Original article

APN Science Bulletin

2023, Volume 13, Issue 1, 87–101, e-ISSN 2522-7971

Climate change risk perceptions, vulnerability, and adaptation in high altitude farming regions of Hindu Kush Himalaya

Saeed Ahmad Asad[a]*, Muhammad Abid[b], Ishfaq Ahmad[c], Gopal Thapa[d], Tashi Dendup[e]

[a] Department of Biosciences, COMSATS University Park Road, Chak Shahzad, Islamabad, 45550, Pakistan

[b] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Pakistan

[c] Asian Disaster Preparedness Centre, country office Islamabad, Pakistan

[d] Nepal Agroforestry Foundation, Nepal

[e] College of Natural Resources, Royal University of Bhutan, Bhutan

* *Corresponding author. Email: saeed.asad@comsats.edu.pk.*

ABSTRACT

Hindu Kush Himalaya (HKH) is highly vulnerable to climate change, but there is the least understanding of the impacts of climate change. This study explored local climate change risk perceptions, vulnerability, and adaptive responses in the three HKH countries, Pakistan, Nepal, and Bhutan. For this purpose, 379 farm households from low, medium, and high elevations in the study districts of Rasuwa in Nepal, Gilgit in Pakistan and the Central District in Bhutan were surveyed. A semi-structured digital survey was used for data collection. Further, the study used the IPCC climate vulnerability framework to explore the farm-level vulnerability to climate change in three HKH countries. The study revealed that farmers in the study areas strongly agreed that the climate was changing in the region with high summer temperatures and increasing frequency and intensity of weather-related extreme events. Increasing poverty and limited institutional services make farmers more vulnerable to climate risks. Farmers reported reduced agricultural productivity and decreased revenue caused by climate change. Crop yields at high altitudes were slightly higher, but only because of multiple cropping triggered by weather patterns. Lack of information, resources, and institutional support significantly hamper the farmers' adaptive capacity. A small fraction of the farmers adopted improved crop varieties and land management. The study recommends improving outreach and institutional services, especially climate-specific farm advisory services in HKH countries.

DOI 10.30852/sb.2023.2184

RECEIVED 8 December 2022

PUBLISHED (HTML) 27 June 2023

PUBLISHED (PDF) 27 June 2023

CITATION Asad, S. A., Abid, M., Ahmad, I., Thapa, G., & Dendup, T. (2023). Climate change risk perceptions, vulnerability, and adaptation in high altitude farming regions of Hindu Kush Himalaya. *APN Science Bulletin*, *13*(1), 87–101. doi:10.30852/sb.2023.2184

KEYWORDS

Climate smart agriculture, mountains, farm advisory, livelihood, adaptive capacity

HIGHLIGHTS

- Farmers expressed that climate change is hampering agriculture in the study areas.
- Multi-cropping at high altitudes slightly increased agricultural productivity.
- A small number of farmers were adapting through improved agricultural practices.

1. INTRODUCTION

The world is witnessing severe changes in climate in the form of increasing temperatures, uncertain rains, and increased intensity of extreme weather and climate-related events. The impacts of these changes have been increasingly overwhelming, particularly for developing countries with the least adaptive capacity to cope with the adverse effects of climate change (Abid, Scheffran, Schneider, & Elahi, 2019). Future projections suggest a more variable climate with high vulnerabilities in lower-income countries. With no exception, the Hindu Kush Himalayan region is among the areas experiencing rapid global warming. A recent ICIMOD report shows that even if the world can limit global temperature rise to 1.5 °C, warming in the HKH region will likely be between 0.3 °C–0.7 °C having deleterious impacts on mountainous ecosystems (Rana, Kaur, & Sharma, 2021).

The ongoing and projected changes in climate could trigger a multitude of biophysical and socioeconomic impacts in the form of increased glacial melting, biodiversity loss, and changes in river runoff with adverse effects on agriculture, hydropower, and water quality in some regions (IPCC, 2022). The high mountains supporting agricultural livelihoods for centuries are now at high risk due to climate change (Hussain et al., 2021). For instance, agricultural communities depend on adequate soil moisture levels at planting time, often relying on irrigation water from upstream glaciers and snowmelt water, which are now exposed to risk due to cryosphere changes (Mukherji, Sinisalo, Nüsser, Garrard, & Eriksson, 2019). The relative poverty in high-altitude farming regions contributes to their vulnerability to the impacts of these ongoing and future climate changes (Gioli et al., 2019).

Agriculture production in the Hindu Kush Himalayan region is overwhelmingly represented by small-scale monoculture or bi-culture subsistence farms. With increasing recognition of potential climate changes in the Himalayas high-altitude areas, scholars and policymakers are increasingly concerned about how these changes impact the local agricultural systems and what coping mechanisms are being adopted (Mishra et al., 2019). However, limited research on high-altitude farming regions regarding potential climatic changes makes it difficult to understand the exact picture. Further, most of the studies from high-altitude regions (e.g., Krishnan et al., 2019; Usman, Pugh, Ahlström, & Baig, 2021; Wester, Mishra, Mukherji, & Shrestha, 2019; Zahoor et al., 2021) use top-down approaches incorporating scenario-based analysis and future projects and often fail to cover the local socioeconomic dynamics and factors which define a certain adaptation and coping behaviour. The literature on local vulnerability to climate change available from high-altitude regions (e.g., Gupta et al., 2019; Pandey et al., 2018; Venus, Bilgram, Sauer, & Khatri-Chettri, 2022) suggests that increased variability and uncertainty in weather and climate have led to increased uncertainty in the region's agricultural production. This uncertainty in agricultural output often also negatively impacts local livelihoods, mainly tied to the subsistence agricultural system. However, individual farm-level impacts of these changes may affect the magnitude and variability of the stressors, the ability of the farmers to cope with the stressors, and the availability of information, resources, or tools that farmers may use to understand the resilience of their systems. Further, non-climate stimuli also impact farm-level adaptation decisions and make the decision-making process more complex, which may be further characterized by several political, economic, institutional, and biophysical factors (Abid, Schilling, Scheffran, & Zulfiqar, 2016). In addition to external conditions, internal factors such as personal characteristics, social behaviour, attitudes, farming practices, and individual circumstances may also define a particular individual farmer's response and adaptive capacity (Bryan et al., 2013).

To support farmers in adapting to climate change in high-altitude farming regions through innovative policy measures, an in-depth understanding of climate vulnerability, along with an understanding of local perceptions of climate change, related risks and their impact on local production systems, is needed. Further knowledge of current adaptation patterns and vulnerability aspects may also help to devise need-based policies and capacity modules for farmers and relevant institutional capacity measures. Considering this critical knowledge gap, this study aims to explore the research gaps through field data collection and empirical research to better understand the vulnerability of farming communities in the HKH region, focusing on Pakistan, Nepal and Bhutan. For data collection and further analysis, the study took the climate vulnerability framework of IPCC (2014) as a reference. Further, it follows the studies by Abid, Schilling et al. (2016) and Schilling, Freier, Hertig, and Scheffran (2012) for the selection of indicators exploring the vulnerability of farming communities, starting with the assessment of farm-level risks and associated adaptation behaviour of farmers. In the next step, we measure farmers' sensitivity to various perceived risks, followed by exploring farmers' adaptive capacity and various constraints and bottlenecks in adapting to climate change.

In the first step, this paper briefly synthesizes vital aspects of farm-level vulnerability and adaptation in HKK study countries to climate-related risks (1) and provides an overview of the vulnerability concept (2). This is followed by a methodology section (3) that includes the study framework, sample design, sampling and data collection, and description of study areas. In the next step, the study's findings are further divided into sub-sections per the study's objectives (4), followed by the conclusion and recommendations section (5).

2. FARM-LEVEL VULNERABILITY TO CLIMATE CHANGE

The vulnerability concept has its root in various disciplines, such as natural hazards, climate change, food security, and political ecology. Different meanings and interpretations are used to explain the concepts (Brooks, 2003; Smithers & Smit, 1997). For instance, biophysical vulnerability often focuses on the likeliness, magnitude, frequency, and extent of natural hazards (Belliveau, Smit, & Bradshaw, 2006; Turner et al., 2003). On the other hand, social vulnerability focuses more on socioeconomic and political factors while explaining the capacity of humans against related risks (Belliveau et al., 2006; Cutter, Boruff, & Shirley, 2003). Some studies (Downing et al., 2001; Kelly & Adger, 2000) linked access to various institutional services, resources, poverty, and food insecurity to social vulnerability.

However, in the climate change field, the vulnerability concept is considered an intersection of natural and social vulnerability, which combines both factors and may be defined, according to IPCC (2014), as *"the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt"*. Here the vulnerability of any system considers the system's sensitivity and capacity while considering exposure more as part of the risk. It implies that a system's vulnerability increases with the sensitivity of the system to climate risks and simultaneously reduces adaptive capacity (Fellmann, 2012). This study uses the same approach to explore farmers' vulnerability in three HKH countries. Here, we defined climate change as observed changes in the local environment over the past twenty years or more in terms of extreme environmental events such as droughts, floods, and extremely high or low temperatures (Bryan et al., 2013). The degree to which a system (in our case, an agricultural system with a farm as a basic unit) is vulnerable to an environmental or climate stimulus is related to the system's capacity to be negatively affected and ability to cope with its adverse impacts (Abid, Schneider, & Scheffran, 2016). Here sensitivity of a system refers to the "degree to which system is affected or responds to an environmental stimulus and is related to characteristics of the system and to broader non-climatic factors, e.g., livelihood, infrastructure, and government policy" (Adger, 2006; Turner et al., 2003).

In the context of the study, we consider various kinds of climate-related risks, i.e., flood, drought, extreme temperature events, and extremely low or high temperatures, which may influence the productivity of agricultural lands and local livelihood in direct and indirect ways. Vulnerability to the identified risk may be reduced if farmers imply specific coping mechanisms at their farm to adapt to observed changes. (Bryant et al., 2000; Smit & Skinner, 2002; Wheaton & Maciver, 1999). Such ability and potential of a system to respond to potential threats or risks are called adaptive capacity. Adaptive capacity is usually considered a positive attribute of a system in reducing vulnerability (Engle, 2011). The more adaptive capacity a system has, the greater the chances it can cope with it and thus is less vulnerable to climate change (Bryant et al., 2000; Bryan et al., 2013; Gorst, Groom, & Dehlavi, 2015). Further, how farm managers (farmers) understand and perceive climate risks is very important because it may influence their short to long-term decisions in adopting certain practices and ways of managing their farms (Lebel, Whangchai, Chitmanat, Promya, & Lebel, 2015). Technological, financial, and information resources; institutions; social setup, and strong local interactions are some other factors that may influence farm-level adaptation decision-making processes (Bryant et al., 2000; Bryan et al., 2013; Gorst et al., 2015).

3. METHODOLOGY

Based on the data from the three HKH countries, this paper intends to analyze the vulnerability of farmers to climate-related risks, including exposure to climatic risks, their sensitivity and their adaptive capacity to cope with the negative impacts of climate change. The study uses qualitative and quantitative data collected through field surveys to facilitate a more profound understanding of the context. The study implies a bottom-up approach to investigate farmers' experiences with climate change and their responses in line with observed changes; therefore – what, how, when, and where questions were used in the study (Berg, 2004). Farm households were asked to share their experience of climate change and associated risks. Further, we included questions to specify the broad definition of sensitivity, focusing on its resource dimension, which covers the availability of affected resources (before the climate stimuli) and the significance of resources for communities which may help them to cope with the negative impacts of climate change. To explain it further, we collected information from farmers on the availability of essential resources us as water, inputs, poverty, and access to institutional services. Further constraints to adaptation were also investigated through farmer surveys.

The key hypothesis for the study is that the vulnerability to climate change may vary across regions as well, depending on the altitude. Further, the study also assumed that the vulnerability to climate change might be linked to various internal and external factors described by exposure, sensitivity and coping mechanism.

Figure 1 shows the flowchart of various steps adopted to analyze the climate risk vulnerability.

3.1. Study areas

The study conducted a field survey across three study sites in Pakistan, Nepal, and Bhutan. In Pakistan, the Gilgit district was selected as the study site, whereas the Rasuwa district in Nepal and the central district were chosen as the representative area from Bhutan.

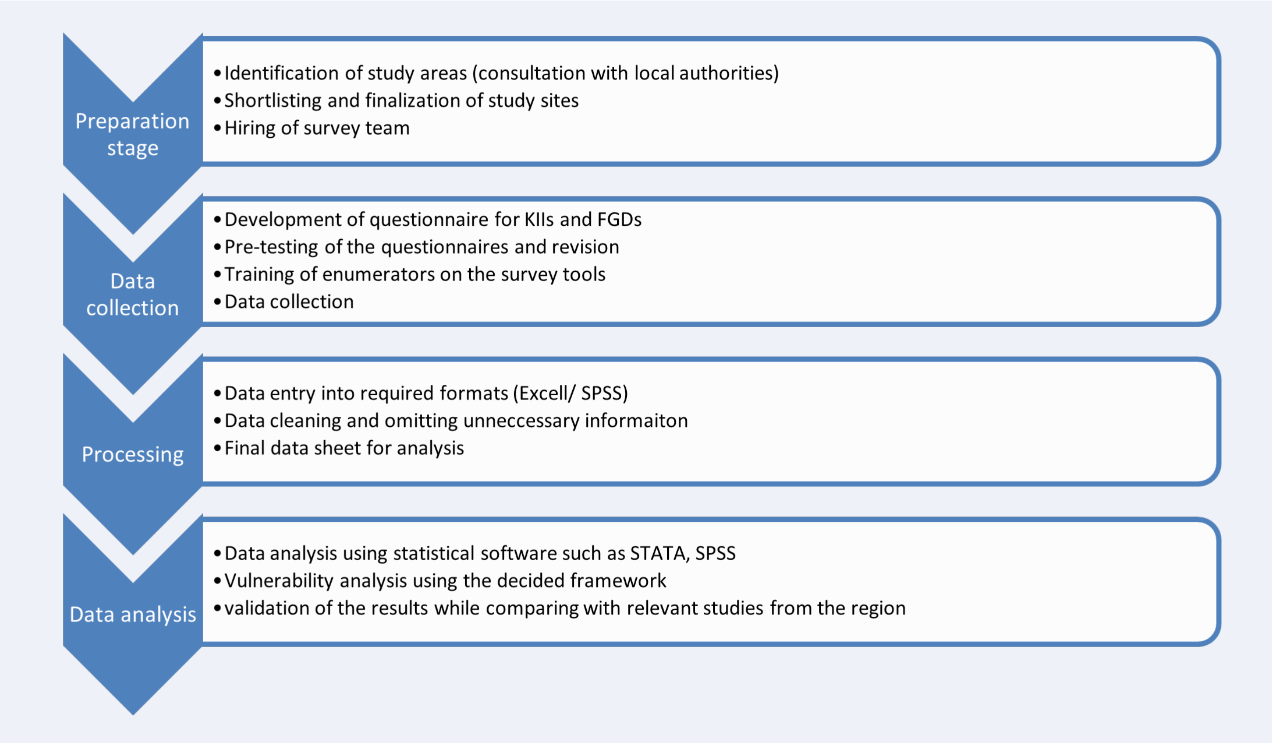

FIGURE 1. Methodology flowchart.

Gilgit is the part of Gilgit Baltistan (GB) province of Pakistan. Future projections show a 1.4 °C–3.7 °C increase in mean temperature in Pakistan by 2060 (higher than the expected global average), with the north, mainly GB, potentially experiencing higher temperatures than the country's south. Temperatures in Pakistan are also expected to rise more in winter than in summer. Precipitation change projections are less confident due to significant model uncertainties for the region. Changes in monsoons and rising temperatures will almost certainly pose substantial challenges to agriculture in the already climate change vulnerable north of the country. Climate variability and extreme events are estimated to cost US$ 270–360 million annually (in 2013), or 1.5 to 2% of the country's GDP.

Future climate projections for Nepal based on the averages of several Global Circulation Models (GCMs) indicate a continued increase in mean annual temperature, faster warming of the country's western regions (compared to the east), changes in precipitation during the monsoon season (with variations ranging from −14 to 40%), and an increased likelihood of heavy precipitation events. While there is considerable uncertainty in precipitation models, Nepal will most likely receive total rainfall in the future, particularly in the central and western regions. Changes in precipitation patterns are expected to impact rainfed agricultural activities, resulting in significant annual yield variability and increased production risks.

The monsoon influences Bhutan's climate, which is characterized by dry winters and high precipitation from June to September. Topography, elevation, and rainfall patterns all influence climate. Rain shadow effects caused by the country's mountainous terrain account for the significant variation in rainfall over a relatively short distance. Precipitation decreases significantly from south to north. Over the last few years, the country has seen rapid changes in average temperatures, precipitation patterns, and increased risks of climate hazards such as heavy rains, flash floods, windstorms, hailstorms, and droughts, resulting in massive losses and damage to farming households. Most farmers rely entirely on monsoons for irrigation. The delayed arrival of the monsoon can cause landslides and floods. Such weather events also put rural

	District			
	Pakistan (N = 126)	Nepal (N = 130)	Bhutan (N = 127)	Average (N = 363)
a. Adaptation practices adopted by farmers				
Change in cropping practices (e.g., alternative crops, new crop varieties, change in planting dates, Integrated pest management)	38	45	49	43
Change in management practices (change input mixes such as fertilizer, water)	30	25	30	36
Conservation practices (zero tillage, water saving, intercropping)	12	25	11	13
Livelihood options (crop diversification, migration to urban areas etc)	20	5	10	10
b. Number of adaptation measures implemented out of ten reported measures				
No adaptation	30	35	36	42
Adapted only one measure	37	59	40	42
Adapted any two measures	8	31	28	20
Adapted any three measures	18	9	12	15
Adapted any four measures	10	01	10	07
Adapted any five or above than five measures	37	00	10	17

TABLE 1. Adaptation practices adopted by farm households (%) across three study areas HKH countries.

communities at risk, as many are isolated due to inadequate or damaged infrastructure.

3.2. Data collection

The study uses a multi-stage sampling technique to select sample respondents. In the first stage, In Pakistan, the Gilgit district was chosen as the study site, whereas the Rasuwa district in Nepal and the central district were selected as the representative area from Bhutan, considering local climate, geography, demography, and cropping patterns. Since biophysical conditions vary with altitude, the second stage involves randomly selecting three villages from each study area's lower (valley), middle and upper elevations of the selected study sites. The third stage involves selecting 40 farmers from each village and 120 from each study area using a stratified random sampling method. This made the overall sample size 364.

Further, nine FGDs (three in each area) were conducted (see Table 1 for summary statistics). The key participants of the FGDs were the local farmers and heads of the farm households. It is important to mention that in Pakistan, women's participation in the data collection was limited due to local customs and their lack of decision-making power. However, in Nepal and, to some extent, in Bhutan as well, the situation was the opposite, where more women than men participated in the FGDs. Moreover, the study conducted 20 key-informant interviews with identified stakeholders, including community leaders and key government officials in each area dealing with the agriculture sector. For data collection, a standard protocol was followed where first we developed standardized questionnaires for each type of data collection, i.e., FGDs, KIIs and household surveys and then pre-tested those questionnaires in the field to avoid missing important information. To ensure uniformity in collecting field data, the project team also conducted a short training for field researchers in Nepal, Bhutan, and Pakistan. A list of key indicators and sub-indicators was developed for survey design and questionnaire construction. The farm household survey includes questions on household characteristics, farming, climate-related risks, effects, adaptation and constraints to adaptation to climate-related risks.

3.3. Data analysis

To analyze the data on farm-level vulnerability to climate change, we followed the IPCC vulnerability framework and used a conceptual comparative analysis as proposed by Schilling et al. (2012) and Abid, Schneider et al. (2016) to explore various elements of vulnerability (exposure, effects and adaptative capacity). Under this framework, we used simple statistical analysis to discuss the current state of various indicators of vulnerability and their relevance to the local context. Under the exposure section of the vulnerability, we explored how climate is evolving in three case study regions and how local agricultural communities perceive these changes. In the next steps, we explored how climate change is impacting local agricultural communities. Then, we explored the sensitivity and factors that affect agricultural households' sensitivity to climate change. At the end, we explored how farmers are adapting to climate change and what constraints they are facing while implementing adaptation at the local level.

4. RESULTS AND DISCUSSION

The study's findings start with analyzing farm-level perceptions of climate change and related risks to agricultural productivity and livelihood in three HKH countries (4.1). The analysis then proceeds to explore the different aspects of vulnerability, including farm-level sensitivity to climate-related risks and their impact at the farm level, adaptation practices, and the role of factors affecting the adaptive capacity of farmers' adaptive ability including constraints to adaptation and finally a synthesis of results (5).

4.1. Farm-level vulnerability in the HKH region

4.1.1. Exposure to climate change

This section focuses on the most important climate variables, temperature and precipitation and related factors in the agriculture sector in Hindu Kush Himalaya with a particular focus on Pakistan, Nepal and Bhutan.

To fully capture the situation, first, we collected information on local perceptions regarding overtime changes in the key climatic parameters in three study countries and tried to tally it with the climate data using a literature review.

Field research in three study areas reveals important information on how the region's climate is evolving and how much farmers are observing those changes. The distribution of farm-level perceptions regarding overtime change in climate-related parameters and related risks are summarized in Figure 2. Regarding changes in winter temperature, there is an agreement between farmers in Nepal and Bhutan that the winter temperature is increasing; on the contrary, a vast majority of the farmers in Pakistan (>50%) observed winter temperature decreasing. However, more than 60% of farmers in all three study sites believed there had been a significant increase in summer temperature over the past 20 to 30 years. In case of changes in precipitation patterns, farmers' perceptions were divided. For instance, more than half of the farmers in Nepal perceived winter precipitation as increasing. Still, on the other hand, around 40% of farmers from Nepal perceive winter rainfall as decreasing. The same is the case with Pakistan. However, in the case of Bhutan, more than 40% of the farmers did not observe any significant changes in winter rainfall patterns. Concerning changes in summer rainfall, most farmers in all three study sites observed a substantial increase in summer rainfall, except in Pakistan, where most farmers perceive a decline in summer rainfall. As demonstrated by other scientific studies (e.g., Abid et al., 2019; Budhathoki & Zander, 2020), a significant variation in farm-level responses in perceiving rainfall patterns may be explained by uncertainty in the overall precipitation patterns in the Hindu Kush Himalaya region.

While responding to additional questions on growing season length, most farmers in the three study countries agreed that growing season length has increased over time. The same is the case with

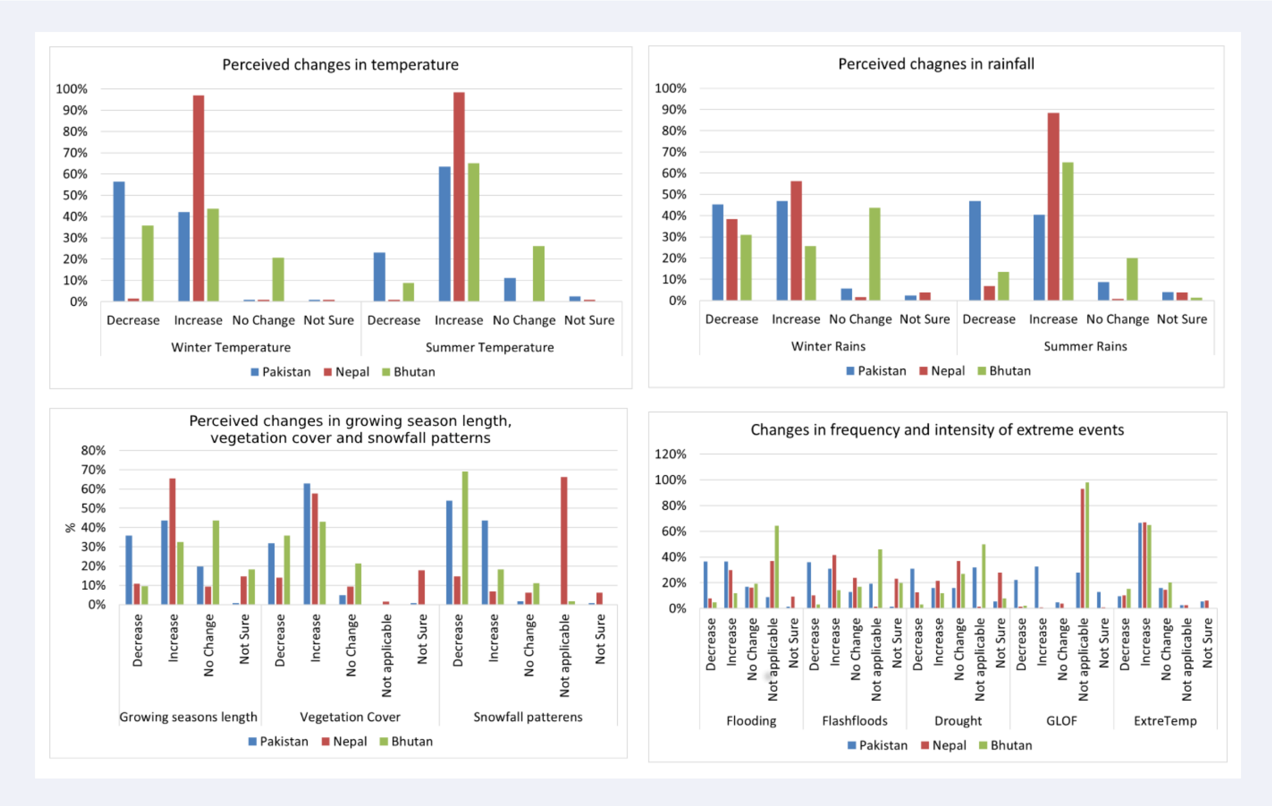

FIGURE 2. Climate risk perceptions in the HKH countries.

vegetation cover, where most farmers see it as a positive impact of changes in climate conditions that led to more vegetation and allow farmers to shift their farming from monoculture farming to a bi-culture farming system in many cases. In the next step, we explored farmers' perceptions of changes in extreme events. The key extreme events perceived by farmers include flooding, flash flooding, extreme temperatures and drought. These findings extend nuanced findings from previous work in the HKH region (Baylis & Githeko, 2006; Hussain, 2015; Younas, Ishaq, & Ali, 2012), which identified an increase in the extent and occurrence of climate-related events.

Effect of climate-related risks

This section summarizes the effects of climate-related risks at the farm level explored through field research conducted in three study areas. Overall, farmers in HKH countries are facing three types of impacts from changes in climate, namely, direct effects, indirect effects, and adaptation costs. Direct effects include impacts on crop production, livestock production, and risk of natural hazards. On the other hand, indirect effects include socioeconomic consequences from climate change at the farm level. Further, the adaptation cost incurred to minimize the negative impacts of climate change is an additional expense that farmers have to bear in addition to regular production activities. In Figure 3, we explored farmer responses to the potential impacts of climate change at the local level in three countries. As shown in Figure 3, most farmers were concerned about increased climate-induced diseases for humans and livestock, followed by damages to physical assets due to the increased severity of extreme events.

Further, we received mixed responses on the impacts of climatic changes and related risks on crop and livestock productivity. For instance, farmers in high-altitude regions benefit from increased summer and winter temperatures as they can grow more crops and hence see an increase in their productivity of crops and livestock production due to more grazing available for their livestock. On the other hand, farmers located at the tail of the

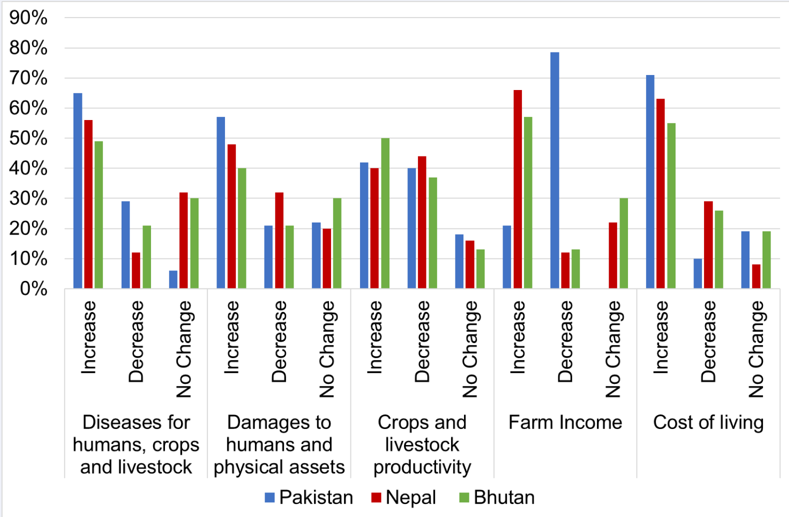

FIGURE 3. Farmer responses to potential impacts of climate change at the local level in three countries.

mountains observed climate changes negatively impacting the productivity of their crops and livestock. The same is the case with changes in farm income, where farmers in high-altitude regions of Nepal and Bhutan see an overall increase in their income. However, most farmers in Pakistan perceive a decrease in their farm income due to the rise in production costs because of climate change. The study results follow the findings of other studies in the region. For instance, Baig and Amjad (2014), and Tingju et al. (2014) have indicated a considerable decline and inconsistency in the yields of major crops such as wheat, maize, rice, sugarcane, and cotton in Pakistan due to climate-related extreme events.

4.1.2. Sensitivity

Sensitivity to climate change and climate-related risks explains how a system is affected by climate stimuli. Here, we focus on the resource dimension of sensitivity as suggested by Barnett and Adger (2007) and therefore explore the status of resources at the local level in HKH countries, first by discussing the effect of observed climate-related risks at the farm level to show how farm households are being affected by climate change. It is followed by exploring several factors, i.e., such as availability of water, the status of poverty, and the role of locals in describing the farm-level sensitivity to climate change.

Factors affecting sensitivity at the farm-level

Water is one of the essential resources for agriculture at the farm level, whose non-availability may increase the impact of climate-related shocks. For instance, despite being close to the river, farmers in Gilgit (a study area in Pakistan) often rely on water from streams and use it through community-led water channels. Similarly, farmers in Bhutan and Nepal face water availability fluctuations due to climate changes. Uncertainty in water availability puts agriculture and the livelihood of rural agricultural households in HKH countries at risk.

Poverty is widespread across the HKH region due to limited access to economic resources and heavy reliance on natural resources and hence may define the sensitivity of farming communities to potential climate-related risks or threats. According to an estimate, about one-third of HKH countries' population lives under the poverty line. Lack of resources and limited income may restrict farmers from adapting their agriculture to the negative impacts of climate change.

Livelihoods in the HKH region are mainly dependent on natural resources and subsistence agriculture, characterized by low yields due to limited

Study country	FGDs	Total Participants	Gender		Average age
			Male	Female	
Pakistan	FGD1	25	20	5	34.40
	FGD2	29	21	8	40.33
	FGD3	35	30	5	41.11
Nepal	FGD1	24	7	17	36.51
	FGD2	21	5	16	38.67
	FGD3	26	8	18	37.10
Bhutan	FGD1	28	16	12	39.09
	FGD2	23	13	10	37.04
	FGD3	22	14	8	35.69

TABLE 2. Summary statistics for participants of the Focus Group Discussions (FGDs).

access to productive resources and finance. Due to a high level of rural poverty and associated limited access to farm resources, crop yields in our study regions were far below potential. Further, poor households usually do not have access to improved seeds, advanced technologies, and other inputs that can reduce the vulnerability of crops to climate-related risks. Poor and small farmers thus have little capacity to absorb climate-induced crop or livestock income shocks and recover. A slight income loss may be devastating and set off a ratchet effect that leads to further poverty and future vulnerability due to a lack of limited assets and the absence of economic and social safety nets.

4.1.3. Adaptation to climate change

While farm households are exposed to various climate-related risks, the degree of their vulnerability depends on their ability to adapt to those risks. Farm households who adapt timely to risks may be less vulnerable or more profitable than farm households who adapt lately or do not adapt. Distinguishing between adaptation to climate-related risks and adaptation to other risks is challenging. However, when farm households were asked about risks, the households were able to distinguish between measures to manage climate-related risks and other risks.

Adaptation measures

Table 2 shows the adaptation measures taken in response to various observed climate-related risks by farm households. We here divided the adaptation options into four main categories; (1) Change in cropping practices (e.g., alternative crops, new crop varieties, change in planting dates, Integrated pest management); (2) Change in management practices (change input mixes such as fertilizer, water; (3) Conservation practices (zero tillage, water saving, intercropping) and Livelihood options (crop diversification, migration to urban areas, etc.).

Changing cropping practices, which were implemented by farm households at the farm level, may be short-term or long-term, depending on the nature of the risk. Specifically, changing crop variety was employed by farmers in response to more crop pest attacks on old varieties or to an extreme maximum temperature which were negatively affecting the growth of old varieties. Similarly, farmers in Bhutan reported more use of heat-tolerant wheat varieties in response to an increase in the frequency of extreme maximum temperature events. Changing crop types were adopted by farmers against incidents of heavy pest and insect attacks, soil problems, and extreme temperature events. For instance, in Nepal, many farmers reported replacing maize with rice due to its exposure to heavy pest attacks due to changing weather conditions. The measure of changing planting dates was adopted by farm households in response to variability in daily weather conditions.

Changing farm management practices include changing fertilizer and pesticide, irrigation, and changing farming techniques implemented at the farm level by farm households. For instance, in case of drought or extreme maximum temperature, farmers reported using more irrigation for their crops, especially at the sowing stage. In case of more crop pests due to heavy rainfall in the monsoon season, farm households reported increased use of pesticides to protect their crops from pests. Similarly, farmers who reported soil problems as well used micronutrients or changing combinations of different fertilizers to maintain soil fertility. The increased irrigation adaptation measure was mainly used by farmers in Gilgit, who reported a decrease in overall rainfall over time. Farmers also complained about increased hot and dry days and their negative impacts on crop growth. Changing farming techniques were implemented by farmers to prevent their crops from different weeds and soil issues such as salinity.

Advanced land management measures were also adopted at the farm level to cope with livelihoods against different climate-related risks. Farmers who reported an increase in the frequency of extreme temperatures often found conserving their land through soil and water conservation measures and involved in intercropping and diversifying their cropping patterns. For instance, farmers in Gilgit reported more use of organic matter (farmyard manure) as a soil conservation technique to preserve soil quality. Some farmers also used intercropping as an adaptation measure in Nepal and Bhutan to protect crops from increased temperature and reduce the damage to crop growth from increasing temperature.

Changing livelihood options was another adaptation mechanism adopted by farmers across study areas to minimize the risks from climate-related risks. For instance, farm households in Nepal reported increased migration to urban areas or abroad due to losses in agricultural production due to changing climatic conditions and reduction in farm margins. Similarly, few farm households diversified their farms by increasing the number of animals, having more crops under cultivation instead of one or few crops due to the loss of a single crop by extreme climatic events such as sudden rainfalls or floods and drought. Primarily farm diversification was implemented by farm households in Pakistan.

The results also showed that most households in all three study countries preferred changing cropping practices as key adaptation options followed by changing farm management practices etc., at their farms, keeping in view the nature of the problem and their capacity. A small number of farm households adopted advanced land use management options such as soil conservation and plantation of trees. Results also demonstrate that a minimal number of farmers in the study districts adopted different livelihood options as an adaptation measure to climate variability and related risks. Table 2b shows the frequency of adaptation practices applied in three study areas in the HKH region. Results revealed that most of the farmers in the study areas were restricted to only one or a few adaptation options. The study findings stand at par with other studies conducted in the region.

Constraints to adaptation

The study identified the following key constraints that restrict farmers from effectively implementing adaptation practices at the farm level: (1) lack of farm resources, (2) limited financial capacity, (3) information and knowledge gaps, and (4) poor advisory services (Figure 4).

The first constraint is related to the limited availability of the resources required to implement farm-level adaptation practices. One of the main reasons behind limited access to resources for farming is the geography and topography of the Himalayan agricultural system, making farming a challenging job in the HKH region. Farmers had to struggle to manage water and other inputs for their agriculture. In the last few years, climate changes have badly impacted the water supply to

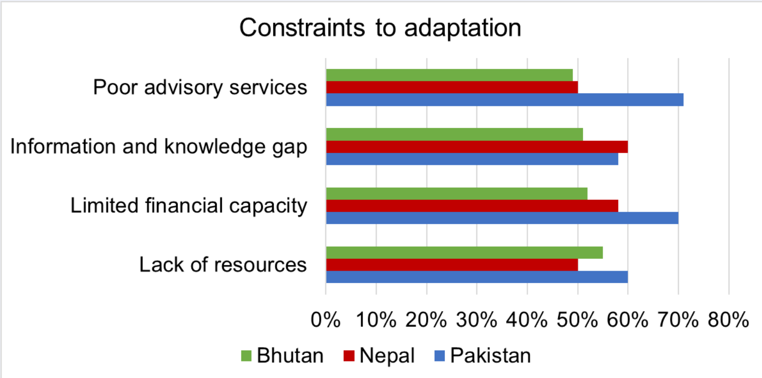

FIGURE 4. Key constraints that restrict farmers from effectively implementing adaptation practices at farm level.

high-altitude farming regions due to considerable fluctuations in water availability, followed by damages to water channels caused by flash flooding and heavy rains in parts of HKH.

The second major constraint that limits farmers' adaptive capacity is their limited financial capacity which is again linked to their subsistence agriculture and heavy reliance on natural resources. Being in high altitudes, farmers often complain about limited access to formal financial systems. Even if services are available, farmers often do not have the collateral required to take credit for agricultural purposes. In some cases, misuse of agricultural credit is also reported when farmers do not have access to non-agricultural credit.

The third constraint to adaptation is the information and knowledge gap, which restrict farmers from accessing relevant information on best management practices and climate change. Here farmers also reported a lack of a proper early warning system, which is very important to protect livelihoods from potential natural disasters such as flooding or heavy rains. Another critical constraint restricting farmers from adapting to climate change is the poor advisory service network. In many cases, farmers report little to no contact with the agricultural extension department and often rely on their informal contacts to get advice on issues related to agricultural production. According to the results presented in Figure 5, only one-third of the farmers have access to proper advisory services in Pakistan. In Nepal, the extension system is well developed, and more than half of the survey farmers have access to advisory services available through public and private sources. In Bhutan, about 40% of the farmers have access to extension services.

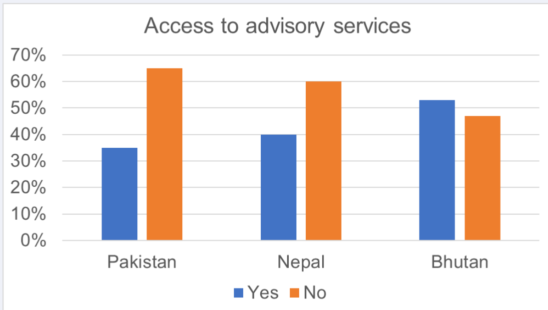

FIGURE 5. Access to advisory services.

5. CONCLUSION AND RECOMMENDATIONS

This study provides an overview of climate-related risks faced by farmers in three HKH countries, followed by exploring the sensitivity and adaptive responses to identified risks. Further, we also discuss constraints limiting farmers' adaptive capacity to cope with the negative impacts of climate change in high-altitude farming regions. The perception of changes in climate and the occurrence of extreme events vary across three study regions, which are in line with the past and projected changes in the climate as per scientific findings. For instance, farm-level observations on the overall increase in summer and winter temperature agreed with the latest IPCC 6th Assessment Report. The same is the case with overtime changes in the precipitation trends, where mixed responses were reported. Regional climate modelling studies also explain the same uncertainty.

While exploring the sensitivity aspect of climate vulnerability, we investigated how farmers link climate changes and the occurrence of various extreme events with changes in their livelihood or agricultural productivity. Most farmers in the three study regions agreed that climate changes directly or indirectly impact their livelihood through fluctuations and decrease in crop and livestock yields, changing cropping calendars, reducing farm margins due to reduced productivity, and increase in input cost on account of climate impacts. The study also found variations across three study areas regarding the impact of climate-related risks. For example, farmers in Pakistan reported more uncertainty and reduction in crop and livestock yields and change in farm income compared to the other two regions. This study also found that challenges of decreasing or uncertain water availability, poverty, and lack of access to institutional services in adaptation make farm households more sensitive to climate-related risks.

Key adaptive measures reported by farmers include changes in crop type, crop varieties, and sowing dates, followed by implementing land management practices. On the other hand, farmers also identified a lack of resources, limited financial resources, and a lack of institutional services as crucial constraints to adaptation in KHK countries. Further, limited marketing services and access to weather forecasting and information were other factors in adapting farming to climate change. Based on the study findings, we recommend improving the outreach and extending institutional services related to climate adaptation so that farmers may have better access to information on climate risks and coping measures.

6. ACKNOWLEDGEMENT

The authors gratefully acknowledge the Asia-Pacific Network for Global Change Research (APN) for its financial support in conducting this research. We also thank our regional partners from Pakistan, Nepal and Bhutan for helping the project team with data collection.

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