HI-AWARE Working Paper 24

Participatory Assessment of Multiple Socio-economic Drivers and Climate Stresses Leading to Differentiated Vulnerabilities in the Hindu Kush Himalaya

Consortium members

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 Wageningen Environmental Research (Alterra). 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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HI-AWARE Working Paper 24

Participatory Assessment of Multiple Socio-economic Drivers and Climate Stresses Leading to Differentiated Vulnerabilities in the Hindu Kush Himalaya

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Contents

Acornyms and Abbreviations

BCAS	Bangladesh Centre for Advanced Studies
BDT	Bangladeshi Taka
CBS	Central Bureau of Statistics
CIA	Central Investigation Agency
DDC	District Development Committee
FGDs	Focused Group Discussions
GOI	Government of India
GTI	Gastrointestinal Infections
HI-AWARE	Himalayan Adaptation, Water and Resilience Research
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
KIIs	Key Informant's Interviews
LGI	Local Government Institution
LPG	Liquefied Petroleum Gas
masl	metres above sea level
NGO	Non-government Organisation
NPC-GON	National Planning Commission - Government of Nepal
PAR	Participatory Action and Reflection
TAR	Tibetan Autonomous Region
TERI	The Energy and Resources Institute
THT	Thamang Heritage Trail
UJVN	Uttarakhand jal Vidyut Nigam Limited
USD	United States Dollar
WSMD	Watershed Management Directorate

Executive Summary

This synthesis report summarizes findings from a participatory assessment of socio-economic drivers, conditions, and climatic and environmental stresses leading to different levels of vulnerabilities in the Hindu Kush Himalayan (HKH) region. The study sites included high mountain, mid-hill, and downstream regions of the Indus, Upper Ganga, Gandaki, and Teesta– a tributary of the Brahmaputra River – basins. An integrated and multidimensional approach was adopted to understand social drivers, conditions, climate stresses, and multiple causes of vulnerability. Community perceptions about major socio-economic drivers and conditions were collected in geographical contexts. Upstream regions are characterized by an abrupt rise in topography, extremely rugged terrain, steep slopes, and deeply cut valleys. Midstream characteristics include hills with large areas of dense broad-leaved and mixed forest and extensive agriculture, often on terraced slopes. Downstream areas are mostly flat and characterized by vast floodplains that are prone to flood and river erosion.

Changes in temperature and rainfall have been identified in all sites of the four river basin areas. Along with this, in the upstream and midstream regions, the situation is acute due to a decrease in snowfall and winter rain, which has created water scarcity and is impacting peoples' lives and livelihoods. Landslides have also been observed – an environmental extreme occurring due to extreme rainfall in upstream and midstream areas. In downstream areas, extreme conditions such as floods, flash floods, cold waves, and drought have been identified and are increasing peoples' vulnerabilities. River erosion is making farmers, fishermen, and wage labourers vulnerable to climate change in the downstream region.

In upstream areas, subsistence agriculture, horticulture, pastoralism, small businesses, and tourism are major livelihood sectors. These sectors are also characteristic of midstream areas, where floriculture and ecotourism present other livelihood options. In downstream regions, people largely depend on agriculture. Again, small-scale business are found here as are fisheries. It should be noted here that more people live below the poverty line in the mountains where livelihood opportunities are limited. Several drivers compound the impacts of the changing climate and affect the lives and livelihoods of the communities in the four river basins. This study identified a pattern across its study areas– vulnerable communities often come from economically marginalized, socially excluded, and geo-physically remote locations.

According to community perceptions, weak physical connectivity and infrastructure (lack of transport), improper management of water resources, water scarcity, increase in unemployment, local- and state-local political insecurity, poor governance in disaster risk management, land ownership issues, breaking up of traditional and communal institutions, lack of energy supply, and lack of quality education are key socio-economic drivers and conditions affecting the lives and livelihoods and making communities vulnerable. Rising outmigration and social insecurity, increasing cost of food items and production equipment, community conflict, and human-wildlife conflict were reported across the river basins, as factors affecting the social lives and livelihoods of people. The caste system, as a traditional social and religious institution, continues to aggravate social inequity, deprivation and differentiation, particularly in Nepal and India, which limits the capacity of individuals, families, and communities to face and cope with externalities like climate change. Further, changing demographic trends, proximity to multiple climatic hazards, lack of development, remoteness, limited awareness about climate change impacts etc., have also been identified as key drivers determining social vulnerability. In all the study sites, gender discrimination is a major socio-economic factor, which makes poor women highly vulnerable.

Small farmers, daily wage earners, and communities who depend on natural resources are the most vulnerable groups in the HKH river basins. Due to climatic hazards, marginal farmers are badly affected if agricultural productivity falls. In extreme conditions, work opportunities are reduced locally and wage labourers migrate seasonally in search of livelihood options. People who migrate for work leave behind their families in remote village areas. The women of these families often manage the household and everything outside it in the absence of their

male partners. With no former agricultural labour experience, fishermen struggle even if they can find work as agricultural labourers. Sometimes, even finding such work is difficult.

Caste differentiation, inequity, and social deprivation are social drivers that result in greater vulnerability among lower castes. Poor, forced migrants who live on embankments, khas land (government-owned fallows), *char* land (river islands), or in cluster villages are largely socially and economically excluded and are thus highly vulnerable. In Hakimpur village, situated in downstream Upper Ganga, the caste system governs ownership of land and water. During extreme weather conditions, people from the so-called lower castes suffer the most from scarcity of safe drinking water. In Sanjen Kharka, Gandaki basin, pasture degradation due to rising temperatures and climate change, combined with the growth in local population and livestock numbers, is leading to social and political conflicts.

In neighbouring India, conflict has added to the socio-economic vulnerability of people. Since the last three decades, there were agitations in Darjeeling and Kalimpong hills, associated with the proposed statehood demand for Gorkhaland, and therefore, Chibo-Possyor in Kalimpong and Teesta Valley in Darjeeling were severely affected. The government has done little to build infrastructure, introduce modern technology in traditional agriculture, or improve livelihoods in these areas. In Teesta Valley, locals are at the mercy of the tea estate they live and work in as they do not own land or property, and live within the hierarchical structure of the tea estate.

Tea pickers also have to fight harsh, unfavourable climate conditions and brave landslides or frost bites due to heavy rainfall and cold waves for low wages. In Bangladesh, people living on *char* land on the banks of the Teesta in Bangladesh are highly vulnerable. They are routinely exposed to floods, river erosion, sand deposition, and drought. They are often socially excluded and have no decision making power. In all the communities studied in all the basins, women face greater risk and vulnerability due to the combined effect of climate stresses and their subordinate social positions in their families and societies as well as their limited access to resources – land and productive assets, knowledge, technologies, and institutions.

Communities and vulnerable groups are coping with climate stresses and taking limited adaptation measures, particularly in agriculture, home gardening, horticulture, livestock and fisheries, tourism, small trading, and business. In a few cases, government departments and development agencies like NGOs are supporting such local adaptation. These efforts are reducing some level of risk and vulnerability, but planned adaptation will be required in all the river basins considering the long-term climate change terms and impacts on societies, populations, and livelihoods.

Attention must be given to the most vulnerable sectors and groups. Adaptation measures are to be designed taking upstream and downstream linkages into consideration. Pro-poor and gender responsive adaptations are to be promoted in all the river basins with communities and actors. The social and structural causes of vulnerability must be addressed through policy and institutional measures. Adaptation measures are to be undertaken considering the local climate contexts and social drivers and conditions. Social and human capital must be enhanced for resilience building and ultimately to reduce the differentiated vulnerabilities of groups and communities. Better governance and institutional responsiveness are urgently required to enhance the access of poor and marginal groups to services and support from government departments and actors. Further, multi-disciplinary and participatory research initiatives are to be undertaken at the basin and community levels for deeper understanding of the various dimensions of vulnerability as well as the adaptation needs and priorities of communities.

1. Background and Introduction

The Himalayan Adaptation, Water and Resilience (HI-AWARE) research consortium conducted a participatory assessment of socio-economic drivers, conditions, and climate stresses leading to different levels of vulnerabilities. The assessment aimed to understand the socio-economic drivers and climatic stresses leading to vulnerability and the ways in which communities living in the HKH region are currently coping. The most densely populated region in the world, the 10 major rivers basins originating in the HKH mountains is home to 1.9 billion people, of which 240 million live in the mountain and hills of the HKH. Of the total HKH population in the mountain and hills, one third lives in extreme poverty; more than 70% of people live in rural areas and agriculture is the principal occupation of the region (Ahmed and Suphachalasai, 2014). The agricultural sector plays a critical role in the development of South Asia and employs 47% of the work force as average in Bangladesh (47%), India (47%), Nepal (69%) and Pakistan (42%) (CIA, 2017). Floods accounts for more than a third of the total natural disasters in the region and affect millions of people directly or indirectly (ICIMOD, 2013).

The study intended to assess vulnerability in the context of interrelations between socio-economic and biophysical drivers. The study was conducted in 12 HI-AWARE study areas, located in four river basins in HKH. The study sites included high mountain, mid-hill, and down-stream regions of the Indus, Upper Ganga, Gandaki, and Teesta – a tributary of the Brahmaputra River – basins. An integrated and multi-dimensional approach was adopted to understand social drivers, conditions, and multiple causes of vulnerability.

1.1. Conceptual Framework: Multiple Drivers and Conditions of Vulnerability

The geophysical conditions of a locality and the severity of climate change stresses are primary causes of risk, but social vulnerability is embedded in society and culture (IPCC, 2007). Vulnerability describes a set of conditions of people that derive from the historical and prevailing cultural, social, environmental, political, and economic contexts. In this sense, vulnerable groups are not only at risk because they are exposed to a hazard but as a result of marginality, of everyday patterns of social interaction and organization, and access to resources (ibid). Thus, the effects of a disaster on any particular household result from a complex set of drivers and interacting conditions. Therefore, integrated and multidimensional approaches are highly important to understand drivers and causes of vulnerability. The IPCC approach emphasizes consideration of the magnitude and frequency of potential climate hazards along with diverse social drivers to understand levels of vulnerability and adaptive capacity. Further, the IPCC suggests that differences in vulnerability and exposure arise from many non-climatic factors such as the social, economic, cultural, political, and institutional marginalization of people.

Hence, both the physical dimensions (e.g., locational, spatial, and temporal; level of exposure and sensitivity) and the social drivers and conditions are to be assessed to determine the level of vulnerability in geophysical and social contexts. The non-climatic factors and drivers that enhance vulnerability at individual, family, and community levels need to be assessed. These factors include: remoteness and development deficiency, economic constraints and poverty, human displacement and migration, gender inequality; governance, market orientation, knowledge and information, institutions, access to resources and governance.

1.2. Objectives of the Research

The participatory assessment aimed to improve understanding of how socio-economic drivers and conditions, in combination with climate change stresses, are determining the differentiated vulnerability of communities across the river basins; as well as to identify the levels of adaptive capacity and the role of different actors to promote adaptation.

The key research questions are: How are populations and communities in a locality differently affected by climatic stresses and social drivers based on their social categories and capabilities? How do the social structure and process interact with climate-induced ecosystem changes and who are the most vulnerable?

Specific research questions for the assessment of drivers and conditions leading to vulnerability are:

1. How do climate stress and social drivers affect access to and control over natural resources including water, forest, and biodiversity at the basin and community levels and how are these again undermining the basic securities and primary needs for life, health, and social relations, which are key elements of human well-being?
2. How are different livelihood assets and sectors– e.g., agriculture, wage earning, small businesses, tourism etc. – of poor and marginal sections of society affected differently due to exposure and sensitivity to climate change, multiple drivers, and conditions in the last 10–15 years?
3. Do people of different categories (including women and men in the society) and the vulnerable groups undertake gender responsive strategies to address the current and future climate stresses and vulnerability? and
4. How are different actors, stakeholders and institutions responding to the needs and interests of the vulnerable communities?

1.3. Research Methodology

The assessment of the multiple drivers, conditions, and differentiated vulnerability required a participatory and inter-disciplinary approach. The researchers of the consortium and the strategic partners worked together with the active participation of members of vulnerable communities who gathered, organized, and analysed diverse information on bio-physical and socio-economic and institutional, primary, and secondary qualitative and quantitative data. The assessment process further integrated scientific information (climate change trends, impacts, and risks) with local and experiential knowledge, community insight, and views of experts to get a more comprehensive understanding of multiple drivers (economic development, infrastructural development, market technology, urbanization, push and pull factors of migration, marginality, inequality etc.), and conditions that determine differentiated vulnerability for communities living in the study areas. The assessment process attempted to blend climate data (climate trends, variability and impacts) with social information (population, poverty, inequity, marginalization, social exclusion, wealth and human well-being, and vulnerability) to understand the nature and types of vulnerability. The study team used a number of Participatory Action and Reflection (PAR) tools and techniques (Mallick, D., et al, 2016).

The methodology, along with the tools and guideline, was developed through a number of consultations within the HI-AWARE research team and was field tested in Chitwan, Nepal in July 2015. Climatic stressors have been identified through hazard mapping and prioritization and the use of the seasonality calendar and vulnerability matrix. Data on socio-economic stresses was collected through tools like village profiles, ethnography, social ranking, social drivers analysis, and stakeholder mapping. To understand differentiated vulnerability in the community, focused group discussions (FGDs), key informant's interviews (KIIs), case studies, and life stories were conducted during the study. FGDs were conducted with different homogeneous and heterogeneous groups of different socio-economically marginalized and vulnerable groups including farmers, wage earners, fishermen, and women while KIIs were conducted with NGOs and local government institution (LGI) representatives. Case studies and life stories were conducted with representatives from different vulnerable groups.

1.4. Research Sites and the Communities

The participatory assessment was carried out at three levels of the river basins i.e. upstream, midstream and downstream in the Indus, Upper Ganga, Gandaki, and Teesta/Brahmaputra. The work was carried out the HI-AWARE consortium members and strategic partners – the Pakistan Agricultural Research Council (PARC), Pakistan; the Energy and Resources Institute (TERI), India; the Bangladesh Centre for Advanced Studies (BCAS), Bangladesh – and

the International Centre for Integrated Mountain Development (ICIMOD). Field studies were conducted and basin-level reports prepared. In the Indus basin, the sites covered include Hunza (upstream), Soan (midstream), and Chaj Doab (downstream). In the Upper Ganga, the sites were Rudraprayag (upstream), Tehri and Devprayag (midstream), and Haridwar and Rishikesh (downstream). Similarly, sites in the Gandaki basin were Rasuwa (upstream), Nuwakot (midstream), Chitwan and West Champaran (downstream). In the Teesta, the sites were North and West Sikkim (upstream), Pandem and Melli in Sikkim and Poshyor and Teesta Valley in West Bengal (midstream), Jalpaiguri in West Bengal and Nilphamari Rangpur and Lalmonirhat districts in Bangladesh (downstream). The study sites are represented in Figure 1 and Table 1.

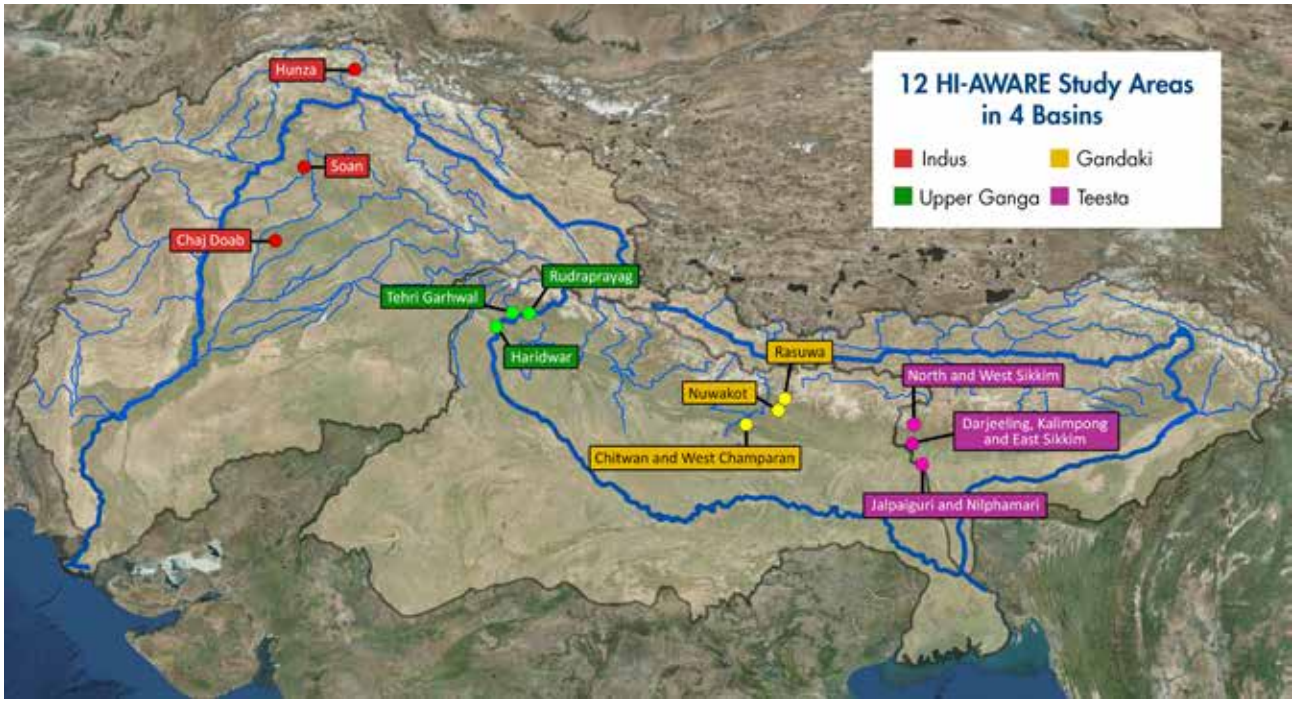


Figure 1: Study sites in the Indus, Upper Ganga, Gandaki (of Ganga); and Teesta (of Brahmaputra) basins

Table 1: Names of study sites by river basins

River basin	Upstream	Midstream	Downstream
Indus	Hunza	Soan	Chaj Doab
Upper Ganga	Rudraprayag	Tehri and Devprayag	Haridwar and Rishikesh
Gandaki	Rasuwa	Nuwakot	Chitwan and West Champaran
Teesta	North and West Sikkim	Pendam and Melli (Sikkim)	Jalpaiguri (West Bengal)
		Poshyor and Teesta Valley (West Bengal)	Nilphamari, Lalmonirhat and Rangpur (Bangladesh)

Crop filed (in Summer) in the river bed in the downstream of Teesta, Dimla Upazila, Nilphamari district, Bangladesh

2. Geographical Conditions and Socio-economic Drivers

Geophysical and socio-economic contexts are important to understanding the nature of vulnerability and the factors that affect it. The impacts of climatic factors, levels of exposure and sensitivity, and socio-economic drivers affecting communities often determine the differentiated vulnerabilities of individuals. The socio-economic conditions of people have been assessed as part of this study. A brief summary of geographical conditions and socio-economic drivers is presented below.

2.1. Locations and Geographical Features

Upstream: Study sites in the high mountains were Hunza in the Indus, Rudraprayag in the Upper Ganga, Rasuwa in the Gandaki/Trishuli, and North Sikkim in the Teesta/Brahmaputra. The villages studied in the high mountains are characterized by mountainous terrain, deep incision with valleys, and streams. The key climatic factors include temperature rise, persistence of heat stress, reduced snowfall, frost, and heavy rain-induced flash floods and landslides in recent years, as well as shorter winters and reduced winter precipitation (both snow and rain).

In upstream Indus, Hunza is situated at a high-altitude, ranging from 2,500 masl to close to 8,000 masl. Water flow in the Hunza River is usually at a maximum in July when snow and glacier melt are at their peak and at a minimum in March, when the contribution of snowmelt is minimal due to low temperatures. In the Upper Indus basin, floods, erratic rainfall, decreased snowfall, and storms are increasing say locals, based on their observations of the occurrence of major climate-related hazards in recent years (Abbasi et al, 2017).

High elevation study sites in the Upper Ganga include Huddu, Ginwala, Guptkashi and Ushara, all in Rudraprayag district, India. The main sources of water are rainfall, sub-surface flows, and snowmelt from glaciers. Floods, landslides, and decreasing snowfall are major climate-related hazards in the area .Upstream Gandaki essentially includes the high mountains of the Trans-Himalaya and Higher Himalaya and features an abrupt rise of topography, extremely rugged terrain, steep slopes, and deeply cut valleys. Along with this geophysical condition, climate-induced hazard like cloud burst events, landslides, heavy wind and fog, decreases snowfall, and water scarcity due to decreased winter rainfall are causing difficulties and posing threats to the livelihoods of local communities.

Situated in upstream Teesta basin, Sikkim, a state in the northeast region of India, is nestled in the Eastern Himalaya and has the steepest landscape in the country. The study sites in North Sikkim are in remote locations and extend up to the Trans-Himalayan region. Water scarcity is one of the major impacts of changes in temperature and precipitation observed across the research sites. Hailstones, increase in temperature, frost, heavy rainfall, and landslides are among major climatic stresses in the region (GOS 2011).

Midstream: Study sites in the midstream were: Soan in the Indus basin, Tehri and Devprayag in the Upper Ganga, Nuwakot (Trishuli) in the Gandaki basin, Pendam and Melli in Sikkim and Poshyor and Teesta Valley in West Bengal in the Teesta basin. Major climatic stresses in this area are floods, drought, erratic rainfall, landslides, heavy fog and wind, hailstorm, and water scarcity. Mid-elevation sites in the Upper Ganga selected as study sites were Kimkhola, Pyunkhari, Amni and Bagi of the Upper Ganga (500–1,500 masl). These lie within the administrative boundary of Tehri Garhwal district in the state of Uttarakhand, India. Tehri Garhwal is one of the largest districts in the state with its headquarters in New Tehri. Flood, drought, erratic rainfall, heavy wind, and water scarcity are major climatic stresses in this area. In the Gandaki basin, the midstream comprises the lesser Himalayan (middle mountains/ mid-hills) zone to the north of the Siwalik range (Bhadwal S et al, 2017). Nuwakot, the district studied, is located in this range and consists of nine major hills after which it is named, Nuwa referring to nine and Kot referring to a religious site and forts at the top of the hills. Nuwakot is one of the districts severely affected by the 2015 earthquake (NPC-

GON, 2015). Other field sites identified for the study fall in the mid-hills of the Teesta River basin which falls in two Indian states – Sikkim and West Bengal. The Teesta runs through the mid-hills of Sikkim and West Bengal into the floodplains joining the Brahmaputra in Bangladesh. Landslides, flash floods, droughts, hailstorms, and erratic rainfall are major climatic hazards in this region.

Downstream: Downstream sites chosen for the study were: the Chaj Doab in the Indus, Haridwar and Rishikesh in the Upper Ganga, Chitwan and West Champaran in the Gandaki and Jalpaiguri in West Bengal, India and Rangpur division, Bangladesh in Teesta basin. In downstream Indus, Chaj Doab is bounded by the Chenab and Jhelum rivers. Its elevation ranges 150–250 masl. In the Chaj Doab area of the lower basin, canal water supplies are inadequate in the summer pre-monsoon (late April to mid-July) due to the very low river discharge. The Jhelum River is fed by monsoon rainfall and only partially by snowmelt water from the high mountains of the Himalaya, unlike tributaries such as the Hunza river (Ashraf and Ahmad, 2008).The selected lower elevation and plain villages in Upper Gangaare Khadri Kharak Maaf in Dehradun, and Kangri, Mohammadpur Panda, Mohammadpur Bazurg Aht, and Mathana in Haridwar district. While the plains have always been a hotspot for riverine floods, climate change and other social drivers have worsened the situation. Temperature rise, heat stress, change is seasons, erratic rainfall, heavy wind, hailstorm, and water scarcity are major climate-related hazards in the area.

The study sites in downstream Gandaki included the Siwalik hills, and the extensive plains of the Terai and beyond, at elevations down to 44 masl. The Siwalik zone has dry and unconsolidated soil materials highly prone to erosion and landslides, while the Terai is characterized by vast floodplains with deciduous forest and agriculture, which are subject in many places, to annual inundation. In downstream Chitwan, flash floods are more prominent as water drains from the northern Mahabharat through the Siwalik causing flash floods. Major climate-related stresses are floods, river erosion, temperature rise, changes in season, fog, heavy wind, and hailstorms (Dandekhya S et al, 2017).

In the lower Teesta basin, the study areas identified in Jalpaiguri, West Bengal, India lies in between the Teesta and Karala rivers. The sites fall under the Department of Irrigation, making their inhabitants illegal dwellers who face the threat of displacement during floods as well as the rest of the year. In Jalpaiguri, floods, droughts, riverbank erosion, flash floods, storms, and hailstorms are major climatic hazards. The lower Teesta is a sub-region of the Bengal basin, which covers most of Rangpur division in Bangladesh. The village communities were selected from riverine *chars* and adjacent disaster-prone areas. The study focused on remote places where road connection is poor. In the lower Teesta, major climatic stresses are floods and riverbank erosion, sand deposition in riverbeds and on crop fields, drought and heat stress, groundwater depletion as a result of over extraction for irrigation during the dry season, erratic rainfall, water-logging, cold waves, and decrease of number of rainy days (Syed, A., et al, 2017).

2.2. Socio-economic Conditions

Participatory research in the river basin study sites has found that there are differences in socio-economic factors and conditions across the river basins. Upstream and hills areas are less populated and have less diversity of livelihood options. The nature and dynamics of poverty are different across the river basins. Communities living in the mountains and the mid-hills in all the river basins suffer from poor connectivity. These areas lack infrastructure and government initiatives are limited. Communities in flood plains and *chars* in lower basins of the Gandaki and Teesta, particularly in West Champaran in Bihar and Rangpur in Bangladesh also suffer from poor connectivity and development deficit, which again act against their resilience and adaptive capacity and increase vulnerability to climate change.

Upstream: In upstream Hunza (Indus basin), Rudraprayag (Upper Ganga basin) and Rasuwa (Gandaki basin), most people's livelihoods are agro-pastoral. While in the upstream Teesta basin, agriculture and tourism present major livelihood opportunities. The area is comparatively less populated. Agriculture and livestock are major sources of livelihood in upstream Indus. The region falls under a mono-cropping zone and the major staple crops grown include wheat, maize, and potato. More than 70% of the population depends on agriculture and horticulture 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.

The upstream Upper Ganga basin covers the greater part of Uttarakhand. About 60% of the land cover is agriculture (main crops: wheat, maize, rice, sugarcane, millet, and potato); 20% is forest, mostly in the upper mountains; and approximately 2% is permanent snow and ice (Shukla et al., 2014).Uttarakhand is a predominantly agrarian state; average landholdings are small, with about 50% less than 0.5 ha, and around 70% less than 1 ha, reflecting the predominant practice of subsistence agriculture (Bhatt, 2006). The overall socioeconomic condition in the higher elevation district of Rudraprayag is low, with 37% of the population below the poverty line.

Rasuwa in upstream Gandaki, covering an area of 7,363km^2 is one of the worst affected districts from the 25 April, and 12 May 2015 earthquakes. The total population of the district is estimated at around 43,300 persons in the 2011 Dandekhya 2017. The topographical differences have led to different population densities, which is low in the upstream with higher poverty. Rasuwa is also an important agro-pastoral region characterized by transhumance livestock rearing. Fodder in the form of grass, trees, and grains are therefore very important to maintaining healthy stock of livestock.

In the upstream Teesta basin, agriculture and tourism are two important sectors around which Sikkim's economy revolves. Sikkim is also known for its rich agro-biodiversity (Sharma et al. 2016). Both its agricultural and agro-biodiversity systems are highly dependent on climate and water, and variability in climate may have serious consequences for Sikkim's agriculture. Sikkim's population comprises a mix of ethnic groups – Lepchas, Bhutias, Nepalis consisting of Brahmins, Chhetris, as well as Newars, Rais, Tamangs, Gurungs, Mangars and Limbus. Lepchas were the original inhabitants of the state, but at present other groups are in majority (GOS 2015).

Midstream: The Soan basin in midstream Indus extends across two of four districts on the Pathwar plateau in Pakistan (Rawalpindi and Chakwal). Besides agriculture, livestock also forms 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. The study villages in the Soan basin were all well-established and there is no seasonal migration for work except for transhumance. Road and railway infrastructure are also well established and maintained. The districts in the study area were well-connected with railways with main stations at Rawalpindi and Islamabad.

Tehri Garhwal in the mid-hills of the Upper Ganga is one of the largest districts in Uttarakhand, India, with a population of 618,931 (6.1% of the state total) and a growth rate of 2.4% over the decade from 2001 to 2011 (GOI, 2011a). The headquarters are at New Tehri, but only 13% of the population is urban. Agriculture and related activities like household industry, casual employment, and tourism-related activities such as shop keeping, running restaurants, and providing accommodation for tourists are the mainstay of the economy; among 'main workers' (those who work for more than six months a year), 63% are cultivators, 0.8% agricultural labourers, and 36% non-agricultural workers (WSMD, 2009). The district has a high proportion of marginal workers – 32% compared to the state average of 26% (WSMD, 2009). More than 45% of the population lives below the poverty line. The state poverty ratio is around 30 to 40% (WSMD, 2009).

In Nuwakot district in midstream Gandaki, district census 2011 records show 59,215 households with a population of 277,471 residing in the district. Road networks are developed compared to other hill districts in the country. A study focusing on capturing rain-fed scenarios was conducted in two villages. One of the villages is among the poorest hamlets in the district with high rates of migration and populated by indigenous communities such as the Tamang. The other has large populations of so-called high caste communities and the presence of an active cooperative.

Poshyor in Kalimpong and Teesta Valley in Darjeeling are located in the mid-hills along the Teesta River. Residents of Poshyor constitute of mixed ethnic communities such as Lepcha, Rai, Magar, Subba, Chhetri and Tamang. Households in Poshyor practice mainly rain-fed agriculture. Interestingly, commercial agriculture has always taken

a backseat in the area. This is because of issues concerning *parcha-patta* (land documents). The residents of Teesta Valley have no land ownership documents and are completely dependent on and at the mercy of the social hierarchy of tea estates.

Downstream: Chaj Doab, downstream Indus, is densely populated as it is rich in agricultural resources and there is sufficient water for irrigation during monsoon season although there is some water shortage in early summer. Large-, medium-, and small-scale industries, businesses, and trade dominate urban areas and plains are characterized by gentle slopes facilitating transportation of goods from farm to market. Locals report that a sizable number of young residents are migrating from rural to urban areas within the region, as well as overseas, in search of jobs. Migration for work contributes at both the local and the national level. Households in the Gujrat and Mandi Bahauddin districts in Pakistan have the lowest annual income of all the districts in Chaj Doab.

In downstream Upper Ganga, Haridwar district, in the plains is agriculturally rich with high agricultural productivity due to its location in the fertile Terai region. Both Haridwar and Dehradun have well-established road networks and thus good accessibility. The district experienced a population growth of 32% between 2001 and 2011 and has a population density of about 801 inhabitants per km^2. Both Dehradun and Haridwar have high degree of urbanization, 37% in Haridwar and 56% in Dehradun – almost double the state average (GOI, 2011a; Planning Commission, 2009). Dehradun and Haridwar are among the four districts in the state with a concentration of industry, the others being Nainital and Udham Singh Nagar. In the 2002 census, 32% of the population of Dehradun was found below the poverty line and 18% in poverty in Haridwar, which was the lowest percentage in the state (WSMD, 2009).

The Nepal Government promoted a resettlement programme in Chitwan district of downstream Gandaki in the 1950 and 60s, after which the population of hill migrants increased. The 2011 Census records the population of hill Brahmin to be 29% and Chhetris to be 11% of the total (CBS, 2013). Originally, the Tharu were the indigenous dominant ethnic group in the district, who now number around 11% of the total population. Chitwan is the hub of agricultural enterprises such as poultry, vegetables, paddy, and maize that supply good to major cities like Kathmandu and Pokhara. Some key changes in the district after the 2015 Nepal earthquake are increased land prices and decreased in labour costs.

Before 1971, people living in Jalpaiguri, West Bengal, India in downstream Teesta were engaged in a prosperous transportation business. After the completion of the Teesta bridge in 1971, the local transportation business came to a complete halt. The situation was worsened by heavy floods during the monsoon every year, which erode large tracts of land, rending people landless and without shelter, and out of livelihood options. Over the past 5–10 years, displaced people have taken shelter on both sides of the banks of the Teesta and Karala rivers. These people have faced many socio-economic changes over the years as a result of changes and development in the Teesta River and adjoining areas.

The Teesta-Bangladesh study site is highly populated. However, a majority of the people live under the poverty line. Average land holding is less than one acre. Agriculture is a major livelihood option. The study found that villages located in the mainland and adjacent to rivers have good sanitation facilities and energy coverage compared to villages located in *chars*. In *chars*, villages do not have adequate formal and informal institutions. There is a Union Council Office nearby and sometimes the villages get services from the Agricultural Extension Office, veterinary services and rural physicians. Mainland villages are served by NGOs that facilitate micro-credit, health services, and livelihood programme. In *chars*, villages are mostly underserved by government departments and NGOs.

3. Climatic Variables and Extremes: Temperature and Precipitation

Temperature rise and erratic rainfall (late and low rainfall) have been reported in all the four river basins. Temperature rise was reported in both summer and winter seasons and these are causing low rainfall and reduced snowfall in the high mountain and upstream regions of the four rivers. Higher temperature, low and no rainfall and increasing drought are causing forest fires in upstream Gandaki in Nepal. In the midstream region, temperature rise, hot summers and short winters, and late monsoons have been reported. Temperature rise, hot spells, and drought are common climate features with late and heavy rainfall leading to frequent and devastating floods in all the downstream sites of the four river basins studied. In all four basin areas, there is a trend towards rising temperatures and increased variability in precipitation, but the specific trends are slightly different in the different areas from the mountains to the plains.

In the Upper Indus basin, a considerable amount of precipitation is received during the spring season (between April and May). 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 has increased, while winter snowfall has decreased compared to 10 years ago. According to the villagers' perception in upstream Upper Ganga, an increase in summer temperatures with a greater intra-seasonal variation in the temperatures trends have been witnessed over the years. Apart from heavy and intense rainfall, it has also been noted that there are more instances of off-season rainfall, which was not the case earlier. Local people in upstream Teesta feel that summer temperatures are rising and that winters are becoming warmer and drier. Ethnic groups in the areas reported that ten years ago, it was normal to have snow 1.5 m deep. This has reduced to "just a couple of feet or even less" now as more precipitation mostly falls as rain and the glaciers are receding. It has been further reported that changes in climate can be felt in terms of increased temperature during the summer and decreased precipitation in seasons other than the monsoon.

Table 2 shows key climate stresses upstream, midstream, and downstream of the Indus, Upper Ganga, Gandaki, and Teesta.

Table 2: Major climate change-related issues by river basins

River basin	Upstream	Midstream	Downstream
Indus	Temperature rise; decreased snowfall and glacial melting; erratic and low rainfall	Increasing hot weather in summer; decreased total rainfall with heavy rain in some years; decreased duration and depth of snowfall	Hot summers with long dry spells; decreased annual rainfall; local short-period and intense rainfall causing floods; temperature rise and low/no rainfall aggravating pest attack
Upper Ganga	Increased summer and winter temperatures; shorter peak winter season; reduced snowfall; heavy and off-season rainfall	Hotter summers and winters than 20 years ago; dry spells; snowfall only in January; decreased annual rainfall; local short-period and intensive rainfall causing flash floods, landslides, and erosion	Temperature rise in summer and reduced rainfall; higher winter temperatures; shorted winter duration; decreased winter rainfall

Gandaki	Temperature and heat stress rise in summer; drought in dry season causing forest fire; winter temperature rise; low snowfall	Increased maximum and minimum temperature; higher temperature and hot spells during the pre-monsoon; higher minimum temperature in winter; winter temperatures fall sudden causing cold waves	Increased summer and winter temperatures; delays in monsoon onset with less rainfall; sudden heavy rain causing floods; warmer winters
Teesta	Temperature rise in summer; hot and drier winter; no/little snowfall in the last 10 years; erratic and low rainfall	Summer temperature rise; extreme heat stress in summer; cold waves in winter; monsoon onset delays; erratic rain causing floods and landslides	Summer temperature rise; heat stress, warmer and late winter; erratic rainfall; frequent floods and riverbank erosion; drought and cold waves

The Soan River basin around Dhok Pathan, Pakistan experiences very hot weather in the summer, while the more northerly Murree hills have very cold winters with heavy snowfall. 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 midstream Upper Ganga, summers and winters are both perceived to be hotter than 20 years ago. Across villages, when asked about other perceived climatic changes, people mentioned late peaking of rainfall and overall less rainfall, which is problematic for rain-fed farming. Even winter rainfall has reduced. In Bagi, India, locals have noted sudden high-intensity showers followed by dry spells. High-intensity showers put residents at risk of flash floods, landslides, and erosion. In midstream Gandaki basin, local communities have observed increasing temperatures in the pre-monsoon period (April–May), which has caused a decline in the production of hybrid rice. In the mid-hills of the Teesta in Sikkim, and Teesta Valley in Darjeeling, India, local people have reported an increase in warm days. Rainy months have decreased, while rainfall intensity has increased and rainfall has become more erratic with heavy downpours leading to more frequent landslides and mudslides in places previously not affected. In Sikkim people noted that winter rains are becoming a rare phenomenon with winters becoming progressively drier and warmer.

Chaj Doab in Pakistan is situated between two rivers, the Jhelum and Chenab. Monsoon rainfall leads to floods almost every year in the area. Farmers have observed changes in the climate compared to 10 years ago, especially an increased incidence of more erratic rainfall. In the plains of the Upper Ganga basin, perceptions of changes in climatic parameters and stressors have indicated rising temperatures and reduced overall rainfall. Villagers have pointed to an increase in summer temperatures but reduced intensity of summer squalls (sudden rise in wind speeds). Winter temperatures have also considerably increased over the past years. A number of climate variability parameters indicate that temperature in the downstream Gandaki basin shows a strong warming trend. This pattern is, in general, validated by community perceptions and opinions. Data collected from field sites in the Jalpaiguri floodplains through FGDs, KIIs, and transact walks reflects the rise in temperature experienced and even more specifically observed in the last six years. This increase in heat is accompanied by the late arrival of winter, which has further shortened its duration to two to three months as opposed to four months.

Table 3: Variation in climatic parameters and events based on FGDs at Shardapally in Jalpaiguri district (Lower Teesta basin)

Events/ Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature												
Hotness		+	+	++	+++	+++	+++	++	++	+	+	
Coldness	– –	–									–	– –
Rainfall												
Pattern	–	–	–	–	–	+	+++	+++	++	–	–	–
Rainstorms					+	+		++	++	+++		
Wind												
Wind storms				+	++					+	+	
Hail storms							++	++				
Hot winds			++	+++	+++	++						

Temperature: Hotness: + normal ++ hot, +++ very hot; **Coldness:** – normal, – – Cold, – – – very cold; **Rainfall:** + sometimes rainfall occur, ++ normal rainfall, +++ heavy/ erratic rainfall, – no rainfall period; **Rainstorms:** + normal, ++ destructive rainstorms; Wind/Hail storms: + normal, ++ destructive; Hot winds: +++ very hot

Annual mean maximum and minimum temperature trends for Rangpur in the last 35 years suggest that both maximum and minimum temperature have increased in the area. According to the local inhabitants of Dahagram in Lalmonirhat, Bangladesh, drought has increased significantly in the last 15 years due to rise in summer temperatures. Winter temperatures are also reported to have risen over that period. During the FGDs, locals claimed that cold waves in winter and heat waves in the summer have increased in recent years. In recent years, irregular rainfall accompanied by shorter periods of heavy rainfall have also increased.

FGD with the village women, Dahagram, Patgram

4. Community Perceptions about Socio-economic Drivers, Climate Stresses, and their Impacts on Key Livelihoods

The vulnerability of a community is determined by a series of factors not limited to exposure to climate change but including a multitude of socio-economic factors or drivers. Coupled up with a number of climate change risks and stresses, many social drivers actually determine the nature and degree of vulnerability of individuals and communities. This study has found that poverty, along with climate stress, is a major socio-economic driver. According to community perception, lack of physical connectivity and infrastructure (lack of transport), improper management of water resources, water scarcity, increase in unemployment, state and local political insecurity, poor governance in disaster risk management, land ownership issues, dismantling of traditional and communal institutions, lack of supply, lack of quality education etc. are key socio-economic drivers that affect their lives and livelihoods and make them vulnerable. Communities also note that outmigration and social insecurity, increasing cost of food items and production equipment, community conflict, and human-wildlife conflict are affecting their social lives and livelihoods. On the other hand, economic development, infrastructure, technology, and market force are positive drivers that can build adaptive capacity and reduce vulnerability. Community members also felt that the caste system, as a traditional social and religious institution, increases social inequity, deprivation, and differentiation, particularly in Nepal and India. The system limits the capacity of individuals, families, and communities to face and cope with externalities such as climate change. In all the study sites, gender discrimination was found to be a major socio-economic factor, which makes women living in poverty highly vulnerable to the effects of climate change.

4.1. Agriculture and Food Security

Frequent floods, temperature rise, erratic rainfall, and droughts in all the study areas in the four river basins severely affect the agricultural sector and its productivity. Irregular rainfall is likely to impact the agricultural sector, as a result of both too much and too little water. In the Upper Indus basin, in Pakistan, the impact of the Attabad Lake disaster of 2010 on agriculture was severe. The landslide washed away the low-lying Sarat village with its settlements and agricultural land, along with cash crop fields of potato and apricot orchards. The mid-stream area of the Indus basin comprises of major rain-fed agro-ecological zones in Pakistan. Agriculture, and ultimately the livelihoods of people, in the midstream region 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 their livelihood. In midstream Indus, the occurrence of floods cause food insecurity in the locality. Farmers have to delay groundnut and wheat cultivation in low and medium rainfall zones in midstream Indus because of drought. Farmers in the Chaj Doab, comprising the flood plains of the Indus basin, noted that as a result of climate change, they have begun to delay the sowing of rabi crops (lentils and oil seeds traditionally sown in winter and harvested in spring) when there is no rainfall in September, or delayed rains. This has affected cropping patterns as some areas of Chaj Doab lie in a 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.

In the Upper Gages basin, higher altitude locations are known for horticultural crops such as fruit, vegetables, off-season vegetables, floricultural crops, and aromatic and medicinal plants. Rising temperatures are affecting their growth and productivity. There has been a considerable drop in the productivity of key horticultural crops

like peaches, apricots, plums, and apples as the required chilling isn't obtained due to the decrease in snowfall. The flowering season for these plants has also advanced due to the rise in temperature, which is not desirable. Incidences of hailstorm damage have increased raising quality concerns, and apple orchards in the high hills also face the threat of frequent landslides, especially from July to September, the peak season for the apple market. A decline in the productivity of horticultural crops due to monkey invasion (an example of human-wildlife conflict) has also been noted. The lack of well-established markets remains a big problem for farmers. All of these factors are leading to a shift from horticulture to vegetables and no new orchards are being planted in the region.

Intensive cultivation is not feasible in the mid-hills due to the harsh terrain. Limited land is irrigated (only 7.4% of the land is cultivated, the lowest level in the state), which means agriculture is at the subsistence level (GOS 2013). Residents perceive warming and reduced number of rainy days during monsoon and winter seasons. Summers and winters both are perceived to be hotter than 20 years ago. Across villages, when asked about other perceived climatic changes, people mentioned late peaking of rainfall and overall less rainfall, which present problems for rain-fed farming. Since the agriculture is rain-fed here, droughts pose heavy risks on food security in the region. It has become increasingly difficult for villagers to continue farming due to multiple reasons such as conflict with wild boars and langurs, delayed peaks and insufficient rainfall, and poor connectivity to the market. Due to outmigration and reduced availability of fodder, families have reduced the number of domesticated animals they keep. Villagers in Bagi, Tehri, Uttarakhand say that as a result of a cloudburst event in 2014, they have lost 60% of their agricultural fields as these lands cannot be cultivated anymore.

Changes in temperature and rainfall have adversely affected agriculture in the high hills of the Upper Ganga basin as well. Villagers note that prevailing weather patterns have changed and say that the change has affected their farming system. This is especially relevant because agriculture in the hills is mainly rain-fed and changes in rainfall patterns will affect crop productivity adversely. The region's prevalent farming system involves multi-cropping, with very little scope for irrigation. Reduction in rainfall, particularly winter rainfall, has affected the wheat crop, which is widely grown between October and May. A decrease in snowfall, coupled with reduced winter rainfall seems to have an adverse effect on wheat. Locals also say that instances of pests in the crops they grow has increased. Though many *Brassica oleracea* varieties such as cabbage and cauliflower are prone to pests and diseases, locals have observed that instances of pest attacks on crops like wheat, an uncommon occurrence in the past, has increased.

Upstream populations in the Gandaki basin mostly rely on rain-fed farming. Around 80% of the agricultural land in Rasuwa, Nepal is rain-fed; only 21% of the 5,031 ha available in the district is irrigated. Thus farming in the upstream areas is particularly vulnerable to water stress and uncertainty resulting from climate change (DDC, 2006). FGDs with farmers revealed the impact of the late monsoon and other climate related changes on the farming pattern. The traditional mixed crop barley/potato system relies on winter rains and moisture retention through snowfall to grow barley (or another cereal) in winter. In Daibung and Laharepauwa in Nepal, the reduction in winter rain and snow has led to a shift away from traditional cereal-based cropping to cash generating vegetable and organic farming in poly-tunnels. The changing temperature, rainfall patterns, drought, and snowmelt in the meadows and rangelands are, naturally, causing hardships for farming families who are dependent on yak, sheep, and *chauri* (cattle) farming in the *kharkas* (pastures) and other large, medium, and small livestock near their homestead farms.

In the midstream, water for irrigation is an increasing concern amongst farming communities because of the variability of rainfall. Previously, farmers harvested two cereal crops annually in locations above 1,000 masl; paddy in the monsoon season and maize or wheat in winter. Now, the reduction in winter rain can make it difficult to grow a winter crop. In Nuwakot district, Nepal an estimated 47% of agricultural land is irrigated, but only 20% receives sufficient water to grow two crops per year (CBS, 2012). Climate variability has affected many irrigation systems due to damage at the headworks following excessive precipitation or landslides. Downstream communities engaged in agricultural activities are more vulnerable to the impact of flash floods and other water-induced disasters. The areas close to the river are affected by inundation of fields and massive silt deposition during floods, which reduce the productivity of the land. Siltation forces households to either leave the land fallow for a long period or to use increased amounts of chemical fertilizers to maintain agricultural productivity. The main changes observed were

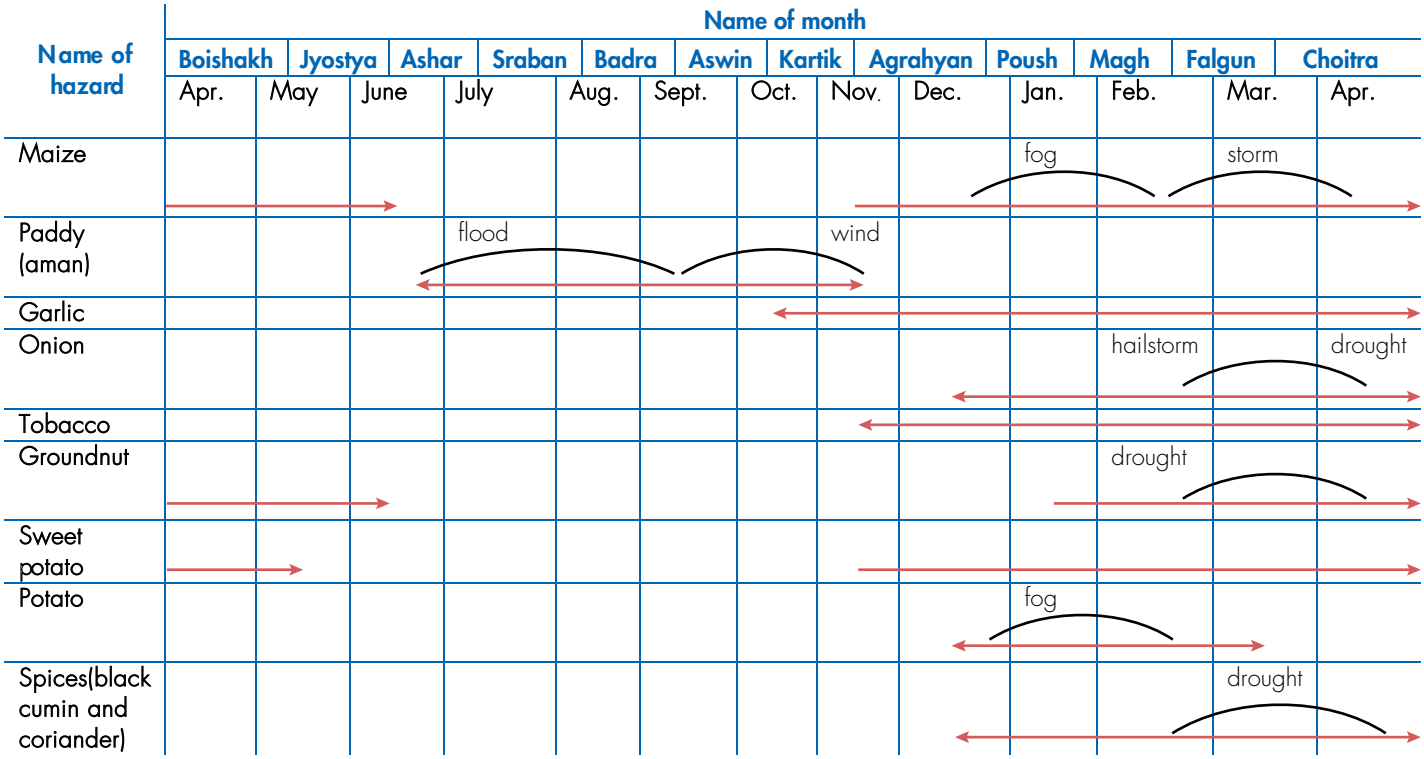
decreased agricultural productivity and shifts in farming seasons, particularly for paddy, which had increased the economic vulnerability of marginal farmers.

In downstream floodplain areas in the south of Makwanpur in Nepal and in West Champaran in India, the most common change in climate perceived by the local communities was an increase in sporadic heavy rainfall events. The changes in cultivation of cash crops (in Makwanpur) also provided an indication of significant change in rainfall patterns. In the floodplains of West Champaran in Bihar, communities living near the river or inside the embankments are unable to carry out any agricultural activities for 3–4 months a year, as their fields are either eroded by the river, or completely inundated. Conflicts around water sharing from the rivers with farmers across the border are common during the dry season, when the farmers grow paddy, which needs much water. This conflict is leading to greater vulnerability of farmers who do not receive water from the river during the sowing season.

In upstream Teesta basin, water scarcity is one of the major impacts arising out of changes in temperature and precipitation. This has been observed across research sites in West and parts of North Sikkim. Increased temperatures directly lead to plants drying up and wilting, and with limited water it is difficult to irrigate them, say the locals. Late winter is flowering season for high value cash crops like large cardamom, and lack of water can lead to wilting of flowers, causing decreased productivity. Winter irrigation is severely affected by warmer and drier winter weather. Extreme snowfall has lasting impacts on agro-pastoralists. During these events, sheep or yak become very weak and die of hunger, resulting in major loss for the herders. Hailstones at high elevation sites in Uttarey, Sikkim damage maize, which is widely cultivated in the western part of the state. It also damages fodder, both on the ground and on fodder trees. Villagers have observed the severity of frost and the damages it causes their crops. Even winter vegetables like peas and potatoes are damaged by frost. In mid-stream areas, an increase in heat directly affects agriculture, especially the cultivation of crash crops like ginger, directly impacting the livelihoods of mid-hill communities. Reduced distribution of rainfall has also impacted cash crops such as mandarin orange in Teesta Valley.

In the Teesta floodplains of Jalpaiguri, communities have been forced to adapt, shifting from cultivation to migration as their main source of livelihood. Delayed monsoons elongate drought periods, and this has led to a loss in jute cultivation. River bank erosion and floods are devastating to the agricultural sector in the lower Teesta Bangladesh floodplains. River erosion is a major cause of poverty as it leads to farmers losing their agricultural land and agriculture-based livelihood. Further, droughts affect maize cultivation in the region. Frequent floods have severe negative impacts on rice (aman) cultivation. The floodwaters carry sand with them and deposit them in fields. Sand deposits at an alarming rate, 1.5–2 feet annually, especially on river-adjacent cultivable lands due to heavy flooding, making agricultural land barren. Cultivation is not possible without removing sand from such land. This is labour intensive and expensive and poor farmers cannot afford the expense in most of the cases which leads to them suffering from loss of crop production. Farmers cannot change their cropping patterns immediately and cannot afford to buy new seeds and the necessary agriculture implements to grow more climate resilient crops. This further increases their food insecurity and vulnerability. The hazard calendar in the lower Teesta shows that major crops are affected by floods, droughts, fog, and cold in different seasons of the year.

Table 4: Impacts of climate disasters on agriculture (Shown in the crop and hazard calendar from hatibandha, a site in the Lower Teesta, Bangladesh)



4.2. Rural Employment and Wage Earning

The poorest people often work as daily wage labourers and most such labourers only have previous experience working in the agricultural sectors. Farmers and wage earners suffer a lot from heat stress during summer. Often, these labourers cannot work for long durations and may fall ill as a result of exertions they are unused to. When these labourers are not able to go to work, their families suffer from food insufficiency as they depend on a daily income. Seasonal migration often occurs as individuals migrate from one place to another in search of livelihood options. In the monsoon, no agricultural work is available in downstream Teesta as the land is inundated by water far months. The poor are forced to migrate in the cities for jobs. As migrants, they are forced to work as daily workers mostly as labourers. A shift in livelihoods in the case of fishermen as much as it does with farmers.

Table 5: Key climate stress and socio-economic drivers affecting different occupations in the lower Teesta basin in Bangladesh

Occupation	Climate stress on occupation	Social dynamics and drivers
Farmers	-Forced adaptation – from cultivation to seasonal migration during monsoon period -Heat stress makes conditions difficult, affecting ability to work in fields -Riverbank erosion have forced many people to migrate permanently as people have lost their agricultural assets	-Have to leave their families alone for long periods to earn money to feed them -Poverty, health issues, food insecurity, and malnutrition in families

Day labourers	-Day labourers face difficulties when there is heat stress or cold wave -During flash flood, they do not have any work in their locality and have to migrate seasonally in search of livelihood options	-Women get less wages compared to men -When male family members migrating for work, females have to manage everything for their families and suffer from food insecurity and difficulty in day to day lives
Fishermen	-Changes in hydrology and water temperature detrimental to fish species -Fish unavailability causing negative impact on earning of fishermen -Change of occupation - Many local fish species has become extinct due to heat stress	-Loss of income and livelihoods -Fishermen face difficulty when they have to change their occupation due to climate stress - Geophysical changes of river also force fishermen to change their occupation.

4.3. Fisheries

In 2006, the Government of Nepal declared Rasuwa (upstream) and parts of the basin in Nuwakot (midstream of Gandaki) areas for raising trout (Shrestha and Pant, 2012). In 2007, there were five farmers involved in trout farming in Rasuwa, but the rising temperature has affected these cold-water fish which are showing increased rates of mortality (Malla, 2008).In the Gandaki basin, heat stress is observed in aquaculture, and many fish are dying of heat. In some places, communities have taken steps to cope with loss. However in some other places, they have not been able to do so, which has further increased vulnerability and driven the local population towards poverty.

- In the last 7–10 years there have been no sightings of dolphins in the Teesta; earlier, dolphins would migrate to downstream Jalpaiguri during the monsoon
- The rise in temperature and the decrease (or rather the uncertainty) in the water level are affecting the health of fish.
- Due to unfavourable condition, fishermen are forced to change their occupation and livelihood
- Fishermen struggle when they work as agricultural labourers as they are not good at the work

In the Teesta floodplains of Jalpaiguri, India the unpredictable river flow and water levels have affected the breeding of fish, leading to a drastic in the variety and number of fish. The fishermen also say that the rise in temperature and the decrease in the water level is affecting the health of fish. In the Teesta floodplains of the Bangladesh study sites, many households were dependent on the Teesta River in the past. Nowadays, fishing as a livelihood is threatened as the river has been drying up. These days, the Teesta remains dry, except during the rainy season. Due to the drying up of the Teesta, the indigenous availability of fish variety has reduced. According to fishermen, there were more fish in the river than now even eight years ago. The Teesta now shrinks to the size of a narrow canal so there is not enough fish to catch, they say. They identified dams and barrages on the upstream and sedimentation on riverbeds as the main causes of the river drying up. Since the availability of fish is low and duration for fishing is short, fishermen are facing economic hardships. Many of them are switching to the occupation of wage labourers.

4.4. Housing and Infrastructure

In the Upper Ganga basin, the loss of forest cover in Haridwar, India has been attributed to the resettlement of Gujjars and other ethnic groups ousted from the Tehri dam area, as well as the rotational felling of eucalyptus trees around Shyampur and Chiriapur. In Kangri, the change in land use was attributed to locals selling their land to outsiders for housing and other uses due to the lack of opportunities to earn money within the village. In downstream

Gandaki, the increase in flooding is resulting in an increase in displaced populations as homes are inundated. The floods in 2011 displaced almost 400 people in Mangalpur, Chitwan, Nepal (ICIMOD, 2011). The people were housed temporarily in nearby urban areas in schools and other public buildings. Such situations can place tremendous pressure on a town's basic services. In West Champaran, Bihar, settlements have been washed away during floods and by bank erosion. The communities felt the need for building flood-safe houses and structures such as *thokar* – a barrier constructed on the edge of a river to divert its flow. In Bidur municipality, the district headquarters of Nuwakot district in Nepal, the population has increased as a result of in-migration of subsistence farmers in search of better facilities and economic opportunities. Major challenges in the urban sector include the poor design and construction of buildings, non-compliance with building codes, increasing unplanned squatting on public and private land, and unmanaged land use practices making land unsafe during extreme events. Growing urbanization has led to an increased demand for sand. Sand mining continues unabated along the river, leading to an increase in landslides, floods, riverbank collapse, and riverbed subsidence.

In the Teesta floodplains, the intensity of river erosion has increased over time, but a number of people are living on *khas* land, on the embankment, and on *char* land. They have lost their homes and cultivable land to river erosion. The people are poor. Not all of them are able to build an elevated homestead to protect themselves from floods and a large number, who are not able to afford the extra money to build an elevated homestead, end up take shelter in embankments. As a result, they face food crises, lack safe water and sanitation facilities, and suffer from diseases. A majority of the population that lives in poverty in the region does not have access to elevated tube-wells and hygienic sanitation systems. The situation affects women disproportionately as they have to wait till dark to defecate.

4.5. Water, Health, and Sanitation

Water: In the upper Indus, 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 on 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 reduced flow in the river, which is severely affecting the livelihoods of vulnerable people. In the lower Indus Basin, the use of groundwater has increased due to 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.

In upstream Upper Ganga, increasing summer temperatures have resulted in a reduction in water that is available through natural sources (springs) in Huddu, Ushara and Guptkashi in Uttarakhand, India. In Guptkashi and in all other study villages in the high elevation sites, water quality during the monsoon is an issue. Water is usually contaminated by mud and faeces during this period, which negatively impacts the health of villagers, particularly the young and elderly. In midstream Upper Ganga, there were four running springs and a farm pond *(chahal)* within the village Kimkhola. Residents mentioned reduced discharge in all four springs with some even left with zero discharge during the lean season. Solani River in downstream Upper Ganga, which was earlier perennial, has almost zero discharge during lean season these days due to reduced return flows and declining ground water table. The water quality is perceived to be poor until 55 feet in Hakimpur village. The water is yellow in colour, has a foul smell, and leaves stains on clothes and utensils washed using it. Residents perceive the water to be unfit for drinking and cooking.

The effects of climate change on water sources have been observed in upstream Gandaki in Rasuwa, Nepal where most piped water is sourced from springs which are drying up, posing a threat to local communities. The effects of climate change on water sources has been observed upstream in the district. In neighbouring Nuwakot (midstream), most villages use untreated spring water for drinking, which is generally seen as good quality and reliable, but the fieldwork revealed that some sources are no longer used for drinking as the water was thought to cause discomfort

and possibly sickness. In downstream Gandaki, farmers mentioned reduced water levels and attributed multiple reasons for the same. Periods without rainfall had prolonged in Nuwakot, Nepal. In addition, urbanization in upstream areas like Padampur has increased since 1998, causing diversion of water to other systems and affecting water availability.

In upstream Teesta, in high-elevation West Sikkim, access to water depends on the location of the village and the source of water i.e. springs. Further, within the villages, access to water depends on the origin of settlers. Newer settlers, who have smaller land-holdings face problems securing water for cash crop cultivation. In midstream Teesta, water is a major concern in the Teesta Valley, especially for women who work at the tea estate. Many ponds and springs have dried up both due to a rise in temperature and as a result of earthquakes. In South Sikkim, Pendam and Melli fall in the rain shadow area and suffer from water shortage, compelling a large number of households to carry water. The increasing occurrence of long-duration dry periods has resulted in the drying up of perennial water sources in Pendam. Mandarin oranges from Teesta Valley, which were in great demand in Siliguri town and a good source of cash for locals, has completely vanished in the last five years.

In downstream Teesta, in response to surface water unavailability, locals are extracting ground water resource for irrigation. This is causing ground water table depletion in most of the study villages in downstream Teesta, Bangladesh. To protect them from floods, villagers who have the money raise the platforms of their tube-wells while those who cannot do so and do not have raised tube-wells need to collect fresh water from long distances. The poor suffer from inadequate water for drinking and domestic use during the dry season, which increases health risks. In many cases, women have to spend much time collecting water from far distances.

Health and Sanitation: In upstream Upper Ganga, water quality is an issue. During the monsoon, the water that is supplied through pipelines feeding on nearby springs carries a lot of silt with it. Villagers say that the water causes gastrointestinal infections (GTI) in the young and elderly. The locals also note that changing temperature trends, especially during the summers, have led to increase instances of febrile illnesses in the young and the old. Greater diurnal variations in temperatures were specially pointed out in Ginwala at Rudraprayag in Uttarakhand during discussions with locals. In downstream Upper Ganga, villagers mentioned that the deterioration of groundwater quality is leading to increased cases of problems related to acidity, indigestion, and kidney stones. In one study site, there is a sewage treatment plant receiving waste from Rishikesh that releases its effluents through land owned by some farmers in Khadri kharak Maaf, a village in Uttarakhand.

In upstream Rasuwa, locals reported the emergence of new health problems including high blood pressure and diabetes, which they attributed to the consumption of food grown using chemical fertilizers and pesticides and other environmental changes. In midstream Nuwakot, the availability of health institutions and access to health facilities depends largely upon the geographical location of communities, their socio-economic status, and transportation facilities, including the condition of roads. Landslides regularly wash away or block roads in remote areas during the monsoon, limiting access to health care facilities. There were no particular health issues that could be directly attributed to climate change, although there seems to be a general feeling that some health problems are increasing with the rising temperature. However, contamination of water sources during floods or even the scarcity of water in the dry season (January to May) may increase the vulnerability of communities and exposure to vector-borne diseases. In downstream areas, increase in temperature is thought to be responsible for a resurgence in cases of malaria, which had been virtually eradicated. People in Meghauli and Ayodhyapuri in Chitwan face many health hazards related to floods, with nausea, vomiting, and diarrhoea common during and after the monsoon floods. In India, the lowest portion of the basin is affected by devastating floods every year. Lack of sanitation facilities forces people into open defecation, which leads to water contamination and contributes to the outbreak of cholera and other water- and vector-borne diseases. People in the study villages in West Champaran district were affected by skin diseases; their scarred legs and feet indicated the adverse impacts of poor water quality and hygiene on health. The women in the villages identified an urgent need for sanitation and toilets, as they are the most vulnerable during floods.

In upstream Teesta, changes in climate have caused winter days and nights to get colder, leading to increased joint pain among the elderly. The locals have noticed an increase in cases of diarrhoea and vomiting, which they

attribute to an increase in the cold and dust. An increase in temperature in the months from June to September has brought about the problem of mosquitoes in the recent years. This has a correlation with warmer weather and climate change. The unavailability of healthy food (organic and fresh vegetables, fruits, fish and meat) and the consumption of non-local food given rise to the number of diabetic patients. People living in poverty cannot seek proper treatment because of their unfavourable economic condition. Wage earners and day labourers are especially vulnerable because they have to work outside, often in harsh conditions, even when they are ill, causing further stress on their health. In midstream Pendam and Melli in South Sikkim, the prevalence of uterine diseases among women and of kidney stones among the general population is increasing. Incidences of diarrhoea, fevers, and stomach aches have also increased, and reflect deteriorating quality of water. The co-relationships between natural disasters, climate change, and health came up very strongly in the Teesta Valley as well as in the case of tea pickers, especially women. Tea pickers work with the risk of landslides, cold waves, and cloud bursts ever present. They have to work in unfavourable conditions because of their very livelihood source and hence become vulnerable. In downstream Teesta basin sites in Jalpaiguri, India, local people have reported the emergence of diseases such as hypertension in their localities. They attribute this to warmer weather and climate change. During stress periods like river erosion and flash floods, people in downstream Bangladesh suffer from health-related issues as accessing health services becomes difficult during floods. Big floods also wash away sanitation facilities used by the poor who live on floodplains and *char*, increasing health risks and economic costs.

4.6. Energy

The primary sources of energy in many parts of the Indus basin are fuelwood, kerosene, electricity, dung cake, diesel oil, batteries, and liquefied petroleum gas (LPG). Fuelwood is the main source of energy in the domestic sector and is used for cooking and heating in rural areas of the Indus basin. The energy crisis is similar across the Punjab region, in Pakistan including project sites in Chaj Doab and Soan. Women are most affected in both urban and rural areas, where LPG availability is limited. The need for cooking fuel in rural areas is increasingly, and is met primarily by burning dung cakes and fuelwood. 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.

It is predicted that extreme events like cloudbursts, landslides, and floods will pose a serious threat to energy infrastructure in the Upper Ganga basin. Field discussions also showed the impact of floods on hydropower facilities. Hydropower projects have been damaged in areas around the villages visited in Rudraprayag following heavy rainfall and an outburst due to a glacial fall near the Chorabari Glacier in mid-June 2013. Two days of heavy rainfall led to widespread flooding in the Mandakini River and caused damage to many hydropower projects, as our study team observed while travelling to the villages. A project with the Uttarakhand Jal Vidyut Nigam Limited (UJVN Ltd) was damaged beyond repair. Another, funded by the Asian Development Bank at Kaliganga, was left in a similar state. The floods also caused extensive damage to power lines rendering a few thousand people without power for over a week. In the mid-hills, fuelwood, kerosene, electricity, LPG, and non-conventional sources of energy like solar and wind are important sources of energy, but the difficult terrain and inaccessibility of remote areas means LPG can be difficult or impossible to obtain and fuelwood from the forests is used for cooking, lighting, and heating. Communities from the lower elevation villages of Kangri and Khadri Kharak Maaf reported a decrease in forest cover. Women spend several hours a day collecting fuelwood and fodder from the forest as they have to walk long distances across difficult terrain. Thus they lose time they could otherwise give to other activities, which might be beneficial or provide a source of income.

In upstream Gandaki, energy use and generation in the sites studied consist of various sources such as fossil fuel, fuelwood, hydropower-generated electricity, biogas and some solar panels. Rasuwa in Nepal relies on fuelwood to meet over 70% of its energy needs. There are three community forests in Rasuwa, which provide much-needed fuelwood and biomass energy. Forest fires and forest encroachment, and a lack of active forest management on the part of the Government and local community, is leading to fuelwood and timber becoming scarce, expensive, and difficult to obtain. Respondents in Rasuwa confirmed that the Chilime Hydropower project has distributed

public shares and almost all the community members in neighbouring villages have shares in the project. However, the respondents of the FGD confirmed that not everyone received shares, particularly those who graze *chauri* in seasonal pastures (*kharkha*), have been left out of this benefit as the community has little influence. Climate change has serious implications for hydropower. The hydropower projects in the Upper Gandaki basin face challenges resulting from changes in rainfall and temperature causing fluctuations in runoff and discharge, which affects power generation.

Fuelwood is also the major source of energy for households in the mid-hills the Teesta basin in Sikkim, India. In West Pendam, Melli Dara, Poshyor, and Teesta Valley, households have started using LPG cylinders for cooking, which has largely replaced fuelwood. The use of firewood continues in Poshyor as LPG is expensive and needs to be carried manually to the village. This is inconvenient and very expensive for the residents, mostly poor farmers with little money. The residents of Teesta Valley are also very critical of the new development projects in the area. The Teesta Low Dam-III power station has caused much controversy as it has affected the daily livelihood of residents and led to an increase in mosquitoes, cold, dirt, and sickness. Hydropower development has rapidly increased along the Teesta River and in its major tributaries, both in Sikkim and in Darjeeling in West Bengal. Even so, more than 40% of the population of the lower basin still lacks direct access to electricity; either because of lack of supply or due to the high price, which makes it unaffordable for the poor. In the Bangladesh plains, *chars* are hard to reach areas for grid power and thus most of the Teesta *char* population relies on conventional kerosene for lighting and agricultural residue for cooking; kerosene is used primarily for heating and lighting. There is limited or no access to electricity for households. At the household level, women are exposed to health hazards from smoke. A limited number of families use solar power to light their homes in the evenings.

4.7. Tourism

In Gandaki, many villagers in the study areas have turned to rural tourism as source of livelihood. The drying or shifting of sulphur-rich hot springs previously visited by many tourists in Chilime, Rasuwa has made life difficult for people whose livelihoods depend on ecotourism. The home-stays, hotels, teahouses, and lodges are facing severe hardship as tourists arrivals have dropped drastically. Small hotels, lodges, and tourism-related businesses along the popular Tamang Heritage Trail (THT) have suffered. People have begun to migrate to cities and foreign countries or have taken up jobs as labourers and porters within the district. In downstream Upper Ganga, the number of tourists visiting Badal village in Uttarakhand has reduced significantly since the 2013 floods. In 2014, the year after the floods, tourist numbers dwindled by 60%. Besides tourism, the residents of Badal village are selling farm products like pulses, vegetables (principally ginger), and milk, providing grocery supplies to nearby camp areas in Tehri Garhwal district. All of the various means of livelihoods built around the tourism sector were negatively affected by reduced tourist influx after the 2013 floods. Tourism is affected by temperature rise and climate hazards like floods.

An increase in the incidence of landslides in the uphill Teesta region has affected tourism and related activities. Erratic rainfall has also led to a fall in tourist flow during the monsoon months, which is a lean period for tourism anyway, and businesses earn smaller revenues. These changes are adding to the vulnerabilities locals already face during disaster periods like floods and extreme cold.

River bank erosion protection at Dahagram village in Patgram Upazila, Lalmonorhat district

5. Nature and Types of Vulnerability by Social Categories: Who are the Most Vulnerable?

The people in the Teesta river basin are having to cope with the impacts of climate change, such as frequent floods, droughts, and riverbank erosion. Farmers here mainly depend on agriculture, then fisheries, and livestock for their livelihoods. During the dry season, extending from winter through summer (November–May), cold, fog, droughts, and heat stress gravely affect the agricultural sector and common people's livelihoods.

The Government of Bangladesh and NGOs have taken sector-based adaptation actions (in the agricultural, fisheries, livestock, housing, energy, and water resources sectors) to reduce vulnerabilities in people's lives and livelihoods by understanding current vulnerability and resilience in different sectors, identifying knowledge gaps and needs among practitioners, and enhancing stakeholder perception of climatic change and adaptation. In addition, practitioners from the government and NGOs at the national and local levels need to take appropriate decisions in developing an engagement plan, encouraging networking amongst themselves, and evaluating and learning in the context of climate change.

This study found that communities use traditional, indigenous knowledge as well as adopt new technologies to adapt to the adverse effects of erratic climatic behaviour. However, the current adaptation practices are not adequate for building resilience of the communities and the impacted sectors in the Lower Teesta basin. They need further support from the government to protect them from floods and riverbank erosion. Additionally, the individual and community-level adaptation options are often specific to the ecosystem or local conditions. In order to upscale these efforts and take them to other ecosystems and conditions, some of these adaptation options may require appropriate modifications. Furthermore, effective adaptation would require the integration of indigenous knowledge with modern knowledge and technologies, local competence, innovation, resources allocation for the poor and the involvement of the local community through the local government. The government, NGOs, and civil society can work together and help design appropriate and innovative adaptation measures, strategies, and practices to combat climate change impacts and reduce vulnerability.

It is essential to understand vulnerability within the context of both climate change and site location, mostly in relation to social structures and institutional arrangement, which thereby increase physical vulnerability in the face of climate change and rapid development. In this section, we explore the vulnerabilities that the various groups are exposed to, based on their social, ethnic and geographical settings. The following sections describe the nature and types of vulnerability of the major social and economic groups and categories in the four river basins. The study has found that small farmers, wage earners, people dependent on natural resources like fisheries and forestry, tourism, and pastoralism are most vulnerable in the HKH river basins. Caste differentiation, inequity, and social deprivation are acting as social drivers which result in greater vulnerability for the poor, women, and marginalized groups. Outmigration is taking place in all the river basins due to both climate change and social factors. The poor and forced migrants – those who live on embankments, *khas* land, *chars*, or in cluster villages are sometimes socially and economically excluded and are highly vulnerable. Women face higher risks and differentiated vulnerability in all the basins due to climate stresses and their subordinate social positions and conditions as well as their limited access to resources, land, and productive assets, and knowledge, technologies, and institutions in all the communities studied.

5.1. Small and Marginal Farmers

Aquaculture is widely practiced in the downstream areas of all four river basins. In downstream regions of the Upper Ganga, rainfall events have become erratic. People from Hakimpur, India report that uncertainty regarding the

arrival and timing of the monsoon rains has made them dependent on ground water for irrigation. Families either have private groundwater wells or rely on government hand pumps or borrow or buy water from their friends and neighbours. People who do not have their own boring system have to suffer the most. The villagers interviewed frequently pointed out that prevailing weather patterns have changed over the years and that this has affected their farming system, creating unfavourable conditions for marginal farmers. The reduction in the intensity of summer squalls has not only increased the magnitude of pest attacks but also led to newer pests (not seen in the area before) destroying crops. Further, frequent wildlife attacks on crops hinder farmers' agricultural productivity and make them economically vulnerable.

There is a sewage treatment plant receiving waste from Rishikesh in upstream Upper Ganga. It releases its effluents through land owned by farmers in the town of Khadri Kharak Maaf, affecting certain villages. This has not only caused considerable damage to agricultural yield but is also threatening food security among farmers. The women often walk through effluent-flooded fields to collect fodder for their livestock. The waste water exposes them to infection.

In the field sites of midstream of Upper Ganga, irrigation is no longer possible due to reduced discharge in most spring sources. Since the agriculture here is rain-fed, droughts pose heavy risks on food security in the region, creating severe conditions for marginal farmers.

In the field sites of the Gandaki basin in Nepal, herders face difficulties grazing large herds of yak and *chauri* because grass and pastures are limited as a result of overgrazing, droughts, and forest fire. The herders as well as the milk collection unit have to constantly shift their temporary sheds. More than a decade ago in the *lekh* or High Mountain pastures in Sangen because of lack of fodder due to both social pressure and climate change on grassland. Good grass can be as far as 3–4 days' of journeying towards the Tibetan border. Changes in temperature, rainfall, drought, and snow melt in the meadows and rangelands are causing hardships for families dependent on yak, sheep, and *chauri* farming in the *kharkas* and other large, medium, and small livestock near their homestead farms.

In upstream Teesta (North and West Sikkim, India), locals report that the remoteness of their region means that essential goods are unavailable during certain periods of the year, especially the winters. As a result, locals stock up on goods, which pushes the costs of essentials higher up, resulting in unfair pricing for the poor, who cannot afford to buy even the most essential goods. The main sources of livelihood upstream are agropastoralism, agriculture, and fisheries. However, water is scarce during the winter, and makes poor and marginal farmers who cannot afford gravity-based sprinter irrigation or privately manage water sources vulnerable.

In midstream Pendam and Melli in south Sikkim, agricultural yield has gone down because of climatic hazards. An increase in the intensity of heat has also brought new crop diseases, which farmers are unfamiliar with. When productivity falls, marginal farmers are affected the most because they cannot afford to cope with any loss this will cause. As noted earlier, the Teesta Valley was popular for its production of mandarin oranges till even five years ago. Locals could generate anywhere from INR 150,000–1,200,000 (USD 1,500–2,000) annually from their sale. Residents say that changes in the climate and increase in pollution and diseases have ended orange cultivation in the valley, ending their access to an alternative livelihood source. This is a huge loss for marginal farmers. The displaced are the most vulnerable as they are forced to work outside their localities, often in urban areas as daily wage labourers. Migration as an option is better available to men than it is to women. Even so, in displaced areas, women are also forced to migrate. This makes them even more vulnerable to abuse and poor working conditions as their dire livelihood needs leave them with little negotiation power where work is concerned.

In downstream Teesta, agriculture and wage labour are the dominant forms of livelihood for a majority of households. Climate change causes huge losses to livelihoods and affects income every year leading to food insecurity. Seasonal loans are very much in demand in the area, usually during crop plantation period (November–December). As loan dependency increases, turmoil within families, creating discord between relatives.

In Dahagram (Union of Patgram Upazila in Lalmonirhat district, Bangladesh), villagers say that some of their land

and property now lies under water. Rebuilding houses requires additional monetary investment and effort, which creates further vulnerability among people. Vulnerabilities due to flood and river erosion continue to exist even after the flooded land is recovered. For instance, in Charpara, Dahagram locals say that although some of the inundated land has been recovered, it is now too sandy for routine cultivation.

Even when they take loans, poor farmers cannot invest all of it in agricultural production as some of it needs to go into procuring basic necessities. Migration is sometimes effective, but not always as surviving in new places is itself difficult. Migrants to new places cannot access socio-economic and others resources easily, because they receive no institutional support and they remain critically deprived.

5.2. Wage Earners

In Badal village in Uttarakhand, in the downstream region of the Upper Ganga, a legal battle between tourism enterprise groups and the court ended in April 2017. This battle significantly affected the income generation and businesses of locals. Such events, coupled with climate stress, make wage earners' lives more stressful in the tourism sector. Except for four rafting groups from Badal which have set up rafting businesses, villagers work for others' enterprises as cooks, guides, drivers, and caretakers. The workers mostly live within camp sites and their stay is taken care of by the company. Besides the above-stated activities, the residents of Badal village also earn by selling farm products like vegetables (ginger) and milk. All of the various means of livelihood built around the tourism sector have been negatively affected by reduced tourist influx since the 2013 Uttarakhand floods.

Poor households such as those of wage earners or day labourers and landless families are among the most vulnerable and affected groups. Most depend on agricultural activities, working in fields as day labourers. During extreme events, work opportunities decrease in these areas and migration (short-term, mid-term and long-term) increases. Of all climatic hazards that affect downstream Teesta, river erosion has affected the most people, leading many to poverty. A number of villagers interviewed during the study said that they have lost their homes and properties at least thrice in their lifetimes as a result of river erosion.

Close to 100 families have migrated permanently from char Dhubni and Dhubni villages (villages of Hatibandha Upazila in Lalmonirhat district of Bangladesh) due to riverbank erosion. They work as garment workers or rickshaw pullers, construction workers, and agricultural labourers in the locations they have migrated to. Those who have stayed back in the village suffer the most during disasters. During the monsoon, there is no agricultural work available in the villages as the water engulfs the land. This is the most difficult time for day labourers who do not have any savings to fall back on when they do not have work. When they do work, they get paid BDT 200–250 (USD 2.5–3.0) a day, which does not cover all their daily expenses.

Poor wage earners are marginalized in terms of social position and decision-making. Char dwellers are marginalized because of their remote location, because of which they have little access to government services. In the rainy season and flooded conditions, access to the mainland, market places, growth centres, and government service centres is limited. The villages, although poor, help each other out in any way they can. The poor have no strong relations with the influential institutions and persons in their areas. They cannot prepare for disaster and thus become highly vulnerable.

5.3. Fishing Community

In downstream Jalpaiguri, India, fishermen say that unpredictable heavy rainfall brings with it excessive siltation and high turbidity in the river water and the associated unpredictable water-flow and water levels have disturbed the breeding of fish. In Jalpaiguri, the fishermen have also come across several changes in the fish health, they find skin diseases, wounds on the body of the fishes or mostly diseased fishes. They had never observed fish diseases earlier 10-15 years ago. People in Dohogram in Patgram Upazila said that where they previously caught 3–5 kg fish in two hours, it is now difficult to get 1 kg after fishing from morning till noon. During the FGD in Patgram, one

fisherman said that he catches fish only three months a year, during which period he earns BDT 150–200 (USD 1.8–2.5) per day. At other times, he works as a wage earner for a small business holder. Fishermen also say that they earn less now than they did 15 years ago, from selling fish as their catch sizes have declined considerably. It can also be noted that eight fishermen families from Dohogram have migrated to India to earn a living. Other local fishermen families (eight families) have also permanently migrated to Kurigram district due to frequent river erosion in Dohogram. Recent changes in rainfall patterns have impacts on river flow patterns. There are also many non-climatic issues such as the dam that lies upstream and the discharge of industrial effluents in the rivers, which hampers fishing communities who are among the poorest and weakest sections of society with no access to government support services.

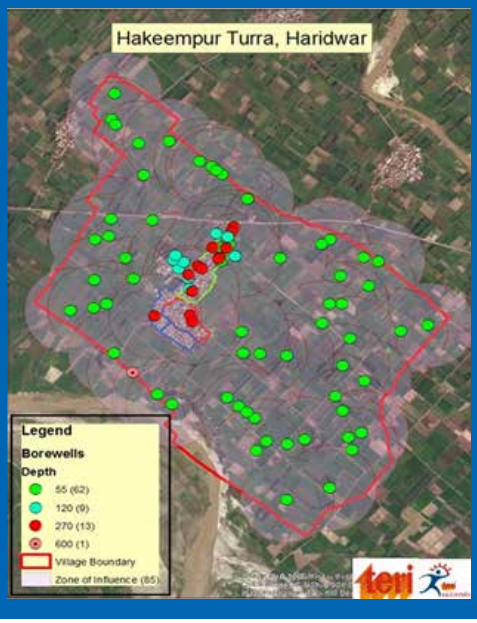
5.4. Caste as a Social Driver of Differential Vulnerability

As an age-old social and religious institution in India, Bangladesh, and Nepal, caste determines the status and social position of each individual and family in society. In downstream regions of the Upper Ganga basin, there are about 114 Buksa families residing in ward number 6 in Haridwar, India. About 20 Banjara families reside in ward number 1 in Lakarghat of Khadri town. Lakarghat has mostly agricultural fields where mainly sugarcane and paddy are grown. Both the Buksa and the Banjara are categorized as scheduled/backward castes/tribes, which are officially designated groups of historically disadvantaged people in India. Garhwali families comprise a majority of the population in Khadri town. However, an analysis of time line charts made with community members during our study shows that the area was originally inhabited by Buksas; Garhwalis came to the region much later. The Garhwali community was allotted land by the Indian government in 1965. From 1965 onwards, some Buksa families sold off their land to finance expenses such as family weddings. Some of their land was also allegedly occupied by force by the powerful elite. People of Buksa community moved away from this land and so did the river course, significantly so after construction of barrage in 1970s. These days, the Buksa live close to the main channel of the Upper Ganga, on land which is not legally owned by them. Because of this, they are unable to claim crop compensation when the river floods and inundates the land they live and farm on. They are rendered vulnerable by their location but inherently because of their caste. The so-called lower castes are socially and economically excluded. They cannot access institutional resources and government services, which make them more vulnerable to externalities including climate change impacts.

Box-1: Caste as a driver for differential access to land and water – A case from Hakimpur Turra Village

The caste system observed in Hakimpur village, in the downstream part of the Upper Ganga, has existed for generations based on the occupation of each caste group. The caste system exists in both Hindu and Muslim religious belief systems. Large sections of land in the village are still mostly owned by the affluent classes, while the other caste groups belong to scheduled castes: Valmiki and Kashyap among the Hindu, and Nai and Teli among Muslims. Individuals from these castes work either as agricultural labourers, off-farm labourers in nearby factories, or masonry works. As evident from a resource map drawn within the village, the ownership of private water boring connections lay largely with well- off communities, while others either rent water from neighbours at fixed rates or fetch water from common sources set up by the government.

Land ownership largely governs crop decision (choice of crops sown) and in turn differential impacts from climate-induced vulnerabilities.



Land ownership is a factor of caste differentiation and domination. To this day, big land owners (with more than 50 bigha (equivalent to 12.25 acres) are largely members of upper caste families and mostly engage in monoculture of crops – sugarcane, paddy, and wheat. There is heavy use of fertilizers and pesticides, which increases input costs per unit area of land. Farmers say that these crops are easier to produce and harvest as they are less labour intensive than traditional crops such as millet and pulses. Although there is labour shortage, small farmers still engage in vegetable and chickpea (*chana*) cultivation. They say that these crops are more resistant to pests and require less water.

5.5. Human-Wildlife Conflict and Community Vulnerability

Human-wildlife conflict is a pressing issue in the study sites (in Haridwar district) across all elevations. The impact of wildlife invasion on subsistence agriculture has been huge. As almost all the study villages lie on the fringes of forests, wildlife infestation of croplands is prominent. The impacts of such infestations are usually concentrated, affecting individual farmers, or sometimes a group of farmers whose lands have been infested, which is unlike the impacts of extreme weather events like rainfall whose impacts are more spread out. Villagers in the Upper Ganga basin noted that the negative impact brought by monkeys, wild boars, and rodents is considerable and that they have no means to reduce it or ward off the animals. The common perception amongst the surveyed villagers was that along with changing micro-climates, what worries the locals equally is the instances of such infestations. In the high elevation of Teesta basin that is in North Sikkim and Uttarey areas of West Sikkim, human wildlife conflict has increased over the past 10 years. Incidences of bear attacks to humans have been experienced. Similarly, in the mid hills of Sikkim i.e. in Pendam and Melli areas monkeys, deers, porcupine and peafowl have been raiding vegetables and cereals, and also horticultural crops, and to date ex-Gratia compensation provision is lacking and as a result farmers have to loose their produce. In Teesta Valley and in Chibo-Possyor areas of Kalimpong and Darjeeling in the mid hills, monkeys raid the vegetables crops throughout the year and thus farmers have to bear a great loss. Therefore, increasing human-wildlife conflict in the high elevation and mid hills of Teesta basin is increasing the vulnerabilities of the marginal and low income group farmers, most particularly women.

5.6. Sanjen Kharka in Gandaki Basin: A Case of Pasture Land Conflict in the High Mountains

Sanjen Kharka (pastureland, 4,000–5,000 masl) has a glorious history. It was depicted during the Mani Rimdu festival twice annually. Before the drawing of political boundaries in 1950, the pastureland was common property shared by Tibet and Nepal. After the drawing of borders, the traditional rights of the Gatlang community from Rasuwa, Nepal over Sangen Kharka, became blurred. Even today, yak, *chauri*, sheep, and goats are taken over to the Tibetan side to graze and Tibetan farmers are paid in kind – butter, meat, or milk. Sanjen Kharka was contested as the meadows stretch from Nepal to Tibet. Skirmishes for grazing rights are common. The Gatlang people are proud that they have fought many battles over this rangeland and obtain the right to graze there from the Tibetan villages. As times has passed, border posts have been established and much of the land has been conceded to the Tibetan Autonomous Region (TAR) of China. Over the years, the herds and herders have grown bigger in number and started to overcrowd this pastureland. Pasture degradation due to rise in temperature and climate change, together with the burgeoning of the local population and livestock, has added to socio-economic vulnerability and conflict in the area.

5.7. Lives of Migrant Families and *Char* Dwellers

The trend of men leaving their villages to work abroad has drastically increased; even women have started to go abroad. Respondents realized that this trend has also become a socioeconomic stressor, especially for those households which take loans to send family members abroad and take up the workload of an absentee family

member to perform farming and household labour. In 2011, 21% of the heads of households in Nuwakot, Nepal (midstream Gandaki) is headed by females (CBS, 2012). Migrant families have to move from one place to another and constantly need to acquire new skills to earn their living. Families who are unable to do so become more vulnerable than before.

In the lower Teesta, *char* dwellers in Bangladesh are more vulnerable than those living in the mainland. *Chars* are badly exposed to river erosion, floods, sand deposition, and droughts whereas other areas are protected by embankments– such as parts of Panjorvanga and Purba Chatnai villages. During the FGDs, respondents said that they are socially excluded and do not have an influential role in the decision-making process. People from the mainland do not even want to marry into the families of *char* dwellers as they do not possess social security or environmental security. Many of the landless live on embankments, and their suffering knows no bounds during and after floods.

5.8. Greater Vulnerability of Women

Women are disproportionately vulnerable to climatic hazards and many socio-economic drivers within their households and communities. This uneven vulnerability is determined by many social factors related to women and gender relations, extreme events, reduced adaptive capacity, and limited or no access to resources. Women's positions in the family and society is lower than that of men in terms of decision-making and access to opportunities like education, health, and work. Gender-based division of work is another major cause behind women's vulnerability. Wage inequality, cultural and religious norms regarding women's mobility, social practices, child marriage, dowry, unequal opportunities for women, and unequal resource distribution are the major social factors that lead them to more vulnerable situations, which worsen during disasters. This is the case across the study sites.

Women are eventually burdened by pressure – both at home and in public spaces. In Pendam, India, women complain that additional work comes with health implications. In the midstream region of the Upper Ganga, there are four running springs and a farm pond *(chahal)* in the Kimkhola village, Uttarakhand, India. Residents have noted reduced discharge in all four springs – some even have zero discharge during the lean season. The area falls under a rain shadow region and has faced severe water crisis since 1989. The crisis that year was so acute that residents from all three villages in the Haridwar study site had to campaign for the water department to augment water supply in their area. Reduced number of rainy days and decrease in the amount of annual rainfall have affected recharge of groundwater, leading to the drying up of water sources. People face acute water shortage and either get water ferried by tankers or rely on hand pumps installed 3 km away from their settlements.

People from Pyunkhari, Uttarakhand report that there have been times when women have had to walk 5 km to and from a spring in Amni to fetch water. Farming is a woman-centric activity in mountainous regions and demands major contribution from females throughout the year. The biggest problem related to farming according to women is wild animal attack. A similar situation prevails in the Gandaki basin where people suffer from lack of water availability, which is putting a burden on women and making them vulnerable.

At the field sites of West Bengal, India, in Poshyor and Teesta Valley Tea Estate – both of which rely on agriculture and tea plantation – women make a significant contribution as they labour daily both in the fields and at the tea plantations. The changes brought by development and climatic changes directly affect the livelihoods of women involved in agriculture. Women across the mid-hills are predominantly dependent on agriculture, which puts additional burden on them and brings health risks. Furthermore, Poshyor is vulnerable to disasters like landslides and flooding, which are regular during the monsoon. Although the disaster affects all the residents of Poshyor – it often blocks road and communication routes, cutting off Poshyor from other areas during the monsoon. Women are affected by flooding and landslides, which can make healthcare inaccessible. In 2015, a pregnant woman could not be transported to a medical centre on time because of flooding and succumbed to death. Such incidents are not uncommon in Poshyor during the monsoon. Women and children are again, more vulnerable than others. In downstream Teesta (Bangladesh), women in villages are concerned about the disasters they face and the causes of those disasters. During the FDGs, they said that all disasters affect them in different ways but that river bank erosion

and floods affect them the most. River bank erosion pushes their families into extreme poverty by destroying their land and other livelihood-supporting assets. When a family becomes poor, its women are affected in many ways: if there is food shortage, women take less food, which affects their health; girls' education is affected and the likelihood of early marriage increases. Poor families consider marrying off their daughters to be a way of reducing food intake in family and to ensure food security of he married of daughters.

When poor families live on embankments or roadsides or take shelter on other people's land, women suffer from a lack of sanitation and basic securities (food, water, health, and social security). Open defecation is the only option during such times. They have to abstain from defecation or urination in daylight and wait till dark to relieve themselves. This causes abdominal pain and gastritis. During the night, women defecate or urinate near flood streams on rafts made of banana trees. Girls and women also suffer from unsafe water during when they are menstruating due to the unavailability of safe water. They also face this problem during floods when their homesteads are inundated. Most respondents said that there have been times when they have had to take shelter on raised platforms inside flooded rooms during big floods. They suffer from lack of food, fuel for cooking, safe water, dry clothes, and a place to cook. While they do try to cook on raised platforms or mobile earthen stoves, it is not possible to make these arrangements at all times, especially during sudden flash floods and extreme flooding. They have to survive on dry food such as puffed rice (muri), *chaura* (beaten rice)-,and guur (molases) during such critical periods. In many cases, they have to move through floodwaters as they need to collect drinking water from afar and perform household chores such as cooking while half-submerged in flood waters. The likelihood of women suffering from skin and water borne diseases is therefore higher.

5. 9. Land Ownership and Vulnerability of Tea Picker in the Teesta Valley

Teesta Valley residents earn a meagre salary of INR 2,400 (USD 35) per month and continue to live within the structure established in colonial India. The issue of the denial of land documents *(parcha-patta)* is a serious one. Residents of the Teesta Valley live on limited cultivable land as most of the area is utilized for tea cultivation. With low salaries and growing expenses, the major source of income in the region these days is remittance. The tea industry in the Darjeeling hills was established by the colonial British government in 1835. These estates have private ownership wherein the tea workers continue to be governed by centuries-old traditions that deny land ownership. In spite of having worked and lived in the tea estates for over 150 years and through many generations, the locals do not own the land. The fact that land ownership documents are absent in the case with the citizens of the Teesta Valley makes them completely dependent on and at the mercy of the hierarchy that exists within the tea estate. About 1,100 locals work in the tea garden out of which 900 are women. Low paid employment make their lives vulnerable but they cannot raise their voices as they do not have legal papers document ownership of the land they live and farm on. Tea pickers also have to fight unfavourable climatic conditions – sometimes braving threats of landslides or frostbite due to heavy rainfall and cold waves, respectively. Even in this conditions, workers are bound to continue their low-paid jobs and suffer.

River beds are prepared for paddy cultivation in Upper Ganga, March 2016 in Haridwar district in India

6. Coping and Adaptation Practices

In all the river basins, vulnerable groups are mainly coping with the adversity of climate change using their limited knowledge, capacity, and resources in all the river basins. In a few cases, they are also taking adaptation measures with support from government departments, sectoral actors (departments of agriculture, water health, and rural development, among others) and NGOs. The community and actors are undertaking adaptation in key impacted areas like small agriculture, horticulture, livestock, fisheries, tourism, and infrastructure in the context of current climate hazards. The adaptations aim to reduce risk in the livelihood sector considering the impacts of temperature rise, heat stress, cold and fog, erratic and heavy rain, flood, landslides, erosion, and drought. The community-based and small adaptations sometimes work against temperature rise, heat stress, drought, cold and fog. However, community efforts very often do not work against climate extremes like flood, land and river erosion. Some examples are presented below.

In upstream Indus basin, during erratic rainfall, farmers cover wheat with plastic sheets if it has already been harvested. Potato cultivation through hedges in high altitude areas and early harvest are another set of coping mechanism. Farmers practice low tunnel farming in high and medium altitude areas and cover their plans with plastic during flowering time to minimize damage from hailstorms. As adaptaion practices to cope with drought conditions, ponds have been constructed by farmers with big landholdings, drought-tolerant varieties of crop have been planted, and fallow land is often used for moisture conservation. Shifting to off-farm activities and migrating to other areas for work are common coping and adaptation mechanism in the basin.

In midstream Indus basin in Pakistan, rooftop rainwater harvesting in mountain areas is common. The establishment of ponds in the area for irrigation is another common coping mechanism. People construct solid house structures and arrange alternate living spaces during times of stress. They minimize their day-to-day expenditures, use the savings, and try to utilize household-level consumables. Most people migrate to Islamabad and Rawalpindi. The surrounding areas of these two cities are completely occupied by migrants from the Soan River basin.

In downstream Indus basin, farmers are taking adaptation measures in agriculture in relation to droughts and floods as well. In a few cases, people have shift from on-farm to off-farm activities and migrated to big cities like Lahore, Rawalpindi etc. People in this area mostly rely on livestock and off-farm activities.

In upstream Upper Ganga, some household members (mostly male members) have out migrated to help boost household incomes. To deal with unseasonal rainfall, which has been on the rise for many years, farmers have been practicing indigenous ways to deal with this stress. Government organizations, NGOs and other entities have been helping villagers rebuild their homes on other pieces of land that they own. Activities initiated by voluntary organizations have also helped build trust and confidence among the people in rebuilding their livelihoods.

In midstream Upper Ganga, a traditional system called baranaja, where mixed cropping is practiced – cereals are grown along with pulses and there is crop rotation between barnyard millet and wheat – is prevalent in *Kimkhola* and Bagi villages in Tehri Garhwal, India. This ensures good crop productivity even without irrigation and reduced chances of crop failure in cases of extreme climatic events or pest attack. To maintain recharge of springs in the region, *Pyunkhari* and nearby villages had collectively prepared a traditional recharge structure in 1960s. Locals agree that the structure, known locally as *chahal*, has proven to be very effective in recharging their springs. Small businesses within the village have diversified livelihoods without migration.

In downstream Upper Ganga's Badal village, people rely heavily on flood early warning systems. In Hakimpur, farming communities have diversified livelihoods as a way to deal with losses from agriculture. In the village, people from less affluent communities were the first ones to move away from agriculture and look for job opportunities in other sectors. Within agriculture, people have resorted to digging deeper tube-wells for readily available water. Even paalej farming – the cultivation of Cucurbitaceae such as melons, gourds and cucumbers along silty river banks after the river recedes during the post-monsoon period – is carried out using water from tube-wells.

In upstream Gandaki, locals in Rasuwa, Nepal have moved steadily away from traditional agriculture and livestock management, although the reason for this changes is the opening up of alternative livelihoods opportunities with road access, trade, and tourism and not the climatic risks threatening agriculture and livestock. Locals have shifted noticeably towards seeking service employment, starting small businesses, and working as skilled or semi-skilled labourers, and have settled down in urban towns. Those who could borrow money have migrated temporarily to the Middle East and Southeast Asia for employment and are sending remittance back home.

In midstream Gandaki basin, the use of indigenous knowledge, changing cropping patterns, and changing the varieties of crop cultivated and livestock kept are common adaptation practices taken up to reverse crop risk. Cooperatives in Kimkhola and Bagi village not only provide collateral-free loans, but also inspire and encourage farmers to take up commercial farming.

In downstream Gandaki basin, early warning systems have been installed to help communities cope with floods. Rice-duck farming is a popular adaptation practice in Hakimpur. Fish ponds serves as an alternative livelihood source in flood-prone areas. Some organizations are working to promoting alternative livelihoods, training local women as beauticians and tailors and bike mechanics to diversify their livelihoods, which are forest-based, and reduce their dependency on community forests.

In upstream Teesta basin, families who can afford greenhouses cultivate vegetables in them during extreme weather conditions. They have adapted some strategies to cope with extreme weather. To protect cardamom from frost or extreme cold, shade plants like common mugwort *(Artemisia vulgaris)* are grown along with cardamom. When there is slow rainfall, farmers have adopted rotational grazing in hill shade areas and minor irrigation is done. Farmers who can afford the technology have started gravity-based sprinkler irrigation in their fields to cope with water scarcity. Some farmers manually carry to and irrigate their fields. Trout fisheries and tourism have become new avenues of livelihood in upstream Teesta.

In the midstream region of the Teesta, people are adopting alternative sources of income and livelihood such as poultry and dairy farming, floriculture, and vegetable gardening replacing agriculture, which requires more water. The main off-farm cash income that households generate both in Pendam and Melli Dara, Sikkim, India is through the Indian Government's 100-day work programme under the Mahatma Gandhi National Rural Employment Guarantee Act. The government and local individuals have started construction of a water storage tank to combat water scarcity. The people of Melli Dara have started various water source development schemes like planting suitable tree species around water sources. They have taken up coffee plantation, tomato cultivation, and floriculture as adaptation practices. They have are also exploring livelihood alternatives, such as tourism-related activities, home-stays, large-scale diaries, bee-keeping, mushroom cultivation etc. In Poshyor, people have started vegetable cultivation along with dairy and poultry farming and floriculture. Some households have started home-stay businesses for tourists, which is a new livelihood option. In Teesta Valley, households with small farmland have started cultivating broom grass and younger generations are involved in floriculture businesses at a large scale.

In downstream Teesta (Jalpaiguri, India), in the case of floods and displacement, locals shift to embankments for temporary settlement. Locals live in houses made of tin and straw that can be easily disjoined and carried off to embankments in case of floods. Community action, flood farming, shifting livelihood (from agriculture and fishing to daily wage labour) and seasonal migration of farmers and fishermen are also common coping and adaptation mechanisms here.

In the lower Teesta Bangladesh sites, people are taking various adaptation measures – agriculture, water, sanitation, health risk management, and the protection of houses and habitats. Changes in cropping patterns and maize, potato, chili, and pumpkin farming on sandy land have become popular coping and adaptation practices. During drought conditions, farmers irrigate cropland using water pump machines to draw water up to the surface from shallow layers.. Shifting livelihood and seasonal migration are also very common here. Rich people raise their homesteads and reconstruct houses to adapt to floods. Poor people take shelter on embankments during floods or river erosion as a coping mechanism. People who can afford to do so have elevated their latrines and tube-wells to combat flood conditions.

7. Conclusions

The participatory assessment included 12 study sites in four river basins – high mountain, mid-hill, and downstream floodplain regions. The aim was to gain a comprehensive understanding of the socio-economic drivers, conditions of community members, and the climate stresses they are under and explore how the interface of social factors and climate stresses leads to differentiated vulnerability in key livelihood sectors and social groups. More importantly, the study sought to understand how non-climate factors and everyday patterns of social interaction, marginalization, gender inequity, social exclusion, and institutional barriers increase the vulnerability of the communities studied. It was found that the poor and socially marginalized groups very often live in fringe areas in all the river basins. They have limited access to resources and ecosystem services and are exposed to the climate hazards. In extreme cases, there is no access to existing government support and services, which increases their vulnerability. In the lower Teesta basin, for example, the poorest sections of society lives on riverine islands or *chars* and face frequent big floods and river bank erosion that affect their livelihoods and damage their resource base every year. Further, *char* dwellers are sometimes denied government support and services to cope with and adapt better to internal and external adversities due to remoteness, bad communication, and poor governance. Thus, the impacts of climate change (frequency, intensity, and the forcefulness of events, level of exposure, and sensitivity) coupled with the socio-economic drivers and conditions, institutional arrangement, governance, and responsiveness as well as the cultural norms, values, and practices that are embedded in society, often determine the nature and level of vulnerability.

The information on social drivers and conditions in the four river basins were collected from both primary and secondary sources and analysed and triangulated with macro- and micro-climate information to understand the nature and seasonality of impacts and vulnerability. The major social drivers and conditions in the high mountains and upstream regions of the four rivers are remoteness and bad communication, poverty, marginalization and gender inequity, lack of awareness, and education. Remoteness, bad road connectivity, and communication were reported in all the high mountainous regions, which is a barrier to sustainable livelihoods and limits the adaptive capacity of communities and leads to higher levels of vulnerability. Social exclusion and caste discrimination (which are the root causes of backwardness and vulnerability) were reported in the upstream regions of both the Upper Ganga and Gandaki. In the mid-hills, there is good communication and connectivity. Well-established infrastructure was found in the Indus basin, which reduces the level of poverty and social vulnerability there. Better employment, economic growth, and urbanization were also reported in mid-hills. However, high concentrations of poverty, remoteness, lack of occupational diversity, and poor income, food insecurity, water stress, marginalization, and social exclusion were reported in the mid-hills of the other three river basins. Caste discrimination and deprivation of indigenous communities were reported in the Gandaki and Teesta midstream regions, respectively. Tea pickers, pastoral communities, and wage labourers are suffering from economic crisis and many forms of social discrimination in Pendam and Melli in the Teesta Valley.

Although there is diversity in livelihoods across the river basins, livelihood options are limited in upstream regions of all four basins. Subsistence agriculture, horticulture, pastoralism, dependency on forest resources, wage earning, and tourism are the dominant livelihood activities in the upstream regions. In the mid-hills, agriculture, wage earning, small business and trading, agro-business, horticulture, floriculture, pastoralism, and tourism are the main occupations across the river basins. In the downstream regions and flood plains, people have more occupational diversity, but they also suffer from seasonality, particularly during the monsoon when many of them do not have adequate employment and income and hence they have to migrate to cities of other districts seeking work. The people are mainly engaged in agriculture, wage earning, small business, transportation by roads and boats, fisheries, and ecotourism. Women from poor sections of society are engaged in small agriculture, home gardening, and wage earning in the Gandaki and lower Teesta basin.

Population and poverty were high in all the downstream areas and floodplains of the Gandaki and Teesta basins. Gender inequity and limited mobility were reported in Chaj Doaba, downstream of the Indus, although economic

activities including the diversification of agriculture and industrial activities are creating employment there. Social exclusion and caste discrimination were reported in the plains of the Upper Ganga – in Chitwan, Nepal and West Champaran, India. In the lower Teesta, a majority of *char* dwellers and the poor in the floodplains (in Dimla, Hatibandha, Kaunia in Rangpur, Bangladesh) are suffering from low employment, lack of adequate income, and food insecurity and migrate to the cities to earn wages during the monsoon. Male members amongst the poorest often leave females, children, and the elderly – who suffer the most from climate-induced disaster risks and social insecurity – back home.

There have been common macro-climate stresses across the four river basins, but the micro-climatic factors and disaster matrixes differ between upstream and downstream regions. For example, temperature rise and erratic rainfall (late and low rainfall) have been reported in all the four river basins. Temperature rise was reported in both summer and winter seasons and this is causing low rainfall and reduced snowfall in the high mountain and upstream regions. Higher temperature, decreasing snowfall, low and no rainfall, and increasing drought are causing forest fires in upstream Gandaki in Nepal. In the midstream region, temperature rise, hot summers and short winters, and late monsoons have been reported. Temperature rise, hot spells, and droughts are common climate features with late and heavy rainfall leading to frequent and devastating monsoon floods in all downstream regions of the four river basins. Such climatic variability and climatic extremes have negative impacts on the physical resource base, natural systems, and ecosystem services as well as on socio-economic conditions (such as employment and income, food and water security, social security, etc.) which increase the vulnerability of communities.

Both climate stresses and social drivers affect the asset base, natural resources, and livelihoods of community members in all the river basins in different degrees. Community members pointed out that subsistence agriculture and food security, water, sanitation, and health as well as working potential, wage earning, and the incomes of the poor have been badly affected in all the river basins. Along with agriculture, horticulture, pastoralism, and tourism are severely affected in the upstream and mountainous regions of all the four rivers. In the midstream, horticulture, floriculture, pastoralism, ecotourism, wage earning, agro-business, and small trading are affected along with crop agriculture. In downstream regions, agriculture, wage earning, fisheries, small trade and business, water, and sanitation are affected by climate stress as well as social drivers. In many cases, poor and marginalized people cannot take the necessary preparedness and adaptive measures due to a lack of resources, disempowerment, and poor knowledge and awareness about the process and consequences. For example, poor framers in the lower Teesta floodplains cannot change their cropping patterns in the face of frequent floods and drought to short duration and high yielding crop varieties (like maize and potato) due their financial constraints and lack of access to the government's seed distribution system. Poverty, marginalization, social exclusion, caste-based social discrimination, remoteness, poor connectivity, poor governance, lack of knowledge and information, and disintegrated markets strongly limit the adaptive capacity of communities in all the basins in different degrees, leading to high level of vulnerability among them.

The combined effects of social drivers and climate stresses are affecting all the people, but the study has found a few social categories and specific groups of people who are more vulnerable across the river basins due to their weak social conditions, disempowerment, structural inequity, and lack of access to resources and services. In upstream areas, wage earners, women, tourism workers, small traders, pastoral groups, and lower caste people (in the Upper Ganga, Gandaki, and Teesta) are highly vulnerable groups. In the midstream, horticulturists, tea workers, wage earners, subsistence farmers, women, and socially excluded groups are the most vulnerable. In downstream areas, small farmers, seasonal migrants, traditional fishermen, women, *char* dwellers and temporary settlers on embankments are the most vulnerable groups. Women face higher levels of vulnerability in all the river basins due to mainly gender-based inequality and their subordinate positions in family and society. Groups of people who depend on natural resources for their livelihoods (like forest dwellers and fishermen) are also facing greater degree of climate risks and social vulnerability.

Community people and vulnerable groups are coping with the stress and undertaking limited adaptation measures particularly in the areas of agriculture, home gardening, horticulture, livestock and fisheries, tourism, small trading, and business. In a few cases, government departments and development agencies like NGOs are supporting local adaptation measures. These are reducing some level of risk and vulnerability, but planned adaptation is required in

all the river basins considering the long-term climate change impacts on the society, people, and their livelihoods. Attentions must be given to the most vulnerable sectors and groups. Adaptation measures are to be designed considering upstream and downstream linkages. Pro-poor and gender responsive adaptations are to be promoted in all the river basins with the respective communities and actors. The social and structural causes of vulnerability must be addressed through policy and institutional measures. Adaptation measures must be undertaken considering the local contexts and social drivers and conditions. Social and human capitals must be enhanced for resilience-building and ultimately to reduce the differentiated vulnerability of different groups and communities. Improving governance and institutional responsiveness is also urgently required to enable the poor and marginal groups to access services and support from government departments. Further, multi-disciplinary and participatory research initiatives are to be undertaken at the basin and community levels for deeper understanding of the various dimensions of vulnerability as well as the adaptation needs and priorities of the respective communities.

Paddy seedlings still waiting in the seed bed, could be planted in the field due to late rain in 2015 in a village, Nuwakot, Nepal

8. References

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