rainfall events causing damage to agriculture and livestock. Likewise, the current study focused on assessing people's perception of climate change and its impacts on water and agriculture, specifically dug wells in the Soan Basin of Pakistan. Results showed that 70% of respondents agreed about climate change in the Soan Basin of Pakistan, and 62% of farmers reported that climate change severely impacted their livelihood by affecting agriculture productivity and water availability. Ninety-two percent of potential adopters reported summer becoming hotter, 72% highlighted winters are becoming less cold, and 96% reported that average annual rainfall has decreased compared to 10 years before. About 72% of respondents indicated that available water in their dug wells decreased, and 80% of respondents explained that their crop yield had decreased compared to 10 years before. These decreases in agriculture productivity and increasing population have a significant impact on the deteriorating food security. By considering the food energy and water nexus, it is critical to think of sustainable ways of practicing agriculture with increased production and reduced water consumption.

The current study's findings follow the findings of [36] regarding people's perception of climate change in the Soan Basin of Pakistan. Based on their analysis of the results, 97% percentage farmers observed an increase in average temperature (max. and min. temperature) in the Potohar region of Pakistan, 48% of farmers noticed an erratic pattern of rainfall, and 96% of framers observed water scarcity in the region due to climate change.

Climate change is impacting Asian countries, and European countries are equally vulnerable to it. The findings of the current study favor the findings of [37], based on the people's perception of climate change and its impacts not only on human beings but also on the environment, ecosystem, infrastructure, and water resources. While considering the impact of climate change on the irrigated area of Marlborough and Hawke's Bay of New Zealand, findings of data survey analysis showed that winter temperature trends significantly increase at around 0.2–0.3 °C per decade. Farmers suggested that the region of New Zealand, where irrigation would be feasible, was also significantly more likely to receive more annual rainfall.

Global warming has not been uniform on Earth; many developed countries such as those in North America, Europe, and northern Asia face more global warming than other developing countries [38]. The results of the current study are also comparable with the findings of many other national and international research studies [39–41] regarding the impact of climate change on water resources and agriculture.

One of the alarming and major threats of climate change on the Earth's surface is water scarcity across the world. Global warming causes disastrous impacts on the water cycle. Climate change is impacting many communities causing extreme water-related events in many watersheds. According to the UNFCC Climate, Action, and Support Trends 2019 report, water has been highlighted as one of the major vulnerable sources of climate change. The current study showed that 72% of respondents indicated that available water in their dug wells decreased with time due to climate change. The results of the decrease in water availability of dug wells coincide with the findings [36].

Similarly, the erratic pattern of rainfall, extreme temperature, and water scarcity can impact the crop productivity of the region. This study highlighted that 80% of respondents agreed with the statement that climate change is causing the decline in crop productivity as compared to 10 years before in the region. According to (Bashir et al., 2018) research, 62% of farmers noticed a decline in crop productivity due to climate change in the Soan Basin region of Pakistan [37].

Current study findings are also in line with the questionnaire-based survey of Borana in southern Ethiopia, which highlighted the negative impact of climate change on water resources, and agriculture overall, causing a decrease in livelihood and economic development [18].

*Climate Change Adaptation and Mitigation Strategies*

When tackling climate change and its impacts, human beings apply two types of measures: adaptation and mitigation. Many adaptations and mitigation strategies can help society cope with climate change, but these two measures should be addressed simultaneously. Effective implementation depends on an integrated approach and link between mitigation and adaptation with societal objectives. The current study showed that 60% of respondents agree to adopt measures to cope with climate change in the Soan Basin of Pakistan. Eighty percent of them feel that adaptation of climate-smart interventions can enhance agriculture productivity, and 56% of farmers feel that if efficient water is used for agriculture, then it can strengthen agricultural sustainability. Many respondents agree to use highly efficient irrigation systems for efficient water management in agriculture. These findings correspond to the study [42] based on their research, in which drip irrigation systems, rainwater harvesting, and responsive drip irrigation can help farmers efficiently use water in rainfed regions such as the Soan River Basin. Adapting efficient drip irrigation systems for agriculture can provide sustainability for agriculture and water resources [43–45]. Likewise, using green and water infrastructure in society can mitigate the global warming issue. Solar water pumping systems can reduce the cost of electrification and diesel up to 100%. Cultivating off-season vegetables under tunnel farming through a high-efficiency irrigation system can double the yield productivity [4,46–49].

It is essential to discuss the climate adaptation and mitigation measures along with climate risks. However, in developing nations (where dug wells are thought to be the most typical approach to extract ground water to be used in agricultural operations), understanding farmers' opinions of climate change adaptation and mitigation is the key to adaptation strategies in the community). Qualitative context analysis in Austria suggests that climate adaptation interventions should be formed only if a farmer is willing to understand the effectiveness of such adaptation measures in the community. To assess the people's perception of climate change and adaptation needs, a qualitative and quantitative questionnaire-based survey was carried out during the southwest monsoon season in India; the results revealed that the perceptions and the information gathered were the same as analyzed observed trends of climate data [50]. People's perception of climate variability (which includes heat, winter and summer temperature, reduced rainfall, and fewer floods) can be used to motivate people for some adaptations and mitigation measures, as an assessment of climate variability from the last 5 to 10 years in Bangladesh showed negative impacts in terms of agriculture, human lifestyle, and water resources of that region [24,51–56]. Another questionnaire-based survey that observed climate change and people's perception of climate change was based on four variables: income, politics, agriculture, and economy in Montana. Results showed that maximum agricultural stakeholders are concerned about climate change and perceived the negative trends and impacts of rainfall and temperature over the region over the last few years [46]. Such types of analyses help policymakers, researchers, and engineers design climate adaptation interventions for specific areas accordingly.

Thus, it is a need of the hour to convince farmers/people and make them understand the importance of adopting mitigation strategies to cope with climate change. It is thus essential to understand farmers' socio-ecological characters and demands while designing and adapting research programs to cope with climate change. The findings of our current study regarding climate change impacts on water sustainability, quality, and quantity of dug wells coincide with the results of [57]. People in rural areas mainly rely on sustainable and conventional water sources, e.g., dug wells, tube wells, or springs. Therefore, efforts should be made to improve water sources for domestic needs.

## 5. Conclusions

Based on the perceptions of local farmers, the elements influencing dug-well-based livelihoods have been identified in the current research, and an inventory and database of dug wells in Potohar have been produced. Dug-well-dependent farmers' perceptions about climate change and its impact on agriculture and water resources have been evaluated through the questionnaire-based survey. The summary of the findings is as follows:

- In the Soan Basin, around 80% of households are dependent on agriculture and livestock for their livelihood.
- Sixty-two 62% of farmers reported that climate change severely impacted their livelihood by affecting rainfall, agriculture, and water availability.
- Ninety-two 92% reported summers are becoming hotter, 72% highlighted winters are becoming less cold, and 96% reported that average annual rainfall has decreased compared to 10 years before.
- Seventy-two 72% of respondents indicated that available water in their dug wells has decreased, and 80% of respondents explained that their crop yield has decreased compared to 10 years before.
- About sixty 60% of respondents practice adaptive measures to overcome climate change challenges.
- Eighty 80% of respondents think that climate-smart interventions can prevent them from being severe victims of climate-change-related problems, and 56% of the farmers maintained water supplies by deepening their dug wells.
- Farmers are aware of water shortage and losses in flood irrigation as 60% preferred drip and 35% sprinklers as efficient water management practices to cope with water shortage.
- High pumping cost is one of the limiting factors for profitable agriculture, as 95% of farmers were ready to use solar pumps for irrigation.

Taking into account the perspectives of the farmers as well as contrasting our study's findings with those of earlier works [18,36–39,58,59], we discovered that people of the Soan Basin are still using dug wells for domestic and irrigation purposes. Our findings indicate that farmer experiences with climate-related exposures should be taken into consideration by policies aiming to raise public knowledge of climate change and its implications. It is becoming increasingly clear that gaining in situ farmer support for local and national strategies to address climate change and its impacts requires an understanding of farmer perspectives and concerns. By highlighting the socio-economic and sociocultural characteristics of local inhabitants in response to changing climate, the study's findings will assist policymakers and other stakeholders in reducing agricultural communities' vulnerability to the effects of climate change.

**Supplementary Materials:** The questionnaire sheet which is used to collect farmers perception can be downloaded at: https://www.mdpi.com/article/10.3390/w15071287/s1, Table S1: Questionnaire Sheet Which Is Used To Collect Farmers Perception.

**Author Contributions:** Conceptualization, B.A., A.K. and M.U.N.; methodology, F.F.R. and M.A.; formal analysis, M.U.N. and N.M.; investigation, M.U.N. and F.F.R.; resources, M.K.J.; data curation, A.K., Z.T.V. and A.A.; writing—original draft preparation, M.U.N. and M.K.J.; writing—review and editing, M.U.N., S.S. and M.A.; visualization, M.A.; supervision, B.A.; project administration, B.A. and T.L.; funding acquisition, T.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research in this study was supported by the Strategic Priority Research Program of the Chinese Academy of Sciences, K.C. Wong Education Foundation (Grant No. GJTD-2020-14), the Third Xinjiang Scientific Expedition Program (Grant No. 2021xjkk1400), Pan-Third Pole Environment Study for a Green Silk Road (Grant No. XDA20060303), the CAS Interdisciplinary Innovation Team (Grant No. JCTD-2019-20), the CAS Research Center for Ecology and Environment of Central Asia (Grant No. Y934031), the Regional Collaborative Innovation Project of Xinjiang Uygur Autonomous Regions (Grant No. 2020E01010). A special acknowledgment should be expressed to the China–Pakistan Joint Research Center on Earth Sciences that supported the implementation of this study.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** This work was carried out by the Himalayan Adaptation, Water and Resilience (HI-AWARE) consortium under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), with financial support from the UK government's Department for International Development and the International Development Research Centre, Ottawa, Canada.

**Conflicts of Interest:** There are no conflict of interest to address.

## Appendix A

**Table A1.** Teshil wise Union Councils under applied buffer Zone criteria.

| Sr. No | District | Tehsil | UC in Soan Basin | UC Having >50% Area Within 5 km Buffer Zone |
|---|---|---|---|---|
| 1 | Islamabad | Islamabad | 1 | 1 |
| 2 | Rawalpindi | Rawalpindi | 26 | 21 |
| 3 | | Kahuta | 12 | 5 |
| 4 | | Kotli Satian | 7 | 1 |
| 5 | | Murree | 8 | 2 |
| 6 | | Gujar Khan | 13 | 4 |
| 7 | Chakwal | Chakwal | 21 | 11 |
| 8 | | Talagang | 6 | 5 |
| 9 | Attock | Pindi Gheb | 3 | 0 |
| 10 | | FatehJang | 4 | 0 |
| Total | | | 101 | 50 |

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