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Challenges Faced by Upper Indus Basin (UIB) Communities due to Climate Change

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Abstract

The Upper Indus Basin (UIB) communities are heavily dependent on water resources for their sustenance. The region relies on glacial and snowmelts for irrigation water, energy, domestic and irrigation uses. Climate change poses threat to vulnerable region all around the world, and Upper Indus Basin (UIB) is no different. The variability in climatic conditions such change in precipitation pattern and temperature fluctuations have disrupted the agriculture practices of the region and threatened food security and livelihoods of the people living in the basin. The transboundary region of Upper Indus Basin is constantly under tension due to geopolitics of the countries involved and the consequence of climate change tend to add to the challenges faced by people living in this region. The research aims to understand effect of climate change on the complex hydrological regime of the basin and its consequence on the communities living there. Furthermore, it intends to explore nexus of climate change with broader socio-economic trends such as demographics, land use patterns and economic activities. The study delves into the implications of changed hydrology and glacial system on agriculture and pastureland productivity. The research also helps in understanding the heightened vulnerability of UIB communities due to increased susceptibility of natural calamities like glacial lake outburst floods (GLOFs) and flash floods. The study seeks to contribute valuable insights to the global discussion on climate change impacts, drawing attention to the need for targeted intervention to protect the wellbeing of Upper Indus Basin (UIB) communities and guarantee the sustainability of this critical watershed region.

Keywords: Food insecurity, pastureland depletion, hydrological regime, climate change, Upper Indus Basin.

INTRODUCTION

The Upper Indus Basin (UIB) comprises the mountainous landscapes of the Hindu Kush, Karakoram, and Himalayan Mountain ranges. This transboundary basin is shared (Figure 1) by Afghanistan, China, India, and Pakistan, is globally recognized for its paramount importance due to the dependency of human on its water resources and agricultural activities. The basin is drained by a cross-border river system, encompassing the western rivers (Upper Indus, Kabul, Jhelum, and Chenab) and the eastern rivers (Ravi, Beas, and Satluj). The water resources in the UIB are seasonal and heavily dependent on runoff from snow and glacial melt in spring and summer, along with the monsoonal rainfall during the summer season.

UIB is home to nearly 300 million people, out of which 61% live in Pakistan, 35% in India, 4% in Afghanistan and less than 1% in China. The basin has seven main rivers (Figure 2) that are the sources of irrigation for over 16 million hectares of

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agricultural land. The water resources of the UIB are used for agriculture, power generation, domestic use, industry, tourism, fishing, and religious practices, as well as supporting a rich diversity of terrestrial and aquatic ecosystems. However, the availability of water, food and energy in this region are inextricably linked with sustainable water supplies, which is prone to alteration by climate change and stressed by increasing population, socioeconomic development and ecosystem services.

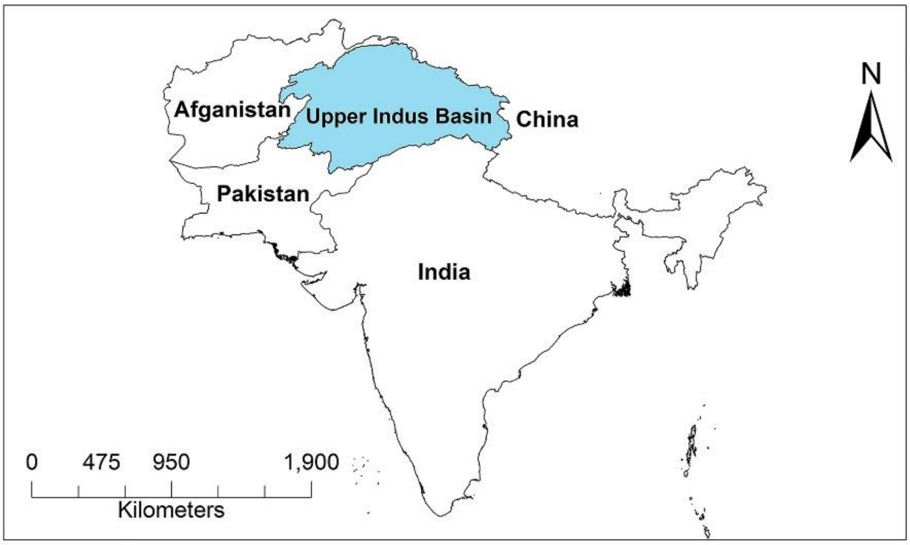

Figure 1. Map showing location of UIB with respect to Afghanistan, China, India, and Pakistan.

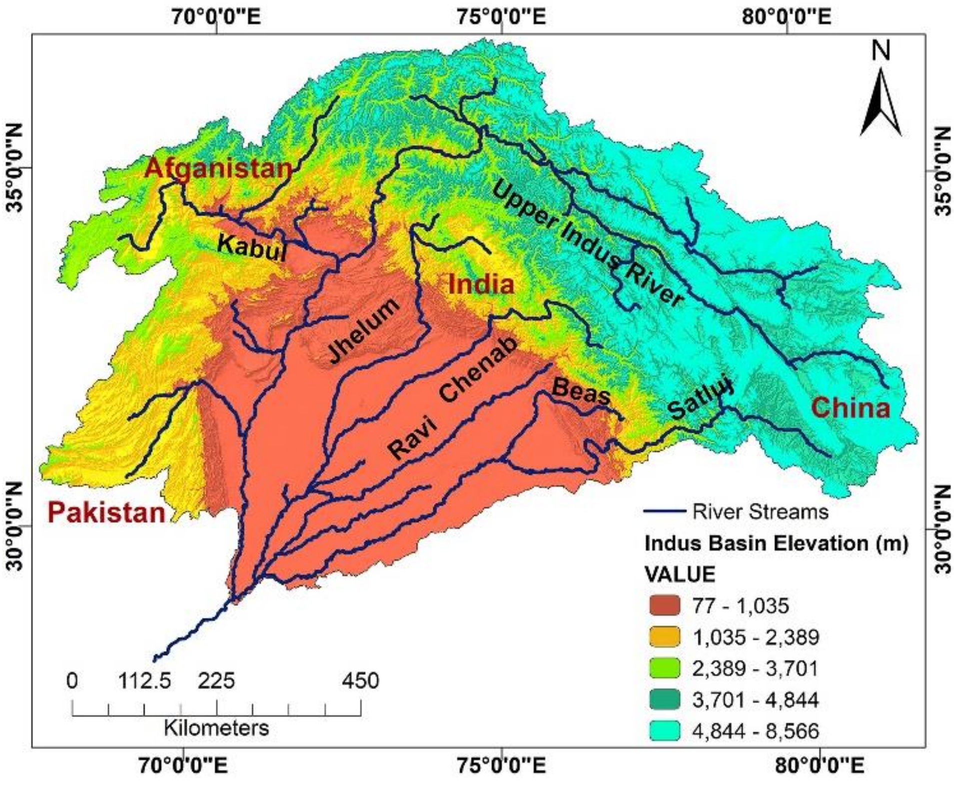

Figure 2. Map showing the seven major rivers of Upper Indus Basin (UIB).

One of the most alarming and evident impact of climate change seen in the Upper Indus Basin is the shrinking of glaciers. The retreat of glaciers in the Hindu Kush, Karakoram, and Himalayan mountains directly affects the flow of water across the seasons in this region. The hydrological system

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of the basin is dependent on slow release of water from the gradual melting of the glaciers. Under the anticipated climate scenario, it is assumed that in a 1.5 and 2 °C warmer world, the temperature in the HKH region may rise to 2.1 and 2.7 °C respectively. This affects the availability of water for farming and energy generation, which overall affects the well-being of the people in this region.

The accelerated transformations in the basin's hydrometeorological regime exposes the UIB communities to extreme weather events such as floods and droughts. This poses threat to infrastructure, food productivity and overall resilience of the communities (Jamal H.,2022) [5]. An additional layer of complexity is added to the lives of the basin dwellers due to the transboundary nature of the UIB.

The communities in this region rely on traditional agricultural practice, alterations in water availability and changing rainfall pattern severely affect their livelihood. UIB farmers contributes around 30%–40% to the annual food requirements of the local people the region. The uncertainties induced by climate change and the pressure to sustain food security make the community vulnerable. It heightens the risk of poverty thereby transforming the socio-economic fabric the communities.

The study aims to understand the complex and interconnected impact of climate change on the communities residing in the Upper Indus Basin. It involves understanding how various aspects of climate change, such as glacier melt, altered precipitation patterns, extreme weather events, and changes in water availability, collectively affect the social, economic, and environmental conditions of the people living in this region.

LITERATURE REVIEW

Geographical Setting and Historical Background

Situated in the northern part of the Indian subcontinent, the Indus basin is majorly shared between Pakistan and India, that is 47% and 39% respectively. The remaining 14% is distributed in Afghanistan and China. The region encompasses a complex landscape characterized by fertile valleys, impassable mountain ranges and seven mighty rivers.

The region is largely defined by its mountainous topography, consisting of Himalayas, Karakoram and Hindu Kush Mountain ranges. These towering mountain ranges are not only responsible for the physical geography but also play a significant role in influencing climate, precipitation patterns and river systems.

In the south of the upper Indus basin lies the Himalayan range which acts a natural boundary between the Indian subcontinent and the Tibetan Plateau. Towards the northwest lies the Karakoram ranges which forms a barrier between Pakistan, India and China. The range is home to the world’s second largest glacier; Siachen Glacier, outside the polar region. In the west lies the most challenging and rugged terrain of the Upper Indus region; the Hindu Kush range runs through Afghanistan and northern Pakistan.

The Indus River, originating in Tibet, is the lifeline of Upper Indus Basin (UIB). Along with its tributaries such as Jhelum, Chenab, Ravi and Sutlej, is responsible for irrigating the plains and valley and supporting human settlements since ancient times. The region includes the fertile valleys of Kashmir, Gligit and Chitral. Deosai National Park is responsible for a diverse ecosystem of flora and fauna in the region.

The Upper Indus Basin stands a testament of rich history of human endeavors, cultures, empires and civilization. From the world oldest civilization, Indus valley civilization to the invasion of Arabs in the 7th century to regional partition for creation of Pakistan and India in 1947 the region has

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withstood and experienced it all. Fast forwarding to 21st century the region in the limelight of geopolitical complexity, including territorial disputes, communal tension and conflicts.

Hydrological Background

Originating from the Tibetan Plateau, the Indus River flows through India and Pakistan, draining the world's highest mountain ranges. The Upper Indus Basin is often referred to as the "Third Pole "as the basin holds more than 20,000 sqkms of perennial ice (Romshoo,2012) [6]. The basin experiences two principal weather systems because of the divide by the Himalayas. The southern and eastern UIB being primarily influenced by the Indian summer monsoon. While the western basin which includes the Karakoram and Hindu Kush Ranges mainly experiences a semi-arid climate, the height of the mountains limits the disposition and influence of monsoon in the region. Precipitation is received in this region during the spring and winter in form of snow due to western disturbances. At elevation below 2500m and elevation above 5000mm, maximum precipitation recorded is 200mm and 1500mm respectively. Most of the hydrological activities such as melting of snow occur at higher elevation which contributes to river runoff from month of March to September. An annual average of 175 billion cubic meters is discharged into the Indus Plains (Bhutiyani,2009) [9].

The arid environment of the basin wasn't suitable for rain fed agriculture therefore Indus Basin Irrigation System (IBIS) was developed during the British colonial era. In today's time it is the largest integrated system in the world. It relies mainly on Tarbela and Mangla storage reservoirs which covers about 18million hectares of irrigation command area that constitutes 78% of Pakistan's total cultivatable land (Romshoo, 2012) [6]. Infrastructure developments facilitated by the treaty, such as Mangla and Tarbela dams and link canals, increased irrigated land and cropping intensities. This, in turn, contributed to better water management and food production.

Another important development in the area was the Indus Water Treaty (IWT) of 1960 between India and Pakistan brokered by the World Bank. This crucial agreement aimed to resolve water related issues between the two countries by dividing the six major rivers of the basin into eastern and western rivers. India was allocated the eastern rivers – Ravi, Beas and Sutlej, while Pakistan was allocated the western rivers -Indus, Chenab, and Jhelum which are crucial for the hydrology of the UIB.

The geographical division between India and Pakistan was on religious grounds rather than on the basis of hydrology in the area. This resulted in a physically asymmetric hydrological divide between the two countries (Romshoo, 2012) [6]. Therefore, one of the most important impacts of the treaty on the hydrological regime is the controlled flow of water in UIB. The regulated flow ensured a consistent water supply in Pakistan and increased concerns about water scarcity in upstream region of India.

Moreover, changes in rainfall patterns, temperature changes and glacial melts heavily influence the water flow of the rivers under the IWT. Collaboration and cooperation between the two countries is much need to provide a framework for water management to help adapting to these changes.

Effect of Climate Change on Various Water Resources

The effects of climate change in the basin can be studied by examining three distinct regimes that represent the nexus of climate and river flow:

1. Glacial regime at elevation above 5000m where river flow is closely dependent on summer temperature.
2. snow regime at middle altitude catchment area, south of Karakoram Range that receive water mainly through melting of snow during summers.
3. Foothill catchments have a runoff or Rainfall regime dependent on liquid precipitation received mainly during the monsoon season.

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Glacial Regime

According to the report published by World Wide Fund for Nature (WWF, 2005), [15] impact of climate change on glacier fluctuations is natural and long-term phenomenon. While climate change is inevitable and has been observed throughout history, in the last few decades the fragile high mountain environment has seen drastic changes as a result of global climate change. Satellite observations confirmed by UNEP (2010) [17] confirm the glacier recession and emphasize on the widespread loss of mass because increased global temperatures.

River Hunza and Shyok facilitating the northern Ladakh region are heavily dependent on runoffs from alpine glacier of the UIB. This runoff is positively correlated to the summer temperatures. Which means if the atmospheric temperature increases, the transformation of precipitation in liquid form also increases at high altitudes (Hasnain 2005; Kadota et al. 1993) [18, 19]. This results in accelerated glacier retreat and trigger future downstream flooding. According to linear regression analysis by Archer (2003) [12] research suggests an 17% increase in runoff for river Shyok and 16% increase for river Hunza per 1 degree rise in mean summer temperature. Together the two rivers contribute to more than 25% of water inflow of Tarbela Dam, which is one the world's largest irrigation system.

The consequence of climate change in the Upper Indus Basin is a global concern as it plays a crucial role in providing water across Pakistan and India. The initial reports and studies suggested severe glacier retreats in the belt. Contrary to the worldwide trend of shrinking of glaciers, the newer emerging evidence suggests that the glaciers in the Karakoram Range have rapidly thickened since the mid -1990s. This is probably because glacier at higher elevations may not respond immediately or drastically to the climate warming as those at lower elevation (Ageta, Y. and Kadota, T. 1992) [10]. The temperature data from the Upper Indus Basin supports growth and stability of glaciers in the region. Despite regional temperature fluctuations, the temperature in higher altitude remains below freezing levels.

The complexity of the Himalayan glaciers' dynamics cannot be fully understood because of lack of comprehensive long-term data. The available information is limited to terminus location data making it difficult to analyze the interplay of climate variability and anthropogenic influence of aerosols, deforestation, forest fires, human-induced pollution, and greenhouse gas emissions on the glaciers of the UIB region.

Snow Regime

The snow regime is the most important because the area covered by seasonal snow surpasses that of perennial snow and ice. This zone covers a large part of upper Jhelum basin which is directly related to winter precipitation and runoff in the summer season.

In the research carried out by Archer and Fowler (2005), [2] the connection between runoff and temperature in the snowmelt-fed catchments shows a negative correlation. The negative correlation results in increased evaporative losses from the snow under high temperatures resulting in lesser runoff. 18% reduction is estimated for every 2 degrees rise summer temperature. This reduction in water availability would result in food insecurity and increase stress on the livelihood of the communities living in the basin.

Rainfall Regime

The southern foothills of Himalayas and the neighboring plains to the south depend on seasonal runoff resulting from monsoon rainfalls. Although when compared to seasonal runoff by glacial and snow sources, monsoon runoff is less volume but it is more intense. The intensity of the runoff is such that it results in the most significant floods along the mountain margins.

According to research done by Archer and Fowler (2005), [2] there has been a statistically significant increase in summer rainfall in the basin and this rise appear widespread across much of

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Pakistan. The disastrous flood of 2010 is a result of the same. The flood affected approximately 20 million people, destroyed agriculture and infrastructure and left millions vulnerable to malnutrition and waterborne disease.

The precipitations received in Upper Indus Basin (UIB) is influenced by both westerlies and Indian summer monsoon and its connection to the El Nino Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). Global weather especially the Indian summer monsoon is significantly affected by El Nino. Studies done by Archer (2005) [2] has shown interrelation between El Nino and winter precipitation in the UIB. By using Multivariate ENSO Index (MEI) and temperature and rainfall data during the strongest El Nino and La Nina years it was found that winter rainfall severely increases during El Nino. However, a negative relation was seen between La Nina and winter precipitation, that is winter rainfall reduced during La Nina.

Studies done by Gardelle (2013) [4] have shown that most Himalayan glaciers have been melting at rates ranging from a few meters to several tens of meters per year as a result of global warming. After carefully examining the meteorological data of 36 years (1973–2008) from the Field Research Laboratory in Leh, revealed a noticeable increase of 1 degree Celsius in the low temperature of the winter season. Similarly, an increase of 0.7 degree Celsius was seen in the maximum temperature during the summer months over the same period of time. Snowfall is responsible for 70% of precipitation in this region has decreased by 4mm over the same study period. While, summer rainfall contributing to the remaining 30% of the total precipitation has declined by 3mm (Bhutiyani,2009) [9]. These alternations highlight the urgency to address climate change impacts glacial and hydrological systems and ecosystem of the region.

Effect of Population Growth on Water Resources

Notable population growth in certain areas of Upper Indus Basin, such as the Kashmir valley has been witnessed over the last decade. The population surge in this region exerts extreme pressure on the water demand, thereby declining per capita water availability throughout the basin. In the lower regions of the basin, per capita water availability is already below the critical threshold of 1000m3/capita. The world bank [16] defines basins as “water stressed “, if the per capita water availability is below 1700m3 per year and “water scarce “basins to those below 1000m3 per year.

According to above categorization a major part of the basin; Pakistan has already crossed the threshold of “water stressed”. The UN projections for 2025 and 2050, indicate per capita estimates of only 711 and 522 m3 for Upper and Lower Indus Basins respectively. This estimate concludes that Pakistan might experience water scarcity by 2035.

Other than, the rapid growth in population is also responsible substantial environmental and socio-economic changes in the Upper Indus Basin (UIB). It has led conversion of fertile agriculture land into land for settlements. The hydrology and climate patterns of the regions have been severely altered due to large scale deforestation, denuded landscape and diminishing grassland to provide land for economic activities like tourism, increased demand for timber and construction of hydroelectric power plants. The change in the hydrological have resulted in a shift from agriculture to horticulture practices, decreasing stream flow, elevated sediment and nutrient loads, deterioration of fish habitat and water quality (Romshoo, 2012) [6].

CHALLENGES FACED BY UIB COMMUNITIES DUE TO CLIMATE CHANGE

Agriculture and Food Security

Agriculture is the main occupation in the Upper Indus Basin (UIB). Majority of the farmers in this region are owners of small landholding of an average size of 0.63 hectares. UIB farmers contribute to 30% - 40% of the total food consumption at a local level. The water sourced from the Hindu Kush Himalayans play a significant role in the production of over 500 million tons of cereals. annually. This

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amounts to nearly 55% of Asia's cereal production and 25 % of the global production. According to Nellemann and Kaltenborn (2009) [20], climate change not only limits the water availability in the region but also poses disastrous impact on food production. Confirmed by UNEP (2009) [21] environmental degradation in the UIB region could result in a 10% to 30% annual decrease in cereal supply when compared to projected demand and 1.7% -5% reduction globally.

The world's largest irrigation system, the Indus basin depends on snow and glacier melts for more than 45% of its flow. 80% of the agriculture practiced in this region is dependent on rains and slightest of change in the precipitation pattern can have major social and economic impacts. Since a large population is relies on irrigated agriculture and meltwater, the upstream discharge and downstream food security of the region becomes highly sensitive to climate change. Changes in food production could decrease the number of people that can be fed in the Indus basin by 26.3 + 3.0 million.

Such change could largely affect countries like Pakistan where 13 million hectares of cultivable land remains barren due to water scarcity. In Water for Food and Rural Development (2000) by Habib Zaigham [13] reports that despite 80% of Pakistan's food demand is supplied domestically, the increasing impact of climate change leading to degradation of land, and decreased water flow pose sustainability challenges on the country.

Effects of climate change UIB includes loss of agrobiodiversity and degradation of traditional irrigation systems directly effects the agriculture of the region. Also, the reduced interest of younger generation of the region in farming poses serious threats to local food requirements and sustainability of food systems (S. Tuladhar, 2022) [7]. Consequently, affecting the demographics by increase in out migrations and labor shortages.

Moreover, changes in local food habits influence the farmers' decision about the type of crop that must be sown. Trends in the region have shown a transition from diverse to monoculture or monocrop practice which may impact the water consumption, especially if they are irrigated by using traditional system fed by glacier and snowmelts; locally called kuhl or gole and springs face depletion due to various climatic factors (Andrew 2020) [1]. The shift from organic to inorganic farming by using chemical fertilizers to meet the growing local food demands a major reason for pollution in land and rivers in the UIB region.

Extreme Weather Events

In 2010, Pakistan faced the worst natural calamity of the country's history caused by the Indus flood. The flood affected 6.88million hectares of fertile valleys of the country, destroying 24% of the standing crops of the total produce of the region. A total of 49 out of 81 cultivable districts were flooded resulting in an estimated loss of US$2.9 billion to agricultural sector alone (Sehrish Khan, March 2021) [8].

In the monsoon month of July 2010, the global temperatures were already on rise making it the hottest year on the record. High glacier runoff had already increased the river levels. Evaporative rate over the Indian Ocean increased above average resulting in highly active monsoon. The severity of the monsoon worsened due to oceanic phenomenon La Nina. Hence flooding was a result of combination of events related to global warming.

Michael Blackburn from the University of Reading study the event and found a global link between the fires in Russia and precipitation activity in Pakistan through polar jet stream. This was responsible for increased levels of moisture over the Himalayas which in turn resulted in heavy pours in the Indus Valley region (Marshall, 2010) [11]. While evidence of climate change cannot be based on a single meteorological event, exceptionally heavy monsoon over India has increased rather doubled in the last decade.

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Extreme weather events such as floods and droughts not only affect the agriculture sector but also tourism, the most popular non-agricultural livelihood in the basin. Such events often led to parallel disasters such as road blockages and landslides which hinder the tourism logistics and accessibility. This discourages tourism and affect the livelihood of several increasing economic stress in the communities.

Depletion of Groundwater Resources

The rapid increase of population in the UIB region, which is mainly shared by India , the most populous country in the world and Pakistan has resulted in expansion of irrigated agriculture . This has led to rise in demand of water for irrigation. The limited canal networks in the region along with diminishing water supply fails to meet the surge in irrigation needs.

Hence, farmers have turned to groundwater pumping to fulfill this gap throughout the basin, excluding mountainous upper basin. In India availability of subsidies has further incentivized groundwater usage for irrigation. This has resulted in a significant depletion of groundwater, effecting its long-term sustainability.

The issue has aggravated by declining recharge from snow fed catchment area and reduced stream flows. Excessive extraction of ground water leads to degradation in quality of land. It makes the land alkaline and increase salinity renders it unsuitable for agriculture. It may also result in an imbalance in downstream groundwater system, as the aquifer system is interconnected (Romshoo, 2012) [6]. Over pumping of groundwater reservoirs, differing surface and groundwater usage in both upper and lower basin could potentially compromise downstream groundwater availability.

However, intensive research on depletion of ground water resources in UIB region and its impact on the shared aquifer system has not conducted. Therefore, a comprehensive study to understand the potential and interaction of aquifer system in the basin is necessary for the formulation of a groundwater management plan.

Degradation of Pasture Lands

Climate change is closely related to the quality of land. Studies suggest significant negative effects on grassland productivity and the distribution and composition of plant communities. Shafi and Romshoo (2008) [22] documented degradation of pasturelands within the Upper Indus’s Jhelum basin. This degradation results to a reduce carrying capacity of alpine pastures. The Tibetan plateau has already experienced a degradation of 40% of its dry land.

The deterioration impacts the livelihoods of local communities, where sheep rearing and other livestock serves a primary income source. Households find it difficult to maintain animal stock and accessing pasturelands for grazing becomes challenging. Consequently, the local dairy enterprise and wool manufacturers experience the brunt of reduced pastureland productivity.

Glacial lake Outburst Flooding (GLOF)

In the last 200 years, 35% of the most devastating floods from glaciers have occurred in Karakoram, primarily resulting from the advancing of glacier across major headwater streams. The sudden advancement of the Chong Khumdan glacier into the headway of Shyok River seen in the satellite imagery of 2009 showed glacier behavior similar to the one between 1926 and 1929. This very behavior during this period led to formation of large ice dams, leading to four catastrophic floods. The rise in the river could be observed from 1,100km away at the Attock gauging station (Romshoo,2012; Dahri,2021) [6], [3].

It has been documented that glacial lake outburst floods (GLOFs) occur in every 3-to-10 years span in this region. Although the severity of large outburst floods like those in 1890- 1905 and 1925-1935

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have reduced, the frequency of occurrence of GLOFs have increased (Archer, 2003) [12]. Several GLOFs on small tributaries near Gilgit have been reported in the past decade causing damage but none of them took the turn of converting into a flood.

The flooding outburst have a potential of damaging hydropower infrastructures developed along the major rivers which are responsible for energy in the Upper Indus Basin. The communities in the basin are heavily depended on hydropower for tourism activities, mining, livelihood and basic functioning of their villages and cities. Loss of energy resource would heavily disrupt their socio-economic activities. An assessment conducted by Romshoo (2012) [14] by using BREACH and FLDWAV models showcases the damaging effect of the damming of water in the form of a glacier lake at the Panjtarni glacier on hydropower infrastructure. The results of the study predict the catastrophic effects of GLOF could last up to 9 hours, extending up to 100 km downstream from the potential outburst site, with a computed discharge at the proposed powerhouse site being about 69,250 cusecs, significantly surpassing the recorded peak discharge of the Sindh River in the UIB.

DISCUSSION AND CONCLUSION

Various studies have shown evidence of climate change in the Upper Indus Basin which has been extensively documented in the previous chapters. However, there is a noticeable knowledge gap in the data to accurately evaluate the repercussions of climate change on stream flows, drinking water supplies, irrigation, food security, and cryosphere. The present study is an attempt to open a dialogue to bridge this gap. It is crucial to amalgamate the sciences of climatology, hydrology, and modeling to conduct meaningful impact studies in the above-mentioned sectors. These forward-looking impact studies are necessary for the formulation of resilient strategies that can help mitigate the challenges of climate change on depleting water resources and corresponding sectors in the basin.

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