HI-AWARE Working Paper 11

HI-AWARE
Himalayan Adaptation, Water and Resilience Research

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

The Indus Basin

A Glacier-fed Lifeline for Pakistan

Consortium members

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About HI-AWARE Working Papers

This series is based on the work of 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. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The programme supports collaborative research to inform adaptation policy and practice.

HI-AWARE aims to enhance the adaptive capacities and climate resilience of the poor and vulnerable women, men, and children living in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. It seeks to do this through the development of robust evidence to inform people-centred and gender-inclusive climate change adaptation policies and practices for improving livelihoods.

The HI-AWARE consortium is led by the International Centre for Integrated Mountain Development (ICIMOD). The other consortium members are the Bangladesh Centre for Advanced Studies (BCAS), The Energy and Resources Institute (TERI), the Climate Change, Alternative Energy, and Water Resources Institute of the Pakistan Agricultural Research Council (CAEWRI-PARC) and Alterra-Wageningen University and Research Centre (Alterra-WUR). For more details see www.hi-aware.org.

Titles in this series are intended to share initial findings and lessons from research studies commissioned by HI-AWARE. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the HI-AWARE consortium, they have only undergone an internal review process.

Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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The Indus Basin

A Glacier-fed Lifeline for Pakistan

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Contents

Acronyms and Abbreviations

OFWM	On Farm Water Management Department
PARC	Pakistan Agricultural Research Council
PMD	Pakistan Meteorological Department
PCRWR	Pakistan Council of Research in Water Resources
UIB	upper Indus Basin
WAPDA	Pakistan Water and Power Development Authority
CAEWRI	Climate Change Alternate Energy and Water Resources Institute
KIU	Karakoram International University
AKRSP	Aga Khan Rural Support Programme
FOCUS	Focus Humanitarian Assistance, Pakistan
WWF	World Wildlife Fund
IUCN	International Union for the Conservation of Nature
ICIMOD	International Centre for Integrated Mountain Development
NUST	National University of Science and Technology
GCUF	Government College University Faisalabad
GCISC	Global Change Impact Study Centre

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Executive Summary

The Indus River is the 8th longest river in the world. It originates in the Tibetan Plateau and flows across the entire length of Pakistan. The Indus river basin is home to a population of nearly 200 million people. It passes through a variety of eco-climatic zones in Pakistan and supports the livelihoods of a large number of communities. The HI-AWARE project in Pakistan is focusing on the unique eco-systems and habitats associated with the Indus River. The project has undertaken research in three sub-basins – Hunza, Soan, and Chaj Doab, representing the upstream, midstream, and downstream – on aspects of hydrology, climate, water, agriculture, health, and urban management to document the existing situation and identify the vulnerability of the people in the basin. The study also documented people's responses to the changing climate and adaptation potential with regard to the different sectors, and government policies related to climate change adaptation. This document presents and assessment of the current situation of these areas in the face changing climate. It provides an overview of the major characteristics of the basin such as hydrology, key climatic trends and socio-economic status of the resident communities. Climate change bears great significance on the livelihoods of the people which are excessively vulnerable to its impacts. Moreover, as a result of climate change the recent increase in the frequency and incidence of natural calamities such as floods, droughts, landslides and glacial lake outburst floods (GLOFs) have increased the risk of vulnerable communities living in the basin. The document assesses the current situation of these vulnerable communities to depict a clear picture for better mitigation and management of such hydro-meteorological disasters.

As the climate induced disaster is expected to rise, it is proposed here that the government should increase investments in climate change adaptation programmes. These investments could also help in improving the food security and livelihoods of the poor people living in these marginal areas. The report will help in community based adaptation schemes being introduced in the Hunza River basin. The Soan basin has a very high potential for crop diversification. Future interventions in this area should focus on improved varieties of diverse crops and the introduction of heat and moisture resistant species. Crop insurance schemes for small farmers should be supported to reduce farmer vulnerabilities. Discussions in the field have also revealed farmers' perceptions about climate change and this study has also served the purpose of community need assessment. The need for proper management systems to sustain livestock rearing, certified and quality seeds for agriculture, improved water availability and improved access to markets for selling fruit and vegetable produce has appeared as the core needs of the communities in the basin.

The main purpose of the document is to provide a holistic situational overview of the entire basin. This overview will support the HI-AWARE project in its efforts of developing climate change resilience and improving livelihoods of the large population living across the Indus Basin. This situation analysis aims at identifying the present situation of prevalent local adaptation practices. These adaptation practices also provide an insight to the coping capacities of the communities, resident in in the study area. An effort has been made in this document to delineate the institutional framework that is currently functioning across various sectors in the country to assist both planned and autonomous climate change adaptations in the basin. Some of the existing policies in place in this regard have also been reviewed and areas of improvement have been highlighted to promote mainstreaming of good adaptation practices in developmental ventures. This situational analysis can prove to be extremely useful, as it highlights some of the most critical points of policy uptake, especially from the perspective of climate change adaptation, livelihoods and disaster. It is hoped that this document will help communities and relevant institutions in developing climate change resilience in Pakistan.

1. Introduction

The Indus is a transboundary international river with headwater tributaries located in China (Tibet AR), India, Pakistan, and Afghanistan. The river originates north of the Himalayas on the Tibetan Plateau, with the main stem flowing initially through the Ladakh district of Jammu and Kashmir and then through the northern mountainous areas of Pakistan (Gilgit-Baltistan) between the western Himalayas and the Karakoram range. The volume of the river increases significantly within Gilgit-Baltistan (GB) where it receives additional water from the Shyok, Shigar, Hunza, and Gilgit rivers in the adjacent catchments in the Karakoram Mountains, and from the Astore River in the western Himalayas. The Indus then turns to the south from Nanga Parbat (8,126 masl), and flows along the entire length of Pakistan, through the provinces of Khyber Pakhtunkhwa, Punjab, and finally Sindh, where it drains into the Arabian Sea near the port city of Karachi. The Kabul, Swat, and Chitral rivers emerge from the Hindu Kush Mountains to join the main stream in Khyber Pakhtunkhwa province, while the Jhelum, Chenab, Ravi, and Sutlej rivers join the main stream in Punjab province from the western Himalaya. The total length of the Indus is 3,180 km, draining an area of more than 1,165,000 km^2 (Figure 1).

The upper Indus basin (UIB) is considered to be the glaciated catchment part of the basin in the western Himalayas, Karakoram, and northern Hindu Kush mountains. Within the UIB, the Hunza river basin covers an area of approximately 13,734 km^2 and contributes nearly one-fifth of the upper Indus flows. It is located at the confluence of the Chapursan and Khunjerab nallas (gorges) in the central Karakoram region at a mean elevation of 4,631 masl (metres above sea level) and is fed by glaciers (Figure 1). The Hunza is further augmented by the Gilgit and Naltar rivers before draining into the main Indus stream. With up to a metre of snow falling in the Hunza valley, the hydrological pressure increases in winter causing a downward movement of landmass, which results in slides, mud flows, and avalanches. The Hunza river basin has two valleys, the Hunza and the Nagar. The Hunza valley is situated to the northwest with an average elevation of around 2,500 masl (8,200 ft). The major settlement of Gulmit was severely damaged by water after the Attabad lake disaster (in which a landslide dam across the Hunza River in 2010 led to formation of a 20 km long lake along the Gojal valley), while a substantial part of the settlement at Shiskat remains submerged. The part of the UIB within Pakistan contains 5,218 glaciers covering an area of 15,040 km^2 and 2,420 glacier lakes (Roohi et al., 2005). Of these, 52 lakes are classified as posing a potential threat of a glacial lake outburst flood (GLOF) making the area vulnerable to these destructive high intensity floods (ICIMOD, 2005).

The mid-basin area contains a number of sub-basins including the Soan basin which is located on the Pothohar plateau (Figure 1). The Soan is a left bank tributary of the Indus originating from the Muree hills and passing through steeply sloping areas before flowing into the main Indus near Kalabagh. The area is subject to active fluvial erosion forming very deep gorges at several places. It is one of the most highly vulnerable zones in Pakistan in terms of climate change.

The downstream plains area of the basin includes the area of Chaj Doab, which is bound by the Chenab River to the southeast and the Jhelum River to the northwest. The word 'doab' is used locally to refer to land between two rivers. The Chaj Doab covers a vast network of canals in the districts of Sargodah, Mandibahuddin, Gujrat, Jhang, and Chiniot. The area is mostly flat with a general slope towards the southwest and is characterized by more or less coarse textured soil (PID, 2005).

This report presents the results of a situational analysis of the Indus basin carried out under the Himalayan Adaptation, Water and Resilience (HI-AWARE) research initiative. The Pakistan Agricultural Research Council (PARC) selected the Indus for investigation due to its glaciated and snow-packed source and the dependence of millions of people in Pakistan on its Eco services. The analysis focused on the hydrological and socioeconomic conditions, upstream-downstream linkages supporting livelihoods, climate change impacts and vulnerabilities of communities and ecosystems, and uptake of adaptation measures. Three study areas were selected along the main Indus to represent the upstream, midstream, and downstream areas of the basin: namely the Hunza sub-basin, Soan sub-basin (Pothowar plateau), and Chaj Doab.

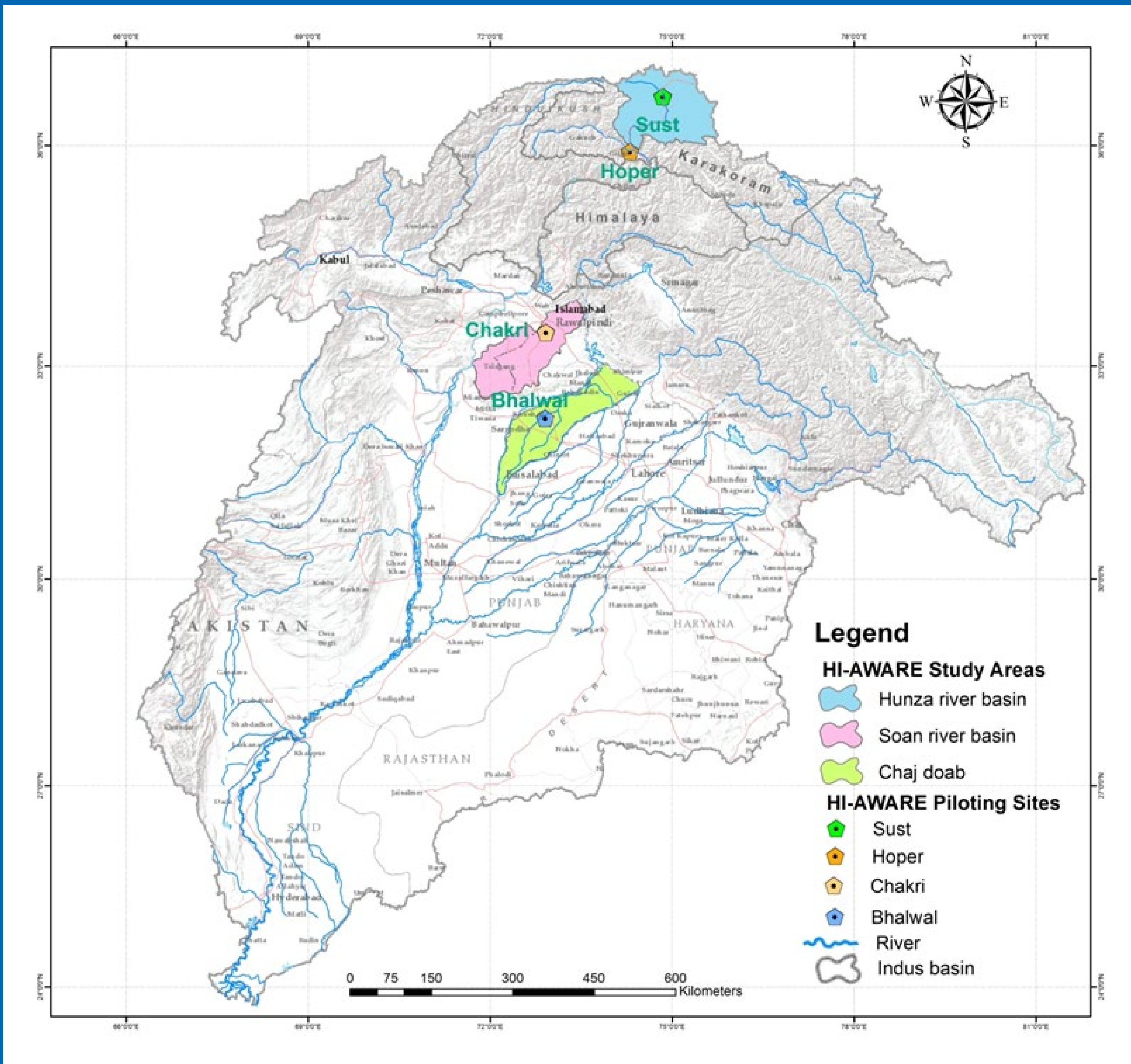

Figure 1: The Indus Basin

2. Methodology

Study Area

The proposed research is carried out along Indus River Basin from Plains (Chaj Doab) which is located at 32°19′60″ N and 73°0′0″ E with elevation at 193m above sea level to high-altitudes (Hunza River Basin) having elevation of 2,500m from above sea level . The study was divided into three geographic regions Hunza River Basin in high altitudes, Soan Basin in mid hills and Chaj Doab in flood plains.

Research Methods

Kumar (2011), identifies two major methods to gathering information: primary data and secondary data. Secondary data is the published, unpublished and grey information which already exists and is not gathered by the researcher himself. This mostly gathered from publications like articles, reports or literature, while primary data (first hand data) is collected by the researchers themselves. According to Merriam (2001), the suitable and common method is a combination of both techniques. Furthermore Yin (1994), says that any conclusion or finding of a research is likely to be convincing and accurate, when it is based on several data sources. By considering the above mentioned statements, the study was conducted by using both techniques to validate and to accurate it.

The research used quantitative and qualitative analysis of field data together with a review of the pertinent literature. Field visits were conducted to gather information about climate change impacts and adaptation practices and the local socioeconomic situation. Structured questionnaires were used to collect detailed and compressive information for quantitative analysis. It was tried that the questionnaire should cover the maximum aspects of the objectives of the study. In order to avoid the chances of duplication, error as well as biasness the same questionnaire was pre-tested in the field. Local languages have been used to fill the questionnaires in respective basins. Qualitative analysis was undertaken through focus group discussions (FGDs) and key informant interviews (KII). Further information about the areas was obtained from secondary sources such as the Pakistan Meteorological Department, Pakistan Water and Power Development Authority (WAPDA), district census reports, agricultural statistics, and irrigation reports.

The Hunza basin, which comprises the Hunza, Nagar, and part of Gilgit districts, was selected to represent the upstream area, and within this Borith, Ghulkin, Gulmit, Hopper, Hussaini, Khunjerab, Minapin, and Passu as representative villages. Field visits were carried out in April 2014. Studies of factors related to climate change impacts and adaptation practices, including hydrology and agriculture, were made at all sites; detailed studies of socioeconomic conditions were carried out in Ghulkin, Hussaini, and Passu. Key institutions were visited and interviews conducted with officials. Discussions with farmers were organized on specific topics (in groups comprising two to three interdisciplinary scientists and eight to ten farmers), and visits were made to some farms to observe and discuss farming techniques and climate change adaptation practices.

The Soan basin, comprising the districts of Attock, Chakwal, Islamabad, Khushab, and Rawalpindi, was selected to represent the midstream in view of its diversity in livelihoods and high vulnerability to climate change impacts. Field visits were carried out on multiple occasions throughout the year. Key stakeholders were identified, including key institutions working on or involved with the specific sectors of water, agriculture, energy, health, and urban management, and selected communities. One factor that differentiates the various approaches used to initiate research at farm level is the extent to which farmers are involved as partners in the process and their experience and insight are matched with the knowledge and experimental rigour of the scientists. An informal rapid appraisal technique was applied to obtain a qualitative understanding of the farming systems.

The Chaj Doab, comprising the districts of Chiniot, Gujrat, Jhang, Mandibahuddin, and Sargodah, was selected to represent the downstream area in view of the diversity in people's livelihoods and high vulnerability to climate change impacts. Field visits were carried out on multiple occasions throughout the year and focus group discussions and key informant interviews conducted. A meeting was held with experts from the Pakistan Council of Research in Water Resources (PCRWR) to further explore and refine the information and discuss important aspects of water resources including irrigation (canal and groundwater), drinking water, and conservation practices.

3. Major Basin Characteristics

Hydrology

The drainage system in the Indus basin is shown in Figure 2.

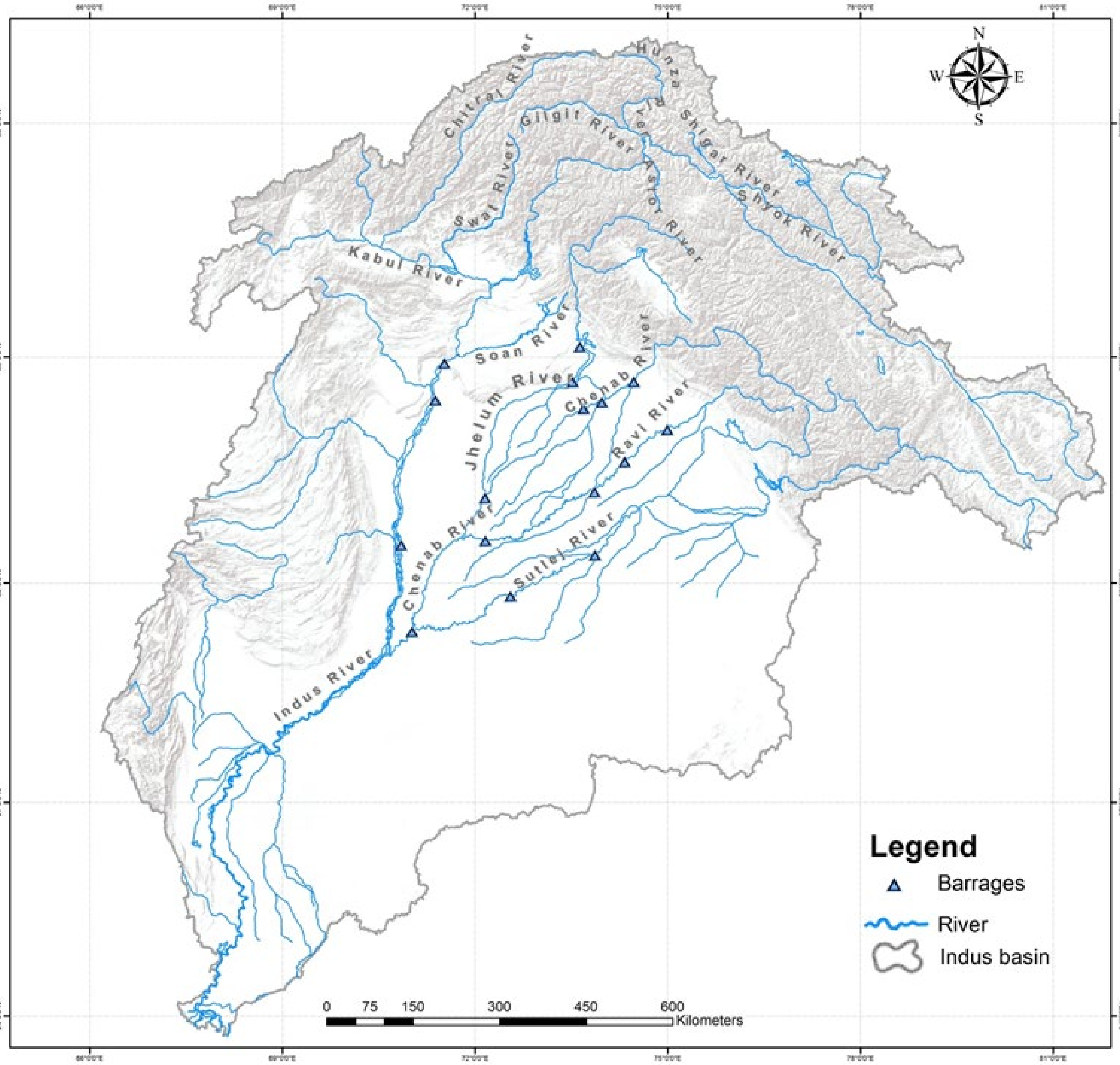

Figure 2: The drainage network in the Indus Basin

Upper Indus: Hunza Basin

The Hunza River Basin is situated in high-altitudes of Central Karakorum, with a mean catchment elevation of 4,631m having drainage area of 13,733 km^2. According to three climatic station at Hunza River Basin installed by WAPDA, shows that annual precipitation is 170 mm at Khunjerab having elevation of (4,730 m), 225 mm at Ziarat having elevation (3,669 m) and 680 mm at Naltar with an elevation (2,858 m) with respect to the 10-year record from 1999 to 2008 (Tahir et al., 2011).

The mountain headwaters of the Indus River contribute approximately 60% of the mean annual total volume of the river, with approximately 80% of the additional volume flowing during the summer months from June–September. This indicates how critical it is for the river to maintain sufficient flow for the upstream and downstream users. According to Tahir et al., 2011; Archer and Fowler, 2004; Hewitt et al., 1989; Wake, 1989; Young and Hewitt, 1990 the most active hydrological zone of Upper Indus Basin Lies in the mountains of Karakorum and Himalayan ranges of high-altitudes and more than 65% of annual flow of UIB is significantly contributed by glaciers and fresh snow having elevation above than 3,500 m. Furthermore research shows that more than 90% of downstream flow is generated from the mountains of UIB (Liniger et al., 1998). Climate change in UIB is directly influencing the inflow to the Indus irrigation system. Linear regression model run by Archer (2003; cited in Tahir et al., 2011) indicates that a 1°C rise in mean summer temperature in high-altitudes of UIB would result in a 16% increase in summer runoff into the Hunza and Shyok River due to accelerated melting of fresh snow and glacier.

The two principal sources of runoff for the UIB are snow and glacial melt. The flow in the Hunza River is usually at a maximum in July when snow and glacier melt is at its peak and the minimum in March, when contribution of snowmelt is minimal due to low temperatures. The maximum discharge ever recorded in the Hunza River was 2,560 m^3/s in July 1973, and the minimum 11 m^3/s recorded in February 2005 (WAPDA, 2016). Flooding is a normal phenomenon, but the frequency of floods was reported to have increased, which could be due to the changing climate and/or change in land use, especially increased infrastructural development.

Midstream: the Soan Basin

Soan Basin is located in Potohar plateau, and highly vulnerable zones of Pakistan towards climate change. This Basin is one of the major hydrological units of Potohar Plateau having drainage area of about 11,085 km^2 which is nearly 55% of the total Potohar region. The basin lies between latitude 32°45′ to 33°55′ N and longitudes 71°45′ to 73°35′ E and it is bounded by Murree-Jhelum Section, Haro basin, Pind Sultani & Makhad areas (Ashfaq et al., 2014). In the Soan basin, as elsewhere on the Pothohar plateau, changes in rainfall patterns and the duration of the monsoon have resulted in changes in river flow. The incidence of erratic rainfall with localized intense rainfall events has increased over time, resulting in a 'too much too little water' situation with a significant variation across small areas within the basin. Some areas are receiving more than normal rainfall, and some are facing prolonged dry spells. The major tributary streams of the Soan are the Ling, Korang, Sil, and Lai. The Korang and Soan are dammed at Rawal and Simly, respectively, to cater for domestic water and minor irrigation requirements in Rawalpindi and Islamabad. The maximum discharge of the river is in July through September, with a subsidiary peak in the early part of the year due to winter rainfall (Rasul et al., 2012).

Downstream: the Chaj Doab

Chaj Doab is area bounded by Chenab and Jhelum Rivers. The latitude of the Doab varies from 31° 11′ N to 32° 58′ N and the longitude from 72° 10′ E to 74° 22′ E and its elevation from mean sea level varies from 150 to 250 m above the mean sea level. In the Chaj Doab area in the lower basin, canal water supplies are inadequate in summer pre monsoon (late April to mid-July) due to the very low river discharge, and irrigation is mostly from groundwater. While during monsoon season canal water become enough for irrigation. The canal system is fed primarily by water from the Jhelum River, which in turn is fed by monsoon rainfall and only partially by snowmelt water from the high mountains of the Himalayas, unlike the tributaries in the UIB such as the Hunza River (Ashraf and Ahmad, 2008). During the droughts of 1999–2002, groundwater abstraction increased manifold due to the rapid increase in the number of private tube wells for irrigation purposes. However, excessive pumping of groundwater from these wells has led to a gradual decline in the water table. Development of irrigation potential using canals has had a negative environmental impact in the low relief areas. Seepage from the entire conveyance system together with excessive irrigation has disturbed the natural groundwater balance, especially where natural drainage is inadequate due to the topography and soil characteristics.

Although the groundwater potential in the region is very high, with water available at less than eight metres depth (25 feet), the water is unequally distributed and is saline across most of the doab, with salt levels varying considerably. Salinity is probably the most alarming problem associated with groundwater (Ahmad and Chaudhry, 1988; Gupta et al., 1994; Bakhsh and Awan, 2002). The major sources of salinity in Chaj Doab are the geological formations in the northwest called the salt range zone (Singh et al., 1993; Van Hoorn et al., 1994, Ghafoor et al., 1997). Salinity in shallow groundwater originates from weathered salt at higher altitudes which accumulates in the upper caustic sediments and is then transported to nearby lowlands and valleys, where evaporation leaves salt at the surface (Boers and Zuberi, 1995; Ahmad and Kutcher, 1992). Salinity can also arise from deep groundwater flows, when water in a recharge area penetrates to the deeper rock salt and is then transported to lowland discharge areas. Salty groundwater is also transported upward through faults and fractures caused by artesian, convective, and capillary flow (Srisuk and Toth, 1994). Most areas located away from rivers and the banks of canals are characterized by saline ground water, which is unfit for human consumption, livestock, or irrigation. Seepage of water has also caused problems of waterlogging and salinity, thereby threatening the livelihood of farmers (Bhutta et al., 1996). In general, as for other aquifers in the Punjab, the aquifers in Chaj are mostly unconfined. However, at sites with significant clay horizons, particularly if these are near the surface, confined conditions may be encountered (Kidwai, 1962; Rehman and Malmberg, 1967).

Socioeconomic Parameters

Upper Indus: Hunza Basin

People along Hunza River Basin are economically dependent on natural resources and traditionally living in an agro-pastoral life (Ishaq et al., 2015). Agriculture and livestock are major sources of livelihood. The region falls under mono-cropping zone and the major staple crops grown include wheat, maize and potato. The sowing season varies in different villages of the Hunza River basin and it starts from 1st week of February and remains till 10th April in the higher altitude areas. While harvesting starts in mid-July the lower regions and extends till the end of October in the upper mountainous area. Apricot, cherry, apple, and peach are produced in abundance in the region. Local do not enjoy these fruits themselves but also sell it in the market and earn profit from these fruits. Until 2015, Hunza-Nagar was a single district, covering most of the Hunza valley, but it has now been separated into the districts of Hunza and District of Nagar. At the time of the last official census in 1998, the population of Hunza-Nagar district was 99,000, around 13% of the population of Gilgit-Baltistan. Hunza district covers about 7,900 square kilometres and has a total of 12,779 households (AKRSP, 2007). Aliabad is the main town, with other large settlements at Shishkat and Ghulkin and popular tourist centres at Altit and Baltit (Karimabad). The current study was conducted in Ghulkin, Hussaini, and Passu of Hunza District. Ghulkin is the southernmost of the three; Hussaini is located northeast of the Ghulkin glacier on a lateral moraine; and Passu extends from west to northeast of the Passu glacier. These villages have an agro-pastoral livelihood. Gulmit is the largest settlement in this area with a total population of 2,463. There are almost equal numbers of males and females in Gulmit.

From ancient times, agriculture has been the backbone of Hunza's economy. More than 70% of the population depends on agriculture either directly or indirectly. Fruit and vegetable production is an important source of income. Fruits include apricots, peaches, pears, apples, grapes, cherries, and melons, while vegetables include potatoes, tomatoes, and beans. The main staple crop is wheat, with maize and barley also cultivated. Due to the short cropping season and high altitude, only one cash crop can grow annually with maize or barley cultivated as a fodder crop before or after the main food crop. Around 96% of households in Hunza-Nagar have access to agricultural land and cultivate both staple and cash crops (ICIMOD, 2014). Agriculture, livestock, and forestry together accounted for 41% of household income in 2005 (AKRSP, 2007). Of this, livestock and agriculture contribute almost equally accounting for 38 and 35%, respectively. Income from fruit accounts for 16%, while the remainder is generated from forest-based products. Livestock are a very important component of rural livelihoods in Hunza-Nagar, especially for pastoral communities, with 95% of households owning more than one type of livestock such as yak, sheep, and goat (ICIMOD, 2014). Buffalo and poultry are also reared on a limited scale (AKRSP, 2007). Horses, mules, and donkeys are raised for transportation in the hill areas where mobility and accessibility is a challenge. The contribution of both men and women in crop and livestock production activities is significant in terms of the rural economy. Freedman and Wai (1988) reported that 90% of women in the rain fed areas of Khyber Pakhtunkhwa participate in agriculture and work on the farm in the post-harvest season. Some people also depend on the service sector for income generation. Men usually prefer to join the armed forces, participate in off-farm activities like tourism, or migrate for work to large cities. In their absence, women carry out all the farm and livestock-related activities. The upper part of the basin has transport facilities, but on some occasions, communities face serious problems. Educational facilities are available up to the primary and middle level in the villages, higher secondary within a radius of 5–10 km, and higher education at the tehsil and district headquarters level. Higher education is mainly undertaken by men for employment in the armed forces or for overseas assignments, when the ability to survive from the land is reduced due to the small size of holdings.

Midstream: the Soan Basin

The Pothohar plateau covers an area of about 15,830 km^2 comprising the districts of Rawalpindi, Attock, Chakwal, and Jhelum, and the Federal capital area of Islamabad. The Soan basin extends across two of the four districts on the plateau (Rawalpindi and Chakwal). Livestock also form an important component of rural livelihoods in this area. Livestock and poultry contribute to both food security and income, with products such as milk, butter, cream, meat, and eggs sold in the market. Almost every household keeps two or three goats for milk and to meet emergency cash requirements. The practice of calf-fattening is also increasing due to good returns. Women play a critical role, not only in raising the animals but also in converting their by-products into useful food items. Grazing is largely the responsibility of men, women only graze animals on fallow lands at the periphery of the village. The project villages in the Soan basin were all well established and there is no seasonal migration for work except for transhumance. The road and railway infrastructure is also well established and maintained. The districts in the study area were well connected with railways with main stations at Rawalpindi, Islamabad, Feteh Jang, Attock, and Gujar Khan. Rawalpindi city is also well connected to all seven tehsils. The Peshawar-Lahore motorway connects the districts of Attock and Rawalpindi with major cities in Pakistan such as Lahore.

Downstream: the Chaj Doab

The Chaj Doab region is densely populated as it is rich in agricultural resources and there is sufficient water for irrigation during monsoon season while in early summer they face little water shortage. Two canals, the Upper Jhelum Canal (UJC) and Lower Jhelum Canal (LJC), originate from the Jhelum River at the Rasul barrage and irrigate large areas of the Chaj Doab. The sediments carried by the river from the vast alluvial basin are also deposited in the Chaj Doab providing fertile soil. Agriculture is still the single largest sector in rural areas, and provides direct or indirect employment to the majority of the labour force. Large, medium and small scale industry, business, and trade dominate the urban areas, as the plains are characterized by gentle slopes, facilitating transportation and the process of transporting goods from farm to market. Local people reported that a sizable number of young residents were migrating from rural to urban areas within the region, as well as overseas, in search of jobs. Migration for work contributes to both the local and the national economy. Waqar et al., (2005) note that poverty is one of the main issues affecting Pakistan; the households in the Gujrat and Mandi Bahauddin districts of Chaj have the lowest annual income of all the districts in the Chaj Doab region. In Gujrat, crop income constitutes only 18% of household income, compared to 44% in Sargodha district, and dependency on non-crop income to meet basic needs is very high, making people more vulnerable.

The observations on socio economic parameters in lower streams of Indus river basin at Chaj Doab region revealed some facts. The rise in temperature is the major emerging phenomenon. The climatic factors further increases socio economic stresses due to many other factors such as unavailability of medical facilities and medicines for livestock and pesticides that further result in loss to their livelihood sources. Furthermore, lack of savings in lower income group, force them to take credit from informal credit sources or they have to sale their livestock or in some extreme cases, a piece of land at cheap rates to obtain cash in hand. These parameters show that how context specific drivers and more generalized factors are important in understanding choice of coping strategy.

Key Climate Trends

Upper Indus: Hunza Basin

The Upper Indus Basin (UIB) is nourished by water from western Himalaya, the Karakoram and the Hindu Kush with an area of 289,000 km^2 (Rauf et al., 2016). The UIB is characterised by permafrost and annual precipitation in excess of 2,000 mm, but the glacier termini extend into the semi-arid valley floors (2,700 masl) where they receive annual precipitation of less than 100–200 mm. In this semi-arid environment, the summer temperature frequently rises above 25°C. In July and August, the mean maximum and minimum temperatures are normally above 35°C and 15°C, respectively. Winter is generally cold from November to the end of March, with the lowest temperatures in January, when the mean maximum and minimum temperatures drop below 10°C and -2°C respectively. In the UIB, a considerable amount of precipitation is received during the spring season (between April and May). The maximum annual rainfall is in the Astor basin (average annual rainfall 493 mm in the period 1954–2015), followed by Chitral (average annual rainfall 471 mm in the period 1964–2015).

It seems that the glaciers in the Karakoram region are characterised by generally increased in total snow and the ice volume with substantial regional differences so as also called the 'Karakoram anomaly' (Hewitt, 2005 ; cited in Parveen et al., 2015). Climatic parameters are significantly influenced by altitude. Northern region of UIB are arid with annual precipitation ranging from 100 to 200 mm, but precipitation is directly proportional to elevation, it increases with increase in elevation to more than 600 mm at 4,400 m (Cramer, 1993; cited in Sharif et al., 2013), and research on glaciers in UIB shows suggest accumulation rates of 1,500 to 2,000 mm at 5,500 m (Wake, 1989). Since most of the precipitation in the northern Himalayas occur from westerly waves (Archer and Fowler, 2004), and mean monthly temperatures from October to March are below freezing above 3,000 m (Archer, 2004).

According to a report by the Northern areas conservation strategy (Jovia and Mir, 2002), the hydrological profile in the Gilgit-Baltistan has been affected by a rise in average precipitation in the region over the past 50 years. It was clearly noticed and remarked by local communities that the climatic condition of region has been changed over the past 15 to 20 years. The mountain ecosystem of UIB is highly fragile and is more vulnerable to climate change (Ishaq, et al., 2015). It was reported that change in climate has significantly altered their lifestyle and source of livelihoods as well. Communities reported of glacial melt and glacial lake formation activities in the surrounding areas. The people in the villages had differing views about temperature change, with some reporting a decrease and others an increase. Many mentioned that the length of the winter season had increased, while winter snowfall has been decreased as compared to 10 years back. Some viewed climate change as a positive phenomenon, but for most, it had increased the number of disasters and created water shortages.

In terms of climate changes, locals reported their experience about temperature shocks and, erratic rainfall which have significantly cast observable impacts on plant phenology and overall livelihood activities. As reported by locals, flowering of almond plants used to take place in the month of March but now, it has shifted to early February due to rise in temperature. The rise in temperature and winters becoming warmer is also evident from the change in the life style of local people. About 10 years ago, majority of the people in Upper Hunza used to add additional stoves in their homes in which they were used to burn coal for heating purposes. But now many people have left this practice, providing the justification that the weather is not that much cold to use additional stoves. Moreover, the number of blankets people used to keep themselves warm has reduced from three to one in the lower regions of Hunza River Basin over the past 10-15 years. Another drastic change has been observed in the use of woolen clothing like (Choogah; a traditional long woolen robe worn by men) and (Shaaye Don; a woolen scarfs for women).

Midstream: the Soan Basin

The temperatures in the mid-basin also fall below zero at the higher altitudes in winter; while at lower altitudes temperatures of up to 47°C are common in summer, especially in the southern part of the basin. The Soan river basin around Dhok Pathan experiences very hot weather in summer, while the more northerly Muree hills have a very cold winter with heavy snowfall. January is usually the coldest and June the hottest month in the year, with dust storms often damaging crops. The highest annual precipitation recorded in the Muree hills in the period 1960–1980 was 1,686 mm, with the maximum amount falling in July and August (Pakistan Meteorological Department, Historic Precipitation Database), this is a major source of moisture in the area. A recent study by the Pakistan Agricultural Research Council, which focused on investigating the spatial variability of rainfall patterns and its impact on the runoff regime in the Pothohar region, found a linkage between precipitation and river flows (Naz et al., 2015).

Analysis of 25 year rainfall data for 1960–1984 and 1985–2009 showed mean annual rainfall values of 529 to 1,643 mm for the period before 1985, and 565 to 1,663 mm after 1985, only a slight increase (Naz et al., 2015). The rainfall range band 400–600 mm showed a slight increase in the Pothohar region, while the 200–400 mm band showed a decline in the kharif (monsoon) season. The 800–1,000 mm rainfall band showed an annual increase of 3.1%. A shift has been observed in the high rainfall zone (>750 mm) towards the southwest, and another minor shift in the very high rainfall zone (>1,500 mm) to the northeast of Pothohar.

There is now high variability in rainfall in July and August, prominent in July especially in parts of the Capital Area of Islamabad and southwest of Chakwal district, and relatively less variable in the western and south-western parts of the basin. There has been an increase in the intensity of monsoon rainfall in July and a decrease in November in most of the Pothohar region. According to local people and farmers, snowfall patterns in the higher elevations have changed drastically and the quantity of snowfall has gone down significantly. In previous times, snowfall began in the last week of October and continued to the end of April, now it is restricted to January, February, and March, and whereas the snow used to reach a depth of around two metres (six to seven feet) every year, the maximum now was less than one metre (two to three feet). Soan Basin is at risk from several natural disasters like droughts and heat and cold waves pose the greatest threat for livelihoods.

Downstream: the Chaj Doab

The climate of Chaj Doab is characterized by very hot summers with maximum temperatures touching 50ºC. The average annual temperature is 22°C, while average monthly minimum and maximum temperatures are 10°C and 31°C, respectively. January is usually the coldest month and June the hottest as in the mid-basin. Dust storms are common and sometimes damage crops. Precipitation has two annual peaks, from the monsoon in summer (July to September) and from western storms in winter. The maximum mean monthly rainfall is in July and the minimum in November. Analysis showed a positive rate of change in annual monsoon rainfall over the period 1901 to 2007, with a total increase of 111 mm and average increase of 10.4 mm per decade. Decadal analysis showed clear cycles of increase and decrease in rainfall over the century, with an increase in decadal average rainfall starting in the 1950s, becoming more marked after the 1970s with a major increase after 1977. After 1997, there was a sharp decrease in the monsoon rainfall. Winter rainfall has less inter decadal variability than the monsoon rains. As Chaj Doab is situated between two rivers, the Jhelum and Chenab, the monsoon rainfall leads to floods almost every year. Historically, floods have damaged agricultural lands and standing crops, as well as property and belongings, of the poor and marginalized people living close to the banks. The disastrous flood of September 2014 led to very high losses (Kharol et al., 2013).

Farmers have observed changes in the climate recently compared to 10 years ago, especially an increased incidence of more erratic events. However, they also consider that the yearly frequency of rainfall has decreased, with more intense rainfall over shorter periods of time, followed by long dry spells. The phenomenon of increased prevalence of heavy fog in winter was reported by all farmers. Changes in temperature and rainfall have also aggravated pest attacks on crops and livestock, thereby threatening the livelihoods of the rural poor.

4. Climate Change Risks, Vulnerabilities, and Impacts

Water

Glaciers in Upper Indus Basin (UIB) of Pakistan cover an area of 13,680 km^2 – 13% of the mountain area of the upper Indus basin (Roohi et al., 2005). But according to ICIMOD 2012, Upper Indus covers glacial area of 15,061.7 km^2 with number of glaciers around 11,413 having an estimated ice reserve of 2,173.5 km^3 with a highest elevation of 8,566 (masl). Water from annual glacier (and snow) melt contributes more than 60% of the flow from the UIB. The World Bank in 2005 projected that Western Himalayan glaciers will retreat for the next 50 years causing an increase in Indus river flows; then, the loss of glacier area could result in a decrease in flows by up to 30 to 40% over the subsequent fifty years (World Bank, 2005). IPCC in its 4th Assessment presented in 2007 (IPCC 2007a, b) stated that "glacier melt in the Himalayas is projected to increase flooding within the next two to three decades".

Presently water resources in the Indus Region are under stressed (Lutz, 2016). Research shows that most of the parts of Indus and Ganges groundwater reservoirs are considered overstressed aquifers in the world (Gleeson et al., 2012; Richey et al., 2015; cited in Lutz, 2016). Among the 100 largest river basins in the world, the Indus Basin is listed in the top 20 of most water-stressed river basins (Gassert et al., 2013).

Community engagement and interaction during field visits revealed that almost all glaciers in the UIB are retreating with only a few exceptions like Hopper Glacier in the Karakoram region. Glaciers are moving faster as compared to decades before and leading to both water scarcities by damaging the major irrigation channels and case destruction of productive lands due to more frequent and disastrous floods. A considerable proportion of the inhabitants had abandoned the old Passu village due to floods and damages of irrigation channels. Communities also reported that glacial lake outburst flood events had become more frequent. Water for irrigation and domestic use, mostly derived from snowmelt and rainfall, has suffered critically due to the changing snowfall pattern. Springs, a major source of drinking water in the area, are rapidly drying up, causing a considerable burden for women who are forced to collect water from far away. Glacial surges have disrupted the irrigation systems resulting in a lack of water for agriculture and loss of livelihoods for a number of households. The drinking water and irrigation requirements for communities living downstream are facing a huge crisis due to the reduced flow in the river and severely affecting the livelihoods of vulnerable people.

In the Lower Indus Basin the use of groundwater has increased due to the rising demand from domestic and agricultural sectors and livestock, poultry, and other industries. The low basin outflow of the river and subsequent dependence on groundwater is at least in part the result of the rainfall variability. Now the declining groundwater table poses a threat to local communities in terms of sustainable water availability. Drinking water sources in the urban and rural areas of the Soan basin include tap water, hand pumps, motorized pumps, dug wells, and many others. Tap water and motor pumps are the most common, especially in urban settlements, whereas dug wells are common in rural areas of Islamabad, Attock, and Rawalpindi. Sanitation services have also increased over recent decades, with 100% flush sanitation in urban Islamabad and 98% in urban Attock and Rawalpindi, and a range in rural areas from 98% in Islamabad to 67% in Khushab. This indicates a rising demand for water in the sanitation sector. Several problems are contributing to the relative vulnerability of people in Rawalpindi and Islamabad, including the rapid increase in population; shortage of available water (World Bank, 2006); reduction in the water table due to excessive withdrawal, especially in Rawalpindi; change in rainfall patterns (Abbas, 2008); and poor socioeconomic conditions (Rabia and Ahmad, 2015).

In terms of climate change, there is high confidence in the projected increases in temperatures, but less certainty about the projected changes in precipitation. Extreme rainfall events can cause floods, such as those experienced in 2010 across the country and in 2001 in Nullah Lai in the Soan basin. Monitoring as well as forecasting mechanisms are needed to be implemented in order eradicates the impact of flooding. The rain-fed areas of northern Punjab (Soan basin) are prone to flash floods after heavy rains during the summer. Since the soils are silt loam, gully erosion is common. Heavy and intense monsoon rainfall due to climatic variability may increase the intensity of soil erosion in these areas.

Recent research on climate science has been revealed glacier melting especially in HKH regions (Immerzeel et al., 2015; Immerzeel et al., 2010; Hewitt, 2005, 2007, 2011). Implying an increase in glacier melt water and rise in the flows of the Indus basin is followed by a permanent reduction. The lack of freshwater flows will dramatically affect biodiversity and livelihoods, with possible long-term implications for regional food security.

Farmers in the Indus river basin especially in the Soan basin have reported that temperature and precipitation patterns have been changed significantly and become more erratic, with a reduction in the annual frequency of rainfall. Many farmers reported that prolonged periods of canal closure (nehar bandhi) had led to a reduction in the overall availability of canal water. However, the district water management officer in the Soan basin reported that water availability in canals has not changed significantly compared to the situation 10 years ago. However, the significant reduction in rainfall frequency and 40–45 days of delay in the onset of the seasons (summer and winter) has increased the demand for irrigation water from the canal and groundwater sources. It was clear from the field survey that in most areas in the Sargodha division of Chaj Doab, the canal water is not sufficient to fulfil the irrigation demands. Regions where PCRWR is located, agriculture mainly depends on groundwater irrigation, and due to its location in the flood zone, groundwater is recharged adequately by the Chenab river (within 2–3 km), and not affected by the changes in climate. However, heavy floods cause a lot of destruction to the agricultural systems and impact on people's livelihoods drastically.

Agriculture

Agriculture is threatened by floods and droughts in all the study areas in the basin. The variability in rainfall is very high and is likely to impact the agricultural sector, as a result of both too much and too little water.

In the UIB, the impact of the Attabad lake disaster on agriculture was severe. The landslide washed away the low lying Sarat village with its settlements and agricultural land, along with cash crops like potatoes and apricot orchards. The landslide dammed lake remains a potential threat and will continue to have an adverse economic impact both now and for the coming generations if not managed appropriately (Iqbal et al., 2014).

In the Northern mountainous areas of Pakistan, wheat production is projected to increase with up to 4°C rise in temperature (Ahmad et al., 2013). At higher elevations, the reduction in snowfall has severely affected agriculture and fruit production. Murree, which is traditionally famous for, apples and pears, is particularly affected by the changes in snowfall.

The mid-stream area of the Indus basin comprises of major rainfed agro-ecology in Pakistan. Agriculture, and ultimately the livelihoods of people, in the midstream zone are heavily dependent on rainfall. The main crops are wheat, maize, barley, millet, groundnut, pulses, oil seed crops, and fruit crops such as olives and grapes, The farming community is also dependent on livestock for milk production and livelihood earning In the Soan basin, the main cropping system consists of wheat in winter and maize in summer, with some minor crops such as millet, pulses, lucerne and berseem, grown for fodder. Wheat is cultivated over a substantial area in winter in almost all districts in the basin, with some fodder cultivation for livestock wherever possible. In summer, farmers also cultivate fodder crops in addition to maize. Mono-cropping is usually practised and crops are usually sown on residual moisture of rains. With climate change, wheat production is projected to decline by 5 to 7% with each 1°C rise in temperature (Sivakumar and Stefanski, 2011; cited in Ahmad et al., 2013). Low rainfall in the Soan basin is a constraint for dairy farming and communities can only raise a limited number of animals, although keeping animals accounts for a major portion of household income and helps increase farm productivity. It is expected that livestock production will be adversely affected by higher temperatures, which could result in lower milk, meat, and fodder production. Reduced reproduction is also expected (IUCN, 2009; GOP, 2010). The Soan basin is deficit in food production but food is easily accessible from the surplus districts in Punjab province. Yields are low due to low soil fertility and low rainfall; climate change may lower the yields further (Oxfam Novib, 2010).

Farmers in the Chaj Doab, comprising flood plains of Indus Basin, noted that climate change has delayed sowing of Rabi crops when there are no September rains or delayed rains – a partial change in the cropping pattern. This is important regarding some areas of Chaj Doab which lie in rain-fed zone. Despite farmers' interest in adjusting their farming systems, market issues often work as a constraint and they are reluctant to accept changes. However in flood prone areas, some farmers have adapted sugarcane to exploit the short period of standing water. A recent analysis which focused on wheat production in Punjab province found that yields would decline for rain-fed production but might increase for irrigated production (Tariq et al., 2014). The authors also forecast an overall decline in per capita wheat production in Punjab – from 198 kg per annum in 2012 to an estimated 86 kg per annum in 2050 – due to the dual effects of population growth and climate change (Oxfam Novib, 2010).

Energy

The primary sources of energy in all parts of the basin are fuel-wood, kerosene, candles, electricity, dung cake, diesel oil, batteries, and liquefied petroleum gas (LPG). Fuel-wood is the main source of energy in the domestic sector and is used for cooking and heating in rural areas of Indus Basin. A study conducted by World Wide Fund for Nature, Pakistan (WWF - P) and Aga Khan Planning and Building Service, Pakistan (AKPBS - P) stated that the fuel wood consumption is the only source of energy for mountain communities and the average fuel wood consumption amounts to 964,000 cubic metres during winters and 234,883 cubic metres during summers. This amounts to 1.1 million cubic metres per year. The recent studies show that, remote areas of Gilgit-Baltistan mostly depend on the forest and rangelands for their domestic energy purposes due to lack of other alternative sources of energy. Having no other alternative energy options, about 89-90% of communities in rural mountain areas exposed to extreme weather conditions particularly winters seasons, so they collect fire wood from local forests and rangelands to meet their domestic energy needs for cooking, warming and heating purposes (Babar, 2012, 2013).

Studies show that about 5 to 8 members per households consume 5.5 tons of firewood during the winter seasons of six months (AKPBSP, 2010; Babar, 2013). Forest and rangelands are the source of carbon sequestrations and play a critical role for atmospheric carbon sink. The local forest areas are under a great pressure of deforestation, so the current study will identify the other energy option for these mountain people for sustainable mountain livelihood development. The mountain people of Gilgit-Baltistan rely heavily on forest to meet its energy need, as a result forest exploitations is increasing year by year. It is essential to cogitate which renewable technologies can be encouraged in mountain areas to improve the livelihood conditions and to promote the sustainable development. In rural settlements in the northern part of the basin, electricity is primarily used for lighting and fans, while use of electrical appliances is minimal. Both the demand for electricity and the supply are affected by the seasons; winters are characterized by a reduced supply, because of the low volume of water in the rivers, but high demand for heating purposes. Summers in the low-lying valleys of the upper Indus basin are hot, and the use of air conditioners (especially in urban areas) increases the demand for energy. In GB about 126 hydro power stations ranging from (50KW to 18,000KW generation capacity) are operating with an installed capacity of 131.69 MW. Current short fall during summer is 52.04 MW and during winter it is 172.79 MW (Water and Power Department of GB Government, 2016). Seasonal migration also affects the overall demand for energy in the UIB. In winter, people migrate from the higher elevation areas to the lower valleys, there is also a significant influx of tourists to the region in summer season.

There is an outstanding potential of Hydel Power Generation in Gilgit-Baltistan, but yet GB is not connected to the National Grid, moreover poor operating practices and insufficient maintenance facilities leads to inefficient power generation. If the federal government focuses simply on the transmission line to connect Gilgit-Baltistan with the national grid, this could attract the independent power producers (IPPs) and the private sector. Women are primarily involved in biomass collection and use as fuel, and have expertise in identifying and differentiating between fuel-wood species that burn fast with high heat, those which burn at a slower pace with low heat, and those which smoke. The energy crisis is similar across the Punjab region including the project sites in Chaj Doab and Soan. Women are those most affected in both urban and rural areas, due to the limited availability of LPG. For example, with the growing scarcity of fuel-wood and other biomass resources, cooking needs in rural areas are being met primarily by dung cakes and fuel-wood. Women in rural areas of Chaj Doab spend 2–4 hours every day making dung cakes for burning and are very aware of the efficient use of energy resources at the household level, while men are mostly engaged outside the home.

In rural areas electricity infrastructures are too costly to be provided, this is why rural electrification is a is a vital issue with abundance complication (Zomers, 2003) because of real conditions like uneconomically low charges, market demand, low shading factors, in some ways, extreme political influence (Munthe, 2009). Because of these problems ruler energy security becomes uninteresting business for government agencies to get involved. This can only be solved with good tactical national policy by government and international aid. Energy security for rural mountain communities with good quality, having low economic, social and environmental problems, by using feasible renewable energy resource i.e. micro hydel option is become very important to improve the sustainable livelihoods.

Health

Health is an important aspect of life which drives the prosperity of a nation and its wellbeing. Climate change is likely to impact the health of the communities in the three study areas. The projected increase in heat or cold waves, spatial and temporal variations in monsoon occurrence and increasing humidity levels due to climate change will most probably to increase human health risks in Pakistan (Malik et al., 2012).Warmer temperatures and high humidity have strong association to increase the risk of water-borne and vector-borne diseases such as malaria, particularly in the northern basin (GOP and UNEP, 2013; Khan, 2011), and of dengue in Soan and Chaj Doab. Despite the efforts of the government, especially in Punjab, the high cost of prevention has limited the country’s ability to control epidemics. An increase in extreme events like floods, droughts, heat waves, and cold waves could also lead to a greater incidence of malnutrition, pneumonia, heat stroke, cholera, and heart attacks (GOP and UNEP, 2013).

The floods in partially or completely destroyed about 515 health units, (5 % of total facilities) in flood-affected districts in the rural areas Punjab, Sindh and Khyber Pakhtunkhwa (ADB, 2010 & WB, 2006), this damage cost is estimated to be around $50 million (NDMA, 2010). Moreover, in the flood affected areas there was an increase in diarrheal disease, infant mortality rate, and maternal health. The main challenge in such climatic disaster was a severe shortage of doctors, para-medical staff and lady health workers which reduce the chances of first aid and health care for human survival (Malik et al., 2012).For drinking water people in the Upper Indus Basin depend on fresh water from spring and glaciers. The quality of thing water is good for drinking and very few number of people surface from water borne diseases. As we move down the Indus River Basin, the water quality degrades due to contamination from human activities and proper water and sanitation management. Water supply in the two main cities of mid-hill (Islamabad and Rawalpindi) comes from Rawal, Simly and Khanpur Dam. The water is then treated through different filtration plants. However, results show that the treated water is not suitable for drinking purposes and has caused multiple health issues (Ahmed et al., 2004).Biomass fuel is the major source for cooking and heating but can lead to considerable pollution. Women are more susceptible to indoor air pollution as they directly inhale the smoke from burning dung cake, coal, and crop residues, which causes respiratory problems. Women in the Chaj Doab area reported relying more on local remedies to treat basic health problems.

Land Use and Urban Development

Loss of forest cover is a concern to the whole country, not only Hunza, and is most likely to be further affected by the impacts of climate change. Based on a survey carried out by the Food and Agriculture Organization in 2007, forests cover only 4.8% of the country and are declining at a rate of 0.2 to 0.4% per year (Khan et al., 2011: p14). The concerns are compounded by a weak capacity to enforce existing environmental regulations (Khan and Pervaiz, 2012); it is estimated that environmental degradation costs the Pakistan economy about USD 3.5 billion (PKR 365 billion) per year (World Bank, 2006, cited in GOP and UNEP, 2013). Precise estimation of forest cover is difficult as it depends on the definition used, but published sources provide an indication. The forests in Gilgit Baltistan are categorized into three classes – private forest, government protected forest, and farmland forest (WDGB, 2015). In the Forestry Statistics of Pakistan, total forest cover in the province is estimated at roughly 9,500 km2, or 13% of the total area of the province (GOP, 2004; UNDP, 2010). More recent statistics give a value of 6,500 km^2 or 9% of the geographical area of the province (GOGB, 2013). A study conducted by World Wide Fund for Nature (WWF-P) and Aga Khan Planning and Building Service, Pakistan (AKPBS - P) in 2001, that the fuel wood consumption is the only source of energy for mountain communities and the average fuel wood consumption amounts to 964,000 cubic metres during winters and 234,883 cubic metres during summers. This amounts to 1.1 million cubic metres per year. The recent studies show that, remote areas of Gilgit-Baltistan mostly depend on the forest and rangelands for their domestic energy purposes due to lack of other alternative sources of energy. Having no other alternative energy options, about 89-90% of communities in rural mountain areas exposed to extreme weather conditions particularly winters seasons, so they collect fire wood from local forests and rangelands to meet their domestic energy needs for cooking, warming and heating purposes (Babar, 2013). Studies show that about 5 to 8 members per households consume 5.5 tons of firewood during the winter seasons of six months (AKPBSP, 2010; Babar, 2013).

The forests are deteriorating due to poor management and monitoring which leads to deforestation and illegal poaching of associated resources (Karim, 2014). Increased urbanization in the Muree hills has also adversely affected forest cover in the area. Forests and agricultural lands have been converted into concrete hotels and shopping centres to cater to and entertain the tourists coming from all over the country to this hill station. Deforestation also exposes the mountains to extreme erosion during flash floods and landslides, leading to greater vulnerability of the local people. Gilgit-Baltistan is home to a variety of wild animals and birds like Marco Polo sheep, ibex, markhore, urial, blue sheep, lynx, snow leopard, brown and black bear, wolf, fox, marmot, chakor, and rame chakor. These resources are being managed for their survival and multiplication through the establishment of national parks, game sanctuaries, game reserves, and community conservation areas (WDGB, 2015). The Gilgit-Baltistan Government has declared nine community-controlled hunting areas, which are jointly managed by the communities, international non-government organizations (INGOs), and the Gilgit-Baltistan Government (WDGB, 2015).

5. Factors Co-determining Impacts and Vulnerability

Several drivers compound the impacts of the changing climate and affect the vulnerability of communities in the Indus basin, including urbanization; population growth; energy scarcity; low affordability; high input cost of seeds, fertilizers, and others; market access; price fluctuations; globalization; efficient agriculture and water management technologies; and resource endowment.

In the Upper Indus, the livelihoods and food security of mountain communities largely depend on the local resource base at all elevations, although the specific agro-ecological and livelihood potentials vary considerably. Remittances, small business, wage labour, tourism, and collection of medicinal plants and other herbs also contribute to livelihoods and food security. However, in recent years, various biophysical and socioeconomic factors have led to a depletion of the natural resource base across the Hindu Kush Himalayan (HKH) region (Rasul and Hussain, 2015). This has resulted in a significant loss of ecosystem services, particularly in terms of soil nutrients, water, and biomass, and a resultant decline in food productivity. The reduced productivity has affected food and livelihood security and increased the overall vulnerability of mountain people, as they have become more dependent on food from outside and thus exposed to market fluctuations. The fragile mountain ecosystem is suffering from degradation of forests, vegetation, and soil, and a reduction in livestock productivity, which increases the impoverished conditions of the pastoral communities and livestock farmers.

Climate change is adding new challenges in terms of water availability and changing temperature conditions (Rasul and Hussain, 2015). Predicted rainfall increases over most of Gilgit-Baltistan, particularly during the summer monsoon, could increase the incidence of floods in Hunza-Nagar district in the short term, and lead to erosion, mudslides, and glacial lake outburst floods during the rainy season (Din et. al., 2014). Warming and the receding snow line are likely to lead to drought and land degradation (Cruz et al., 2007). Almost 54% of the geographical area of Gilgit-Baltistan is rangeland (Rasul and Hussain, 2015), most of which is degrading due to increasing pressure from the human and livestock population, coupled with frequent droughts associated with climate change. In Gilgit-Baltistan, the Attabad landslide has resulted in ecosystem disturbance and unique species becoming endangered as a result of increased sedimentation and disturbed soil stability 100 km downstream from the disaster. The water in the dammed lake upstream is engulfing ecosystems and is a potential threat if it were to burst out following another earthquake, a disturbance that would affect the entire landscape down to Tarbela. The area is already characterized by heavy silting and deposition which hinders agriculture (Iqbal et al., 2014). The Astore earthquake in 2002 and Kashmir earthquake in 2005 were a precursor to the problem, and the Attabad landslide is testimony to the way in which hazards can endanger lives, property, and environmental assets.

Unplanned settlements, population growth, unsustainable farming, and a host of other anthropocentric activities have made Gilgit-Baltistan more hazards prone, with hazards likely to pose a threat to settlements, infrastructure, farmlands, water channels, and natural resources. The threat from earthquakes and landslides leads to physical, social, psychological, political, economic, and environmental vulnerability for the communities who bear the brunt of these events (Iqbal et al., 2014). Agriculture, horticulture, and livestock are the main sources of livelihood, but labour shortage is becoming a challenge for agricultural activities and communities are hiring labour from outside the Hunza valley to meet their demands. The hydropower potential has not been utilized to the fullest due to financial constraints, and the communities are facing acute energy shortages. This is also one of the major reasons for deforestation, as the dependence on firewood as fuel has been increasing. Almost one-third of the population of Gilgit-Baltistan is poor (PSLM, 2005), and Hunza-Nagar is no exception. With over-reliance on the environment for basic survival, and low capacity to mitigate the negative impacts of climate change and poverty, the population is more vulnerable than others in the region.

The Soan Basin is also facing challenges with regard to rapid urbanization, deforestation, migration of the workforce from the agricultural to the services sector, declining surface and groundwater availability, and changes in rainfall patterns, all of which are creating extreme vulnerability for a large population.

In most areas of the Sargodha division in the Chaj Doab, canal water supplies are becoming increasingly insufficient to meet the irrigation demand, which is also increasing due to the increase in cropping intensity. Farmers are relying on groundwater pumping, which has led to falling water tables. At the same time, flooding causes destruction of agricultural systems (irrigation and other infrastructure) and people's livelihoods with loss of houses and livestock. The diversion of water from the Indus river for irrigation through the construction of barrages, particularly the Kotri Barrage (Akhtar, 2015), has significantly reduced water flow from 72,158.7 million cubic metres (58.5 million acre feet) in the pre-Terbela period (1956–1975) to 33,180.7 million cubic metres (26.9 million acre feet, post Terbela (1976–2013), and has led to a 50% probability that the Indus delta will move inland (Akhtar, 2015).

6. Local Adaptation Practices and Responses

People's response to climate change was assessed in each of the sectors. Understanding the impact of climate change and glacier dynamics in the UIB is imperative for the security of large infrastructural investments in the downstream. A field visit was undertaken to identify local adaptation practices and responses. The visit emphasized understanding of the socioeconomic conditions in Hunza and the interactions were well-organized and informative. They helped the team understand the changes in the glacial system, which are the primary source of water, and communities' perceptions of climate change and their approaches to adaptation. The discussions also looked at the natural resource base and ways in which communities identified different means of using them to adapt to the impacts of climate change.

Hunza-Nagar is very suitable for growing a wide variety of food and non-food products such as fruit, nuts, off-season vegetables, seeds, and medicinal plants. The district also has a huge potential for producing handicrafts such as embroidered goods, wood-carved products, shawls, blankets, carpets, baskets, and gemstones. This potential has not been fully exploited, but could be an appropriate way of adapting to the possible loss of livelihoods, or provide a supplementary source of income during the lean agricultural seasons. Attabad-lake can be promoted as a tourist attraction. People are extremely motivated, which is an asset for this region and if properly managed can lead to more planned development in the area. Innovative ideas such as solar pumps and good advice on agriculture can help create opportunities. It is also important to promote afforestation to reduce erosion and revitalize the area.

Important aspects of water resources in the Soan basin, such as irrigation (canal and groundwater), drinking water, and conservation practices, were discussed at the meeting with the Pakistan Council of Research in Water Resources (PCRWR). In flood prone areas, some farmers have substituted cereal cultivation with sugarcane because it can be grown in short periods of standing water. The workshops conducted by PCRWR to train farmers have helped them adopt improved irrigation techniques, such as drip, sprinkler, and furrow irrigation methods. Several farmers are ploughing up to a depth of 20 cm in order to increase water infiltration into the soil during the monsoon for availability during winter, mostly for wheat cultivation. Farmers have also adopted appropriate strategies in allocating land according to the fertility and moisture requirements of individual crops (Khan et al., 1999). The traditional reliance on wheat as the main crop has changed since the mid-seventies when groundnut was introduced, which is extremely suited to the climate of the area and also a good source of fodder for livestock. The introduction of groundnut has not only increased household income, but also the number of livestock in the area, due to the abundant fodder and forage availability. Livestock are now an integral part of the farming system and conventional draught animals have been replaced with mulch animals. Improved breeds of livestock have been introduced and the majority of farmers are now keeping the best breeds of animals.

A number of farmers in the Soan watershed are shifting to growing vegetables in poly-tunnels in place of traditional crops because of the high demand in the cities of Rawalpindi and Islamabad. The areas around Taxila and Hasan Abdal are also well known for vegetable production. Olive production has started in these areas with the support of Italy and the Punjab Government. The largest area under olive is in Chakwal district where PARC has a Mega Olive Project, and Barani Agriculture Research Institute (BARI) is also promoting olive farming. Many farmers in Pakistan have already adjusted to new practices, but future weather predictions suggest a growing need for thorough and prudent location-appropriate adaptation that includes, for example, changing cropping patterns to adapt to faster growing seasons induced by the increasing temperature. Water conservation practices, particularly mulching and laser levelling methods, have also been demonstrated to farmers to help them adapt to low rainfall conditions.

Farmers have also modified their cropping patterns in response to the availability of irrigation and other modern technological interventions, and are concentrating more on commercial crops and boosting productivity.

The On-Farm Water Management (OFWM) programme also focuses on reducing water losses (which stand at close to 30%) by promoting improved designs of water channels; efficient irrigation methods such as drip, sprinkler, and bubbler irrigation; and laser land levelling for efficient and uniform water distribution. Compared to conventional irrigation, improved methods save 30–50% water in cereal cultivation, 20–35% for fruit, and 70–75% for vegetables. This intervention has been useful for farmers in the Chaj Doab in Sargodha who have been using canal water to fill small reservoirs constructed at the farm to feed into a sprinkler and drip system used for growing citrus. Cultivation of grapes and guava in the Soan watershed is expanding rapidly using drip irrigation, which was clearly observed during the fieldwork visits to selected farms in Attock and Chakwal districts. At one farm, water is being pumped from a reservoir to irrigate 7 ha (17 acres) of citrus cultivation through drip and sprinkler networks. The pump is connected to an electric motor and a diesel engine, the latter for use during load shedding. PCRWR has also been promoting organic cultivation in order to safeguard health risks to farmers while improving productivity.

Different kinds of organic fertilizer (poultry residues, green manure, residues of leguminous crops, livestock dung, and others) are being tried out in order to assess the changes in agricultural productivity, and a few farmers are already using the approach. In Chaj Doab, a very well managed farm was observed with integrated activities producing fruit, other trees, cereals, fodder, vegetables, and livestock. The household's energy demand for cooking was being met through biogas produced from livestock dung, and the shortage of irrigation water was being managed through drip irrigation. The farmer was interested in installing a solar pump, but the cost was too high. In the Chaj Doab area as a whole, both men and women reported an increase in wheat production (almost double) per unit area which they attributed to improved certified seed and high yielding varieties, use of chemical fertilizers, better irrigation facilities (tube wells), and the use of herbicides. Livestock productivity has also been reported to have increased due to improved pastures and better availability of forage crops, which were introduced with improved irrigation through construction of tube wells on a large scale. With changes in the climate and an increasing demand for food, farmers have started cultivating high yielding varieties and drought tolerant crop species, using herbicides more frequently along with fertilizers and modern tillage practices.

7. Institutions and Polices for Adaptation

The climate change policies comprehensively addresses all possible challenges of climate change adaptation and mitigation in foreseeable future; and sure to provide rock solid foundational framework for ensuing climate change action plans, programmes and projects. Various agriculture, natural resources, and livestock related interventions have been introduced by different institutions to address the issues identified in the study, tackle the poverty-environment nexus, and build the resilience of local communities. Assess and address the needs for additional infrastructure; up-gradation of the existing irrigation infrastructure to make it resilient to climate change related extreme events. The following section elaborates basin wise different policy outlines driven by different institutions.

Hunza

The Social Economic and Environmental Development (SEED) project in collaboration with its implementing organizations like WWF-GB, AKRSP, Karakoram International University, and Environment and Livestock department of GB has promoted various programmes for adaptation to climate change in Gilgit-Baltistan particularly in Central Karakoram National Park (CKNP).

- Sustainable agro-pastoral livelihoods management;
- livestock and pasture management, which includes livestock breed improvement campaigns, livestock vaccination, and training of herders in improved animal husbandry, grazing management and cultivation of fodder crops, livestock insurance schemes, and improvement of corrals and cattle sheds;
- world-class tourism and mountaineering opportunities;
- Promotion of ecotourism
- Community-based conservation practices and developed community based polices for community natural resource management;
- Developed village development plans
- Afforestation to protect vulnerable catchments with plantation of 500,000 plants on communal lands of more than 400 ha in 20 valleys; and
- Improved agricultural practices, which includes value chain development and farmer training.

The solution to the energy crisis in the upper Indus basin in GB is to lay down an effective power policy for GB. Such a policy should identify the demand in the area, the potential, the resources available for power generation, and the possibilities for investment in the sector. The identified hydropower potential in the Indus River and its main tributaries within GB is 19,696 MW, while the total estimated potential is 40,000 MW. WAPDA recently commissioned a 16 MW hydropower station at Satpara in Skardu and is currently developing two other power projects in Skardu – the 28 MW Basho and 42 MW Harpo (Siddiqui, 2011). WAPDA is also working on various mega hydropower projects in GB with a cumulative capacity of 18,720 MW. There are 27 other hydropower projects with a total capacity of 248 MW under various stages of planning at the GB government level. The project aims to interconnect all existing and future hydropower projects in a common grid to improve the diversity factor, minimize line losses, and establish a power corridor for connection to the national grid. Some other power projects are expected to be initiated by WAPDA in GB in the near future.

Soan Basin

A 60-month Punjab Irrigated-Agriculture Productivity Improvement Project has been implemented by the On Farm Water Management Department (OFWM) through participating farmers and water users' associations (WUAs) since July 2012 in both the mid-hills (Soan basin) and the plains (Chaj Doab). The plan is to bring about 50,000 ha (120,000 acres) under drip and sprinkler irrigation systems, line 5,500 watercourses, rehabilitate 2,000 irrigation conveyance systems in non-canal command areas (NCAs), provide 3,000 units of laser levellers to farmers and service providers, and train professionals (1,000), farmers (3,000), service providers (300), and technicians (200). The Agency for Barani Areas Development (ABAD) is implementing a rainwater harvesting project in Soan basin; about 950 mini dams, 1,551 ponds, 4,112 dug wells, 187 turbines, 399 tube wells, and 1,624 lift-pumps had been constructed by 2016, and 435 hand-pumps provided under different projects for domestic purposes. ABAD has launched command area development of 150 small dams operating with solar water pump-based irrigation systems. PARC is introducing solar water pump-based irrigation systems in the Soan basin and has established a climate-smart agriculture model at a farmer site in Fateh Jung, where all irrigation is operating on solar pumps. This model has a high level of acceptability with farmers and policy makers. Development agencies are developing mega projects based on the Fateh Jung model. Scaling up by PARC of activities on biogas for cooking and pumping water also deserves a special mention, as communities and development agencies are adopting these technologies.

More than 50 small dams, 1,300 mini dams, and 3,000 ponds have been constructed at appropriate locations in the Pothohar region to promote agriculture. However, the available evidence suggests that only about 30% of the projected command area has benefited from these reservoirs, while 70% remains without irrigation (NESPAK, 1991; ADB, 2006). Several studies (Iqbal and Khan, 1991; NESPAK, 1991; Shahid et al., 1996; Ashraf et al., 1999; ADB, 2006; Majeed et al., 2010) also indicate that these schemes have not yielded the anticipated benefits for several reasons. Lack of energy for lifting water was noted to be one of the key constraints; a number of pumps were installed to counter this, but lack operational affordability. Cropping intensities remained very low and several of these schemes have been abandoned as a result.

Chaj Doab

In the Chaj Doab area, PCRWR is conducting farmers' training and workshops on the adoption of improved irrigation techniques such as drip, sprinkler, and furrow irrigation methods; and soil improvement methods for agriculture such as use of poultry residues, green manure, residues from leguminous crops, livestock dung, and others. PCRWR also provides laboratory services for testing water (for both irrigation and drinking) and training courses in water quality monitoring for the water supply agencies of Pakistan, including water and sanitation agencies, public health engineering departments, and local government. Priority measures identified by the government to address some of the possible risks in the Chaj Doab include identifying rainfed agricultural areas that are vulnerable to drought and heat stress; establishing a risk management system for crop production; improving and expanding highly efficient irrigation systems (drip and sprinkler); and promoting resource conservation technologies (water course lining, laser land levelling, raised bed irrigation systems, and others). Another important strategy is the development of water resources through small and mini dams to enhance agricultural productivity and groundwater recharge. Other activities identified as important for climate change adaptation include increasing the awareness of farmers and other stakeholders of efficient land use strategies, water conservation techniques, and integrated cropping methods; strengthening extension services; strengthening agricultural research; and developing drought and heat tolerant crop varieties (GOP, 2013).

The OFWM programme is also helping to reduce water losses and increase efficiency of water use by improving water channels and irrigation methods as described in the adaptation section. OFWM organize frequent events such as farmers' days to demonstrate, and mobilize farmers to adopt, improved irrigation methods.

National Response

The Planning Commission of Pakistan established a 'Task Force on Climate Change' in October 2008 to deal with various climate change issues that Pakistan has been facing over the years, including the rapid melting of the Himalayan glaciers, increased variability of the monsoon, and increased siltation of dams. This task force has the mandate to analyse the situation in Pakistan in terms of climate change and to help policy makers in the formulation of climate change policies so that the country is able to achieve sustained development and growth. The committee is also responsible for recommending various policy measures in order to adapt and mitigate the loss to the country due to climate change and enhance the capacities of the various institutions in the country.

More recently, the Pakistan Climate Change Policy, 2012 has laid down a framework for coping with the threats of climate change through appropriate adaptation and mitigation measures. The policy focuses on development sectors such as water resources, agriculture and livestock, forestry, human health, disaster preparedness, transport, and energy. The goal is to ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate resilient development. Some of the measures include flood forecasting warning systems, local rainwater harvesting, developing new varieties of resilient crops, health impact assessment of changing weather patterns, promotion of renewable energy sources, and efficient mass transport systems. Following launch of the policy the relevant ministries and departments, as well as provincial and local governments, will devise their own strategies and plans to start the work. Policy implementation committees have been formed at the federal and provincial levels. A Framework for Implementation of Climate Change Policy has been identified by the government in terms of Priority Actions (within 2 years), Short-term Actions (within 5 years), Medium-term Actions (within 10 years) and Long-term Actions (within 20 years).

There is a specific focus on human health in the Climate Change Policy of 2012, which is a very important step forward, as the 2009 draft health policy recognized the multiple determinants of health including the environment and natural disasters, but strategies to improve the environment or to increase the level of preparedness to deal with health emergencies during a natural disaster, were missing. The National Drinking Water Policy emphasizes the provision of safe drinking water to all, especially the poor and vulnerable, specifically in areas hit by floods, droughts, and other disasters on a preference basis.

HI-AWARE

The major objective of the present institutional mapping exercise was not only to identify relevant actors but also to identify their different roles in bringing about expected change. The outcome of this exercise has shaped into engagement for strategies to build critical partnerships. Some actors have also been identified by the HI-AWARE team for working with HI-AWARE in Pakistan in particular sectors. Consortia members are expected to work closely with these partners. PARC has already starting collaborating with some and is finding ways to interact with others. They include the following:

- Collaborating partners for knowledge generation – Pakistan Meteorological Department (PMD), WAPDA, Future Water, and ICIMOD;
- Academia – Karakoram International University (KIU) Gilgit, National University of Science and Technology NUST Islamabad, Government College University Faisalabad (GCUF);
- Science and research partners – PMD, WAPDA, PCRWR, Global Change Impact Study Centre (GCISC) and ICIMOD;
- Operation and development partners – Agriculture Department, Irrigation and Water Management, Forest Department, OFWM, Small Dams, ABAD, BARI;
- Partners for scaling up and funding – Ministries of Climate Change, Water and Power, and National Food Security and Research, Aga Khan Rural Support Programme (AKRSP), FOCUS Pakistan; and WWF Pakistan, International Union for the Conservation of Nature (IUCN) Pakistan, OFWM, Small Dams, ABAD, BARI; and
- Dissemination partners – Leadership for Environment and Development (LEAD) Pakistan, Print and electronic media.

8. Conclusion

The Indus network is extremely large and the topography of the areas over which it extends is highly varied. The upper part is the main catchment area for the entire basin, and is characterized by glaciers in the snow-clad mountains of the Karakoram which provide water to the Hunza and GB areas. The lower plains areas are more rain-fed. Punjab province is a rich agricultural belt, with the Chenab and Jhelum tributaries the main sources of water for the river and the country. The HI-AWARE project has undertaken research in three sub-basins – Hunza, Soan, and Chaj Doab, representing the upstream, midstream, and downstream – on aspects of hydrology, climate, water, agriculture, health, and urban management to document the existing situation and identify the vulnerability of the people in the basin. The study also documented people's responses to the changing climate and adaptation potential with regard to the different sectors, and government policies related to climate change adaptation.

The three sub-basins showed similarities in many of the effects of climate change. Higher elevations are characterized by snowmelt, which increases the flow of the river in the summer and sometimes causes flash floods in the monsoon, but the winters are often dry and the resultant water crisis is extreme. Similar conditions are experienced in the mid-basin areas, where agriculture, which is rain-fed driven, faces a water crisis during winter as a result of the reduced rainfall and often suffers from drought-like conditions. From the energy perspective, too, the demand for electricity may be apparently low, but the cold winters mean that heating is essential, and in general the need cannot be met by the existing system as insufficient river flow in winter limits power generation capacity. This is turn means that there is a high dependence on fuel wood, leading to deforestation and degradation of grazing land. The lower basin is a rich agricultural belt, but salinity problems are increasing. These areas have also been facing moderate floods over the years, but their intensity is increasing which creates havoc, as the floods damage crops and other assets. Although groundwater recharge is possible due to the close proximity of the Chenab River, the area is experiencing low levels of water in the canals, the main source of irrigation, in winter. The resultant increasing reliance on groundwater is ultimately affecting the water table, which is declining rapidly. Farmers consider that the actual water available in the canal has not gone down, but the requirement has increased because the rainfall regime has shifted and the onset of the summer and winter season is now delayed. The increasing temperatures reported from all parts of the basin indicate that there is likely to be an increase in the incidence of droughts and heat waves.

Health effects being experienced by the local communities include an increase in malaria and dengue. Unfortunately, the Pakistan Government is not sufficiently equipped to deal with the rising number of cases of such diseases, a further indication of how vulnerable the communities are. The capacity for energy production is very limited. Large projects require a huge investment which the Government of Pakistan cannot afford, resulting in a deadlock; investment by the private sector may help. The city of Gilgit faces 20 hours of power cuts per day in winter and 8 hours in summer, when the power generation is doubled. The link between climate change and people's access to water resources may need further research on the cryosphere, upstream and downstream interactions, and the anomalous behaviour of glaciers. A deeper understanding of the perceived stronger monsoon pattern in UIB is needed, which requires increasing the number of hydro-meteorological stations in UIB and strengthening various kinds of environmental monitoring. More research is also required on the nature of the climatic changes that are occurring in UIB and what it means to the local communities. Integration of science for the benefit of people is a must, and building the capacity of the youth and local institutions is important for the UIB network. Rapid social and demographic changes are occurring in the UIB, which should be studied together with biophysical science. Current policies on adaptation are rather weak and need better integration with existing policies in all the relevant sectors such as water, agriculture, urban development, environment, and health. However, several organizations have undertaken projects to improve mitigation and adaptation in different sectors, with a special emphasis on research, operations, dissemination, and collaboration.

This situational analysis has been extremely useful as it has thrown light on some of the most critical points of policy uptake, especially from the perspective of livelihoods and disaster. As the intensity of flash floods is expected to rise, the Chairman of PARC has proposed that the government should increase investments in building reservoirs and other rainwater harvesting structures, as well as check dams and diversions, and afforestation programmes. These investments could also help in improving the food security and livelihoods of the poor people living in these marginal areas. The focus should be on introducing cost effective technologies for small farmers along with micro-finance schemes. The Soan basin has a very high potential for growing food crops like wheat, maize, beans, pulses, fruit (grapes, falsa, citrus, guava, loquat, and others), vegetables (using poly tunnels), and canola and olive oil crops. Interventions in this area should focus on improved varieties of these crops and the introduction of heat and moisture resistant species. Crop insurance schemes for small farmers should be supported in view of the increased frequency of hydro-meteorological hazards. Discussions in the field also revealed the farmers' need for certified seeds and plants at low prices, to be made available at locally established plant nurseries and seed stores. High input costs and low quality of seed and fruit plants have been affecting the potential for profit and thus discouraging the uptake of certain crops. The need for proper fodder and grazing management systems to sustain livestock rearing is also considered crucial. Improved access to markets for selling fruit and vegetable produce would also be highly beneficial for the communities.

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