HI-AWARE Working Paper 26

Critical climate stress moments:
Evidence from the Teesta River basin in India and Bangladesh

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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Critical climate stress moments:
Evidence from the Teesta River basin in India and Bangladesh

Authors

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Cover photo: Potato needs frequent irrigation due to sandy soil accumulated after flash floods in a village at the charland of Teesta River in Kaunia, Rangpur, Bangladesh (Photo: Nabir Mamnun).

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Contents

Acronyms and abbreviations

ATM	Automated Teller Machine
BCAS	Bangladesh Centre for Advanced Studies
BINA	Bangladesh Institute of Nuclear Agriculture
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
CARIAA	Collaborative Adaptation Research Initiative in Africa and Asia
DJF	December-January-February
FGD	Focus Group Discussion
FMD	Foot and Mouth Disease
HI-AWARE	Himalayan Adaptation, Water and Resilience
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
JJAS	June-July-August-September
MASL	Meter Above Sea Level
MPI	Multidimensional Poverty Index
NGO	Non-Governmental Organization
SDG	Sustainable Development Goal
SWARNA	An Indian rice variety; seeds available in Bangladeshi market too
T-aman	Transplanted aman rice
TERI	The Energy and Resources Institute
TMI	The Mountain Institute

Executive summary

Critical climate stress moments may be defined as those moments when households, communities, and their livelihood systems are vulnerable to climate related risks and hazards. This working paper examines critical climate stress moments due to specific climatic and biophysical causes experienced by the people in the Teesta River basin in India and Bangladesh. Critical moments can serve as a tool for communicating the vulnerabilities of communities and the challenges to sustainable lives and livelihoods and to link vulnerability assessments with adaptation policy and action.

The Teesta, like other river basins of the Himalaya, has a fragile geology, as well as complex climate, ecosystems and socio-economic conditions. For the purposes of this study, the Teesta River basin was divided into three sections to represent different ecosystems at various elevations: high mountain or upstream areas (>1,500 masl); mid-hills or midstream areas (500–1,500 masl); and plains or downstream areas (<500 masl). The study used both qualitative and quantitative survey methods, including focus group discussions, case studies, and key informant interviews for qualitative assessment, and household surveys (487 households in total) conducted with a structured questionnaire using a mobile/tablet based application 'Akvo-flow' for the quantitative assessment.

The Teesta River basin has a population of around 30 million people. Only 2% of the basin's population live in Sikkim, India because of its hilly and mountainous terrain; 71% live in the plains of northwest Bangladesh, and 27% in West Bengal, India which is a mix of hills and plains. Around 78% of the population in the Teesta River basin is rural while the rest is urban. The rural areas in the region are underdeveloped on both sides of the border and the people are dependent on the river and its ecosystem services for their survival. The upstream and midstream areas are home to various ethnic groups e.g., Lepchas, Bhutias, and Nepalis, while downstream areas are mostly inhabited by Bengali people. The key socio-economic characteristics of the Teesta River basin, like other basins of South Asia, are linked to its land and water resources e.g., in upstream and midstream areas, traditional agricultural activities include potato and large cardamom cultivation, agro-pastoralism involving rearing of yak and yak hybrids, and ecosystem services e.g., forest resources.

The critical moments in the upstream include (i) low temperatures during December–January for agro-pastoralism at high elevations; (ii) hailstorms in March, (iii) low rainfall in April; and, (iv) and hailstorms in July. There is no clear coping/ adaptation strategies for potato farmers. However, sowing time of potato is set by the government e.g., in Lachen by the Dzumsa. In the upstream and midstream areas, the most remarkable adaptation is cultivation of large cardamom supported by the government. However, insufficient water for irrigation due to drying up of springs is a major stressor along with other climatic stresses e.g., hailstones in April–May and frost in high altitudes in winter. Nonetheless, springshed management and spring revival by afforestation and artificial recharge by excavating small reservoirs or trenches and other water harvesting structures under Dhara Vikas initiative by the Rural Development Department of Government of Sikkim and The Mountain Institute India may be a useful adaptation or coping strategy for improving water availability.

In the downstream areas, floods and riverbank erosion are the major hazards. Lives and livelihood systems became vulnerable after each devastating flood due to disruption of agricultural production, education, communication, and sanitation facilities. Besides, erratic rainfall, heavy gusty wind during monsoon, and drought, fog, cold waves, and heat waves during dry season have large impact on the lives and livelihoods of the people of the study area.

Communities across elevation in the Teesta River basin are responding to these critical climate-stress moments with their parental and experiential knowledge at a limited scale. Upscaling of present practices and other new adaptation or coping actions with critical scientific and policy review are required for betterment of their lives and livelihoods in all areas of the Teesta River basin.

Critical climate-stress moment is a useful tool and approach to communicate vulnerabilities of the communities and the challenges faced by them to achieve their sustainable livelihoods and opportunities. No single critical moment can adequately represent the complex system of the Teesta River basin. The issue of critical climate-stress moment discussed in this paper is being recognized, albeit slowly by most actors, as a communication tool of vulnerability. This would aid disaster management and sustainable livelihoods of affected communities.

There are three regions of Teesta River basin namely Sikkim and West Bengal in India and northern Bangladesh. These areas have strong traditions of local government institutions and activities of NGOs. Climate change has already entered the development discourse in the Teesta River basin region as well. Further, river basin management has been recognized as a modality for sustainable development considerations. Thus a group of four sets of key actors have been identified to facilitate maximum interactions between the communities and other key actors in each region.

This interaction is primarily envisaged at two levels. First, interactions will need to be undertaken by policymakers, communities and other key actors within each region. Second, a set of interactions will be required between respective policy makers, communities and key actors across the three regions. The four key sets of actors are: (a) communities representing the upstream, midstream and downstream areas and their respective livelihood, geo-spatial and ethnic groups; (b) local government institutions and NGO actors working in the Teesta River basin region; (c) key personnel in policy analysis and decision making process, climate change science, adaptation, impacts identification of climate vulnerabilities and extremes; and (d) professionals and managers of river basin management approaches and working for better convergence. The objective of this interaction would be to enhanced integration process of sharing experiences, knowledge exchange, innovative adaptation, disaster risk reduction and overall sustainable community development.

1. Introduction

1.1 Background

Climate change is evident with variability in long-term trends of precipitation and temperature all over the world. The United Nations Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report IPCC (2014) projected that there is high confidence of extreme climate events that will have an increasing impact on human health, security, livelihoods, and poverty. Key impacts projected for Asia are:

(i) more frequent and intense heat waves that will increase mortality and morbidity in vulnerable groups;

(ii) heavy rain and temperature rise that will increase the risk of diarrheal diseases, dengue fever, and malaria; and

(iii) increasing frequency and severity in floods and droughts that will exacerbate rural poverty, in part as a result of negative impacts on the rice crop resulting in an increase in food prices and the cost of living.

Moreover, multiple stresses caused by rapid urbanization, industrialization, and economic development are likely to be compounded by climate change. Climate change is expected to adversely affect the sustainable development capabilities of Asian developing countries by aggravating pressures on natural resources and the environment (Dilshad et al., 2018; Immerzeel & Bierkens, 2012; Immerzeel et al., 2013; Merrey et al., 2018; Singh et al., 2019; Wester et al., 2019; Wijngaard et al., 2018; Wijngaard et al., 2017).

However, to achieve the global sustainable development goals (SDGs) by 2030, it is essential to acknowledge the adverse impacts of climate variability and change on various sectors, which is still lacking, while combined efforts need to be taken up to address these in the present policies and plans in countries in South Asia. The newly introduced multidimensional poverty index (MPI) – based on education, health and living standards – related to SDGs is very high for South Asian countries (India 28%, Pakistan 27%, Bangladesh 21% and Nepal 19% in severe MPI). The total urban population is projected to increase rapidly in South Asia by 2030 (India 39%, Pakistan 47%, Nepal 25% and Bangladesh 45%, an increase of 6, 8, 6 and 11% respectively compared to 2015) (Palanivel et al., 2016). This increase is mainly due to migration from rural to urban areas caused by both economic development (pull factor) as well as displacement (push factor) due to climatic stressors. Therefore, dependency on land and ecosystems will decrease while the agricultural sector will still play an important role in the development of South Asia as it employs a large percentage of the labour force – Bangladesh (47%), India (47%), Nepal (69%) and Pakistan (42%) (CIA, 2017). Even though agriculture continues to grow, its relative importance is declining in terms of percentage of GDP and share in the labour force.

1.2 Critical climate-stress moments

'Critical climate-stress moments', a concept elaborated in the Himalayan Adaptation, Water and Resilience (HI-AWARE) research (www.hi-aware.org), hereafter referred to as 'critical moments', are defined as those moments when households, communities, and the dependent livelihood systems are especially vulnerable to climate and weather-related risks and hazards (Groot et al., 2017). These risks and hazards include floods, droughts, riverbank erosion, heat waves, cold spells, hail storms, and so on. The concept of critical moments can be introduced as an approach to vulnerability, aimed at overcoming several bottlenecks, particularly when it comes to bridging science and policy-making in transforming adaptation policy and plans into concrete actions at the right time (Groot et al., 2017). Critical moments are a combination of (context-) specific socio-economic and biophysical conditions, in which climate-stressors are particularly likely to be risky and adverse to a particular household or community and the systems they depend on. A 'critical moment' may last days, weeks or even months, depending on the socio-economic or and bio-physical drivers.

The Teesta, like the other river basins of the Himalayas, has fragile geology, complex climate, ecosystems and socio-economic conditions and is prone to regular landslides and floods. These landslides sometimes are responsible for floods and vice-versa. Catastrophic floods occur almost every year in the upper Teesta, mainly in Darjeeling and Jalpaiguri, while in the downstream in Lalmonirhat, Kurigram and Rangpur of Bangladesh the 1968 and 2015 floods were the most disastrous (Pal et al., 2016). In downstream areas, many flood protection structures such as dykes and embankments are already damaged from previous monsoon floods along with the current back-to-back floods (2016, 2017, 2019 and 2020); while the normal recovery cycle after a disaster is 3-5 years, this is hampered due to this increased frequency of floods (NAWG, 2020).

The critical moments due to floods can be broadly divided into two parts: during flood, and after the flood (Groot et al., 2018). When floods hit, the affected communities struggle to protect their lives, livelihoods, and assets. The floods start with the onset of the monsoon in mid-June in the upstream areas and this threat persists until the end of the monsoon in September. Monsoon floods affect lives and livelihoods, mainly agriculture, drinking water, sanitation, health, energy, homes and infrastructure. Early monsoon arrival can cause flood damage when rice seedlings are submerged during the early growth stages, especially when farmers are not using submergence-tolerant varieties while late monsoon arrival can lead to water stress (CSAIPB, 2019). These equally affect lives, livelihoods, and assets (homesteads devour by river bank erosion) and sometime cause forced displacement (Syed & Amin, 2016). After the floods, there are risks from water-borne diseases and snake bites. During the 2007 floods in Bangladesh, snake bites were estimated to be the second major cause of death after drowning and caused more deaths than diarrheal and respiratory diseases (Dewan, 2015).

Other major critical moments due to impacts of floods include loss of employment and unavailability of fuelwood for cooking. Agriculture and other sectors in Teesta River basin experience critical moments mainly during floods and drought, mostly in the downstream areas, and cold and heat waves each year all over the basin (Groot et al., 2018). The critical moments due to climate extreme events (e.g., floods, drought) are not restricted to only during the event for vulnerable people. It extends until they recover and regain the strength to adapt to the natural disasters again.

1.3 Significance of research

To address the adverse impacts of climate variability and change, it is essential to communicate an understanding of climate impact assessment to policy makers and communities. There are many possible reasons for the general lack of concern about climate change; it is possible that people are bored or fatigued because the subject is extensively discussed in the media worldwide (Nick, 2012). Like climate impact assessment, vulnerability assessment, and risk assessment using various methods, ‘critical moment assessment’ may be an important tool to communicate to policy makers the urgency of combating climate change impacts in vulnerable areas and sectors. This is not well documented in many areas like the Teesta River basin.

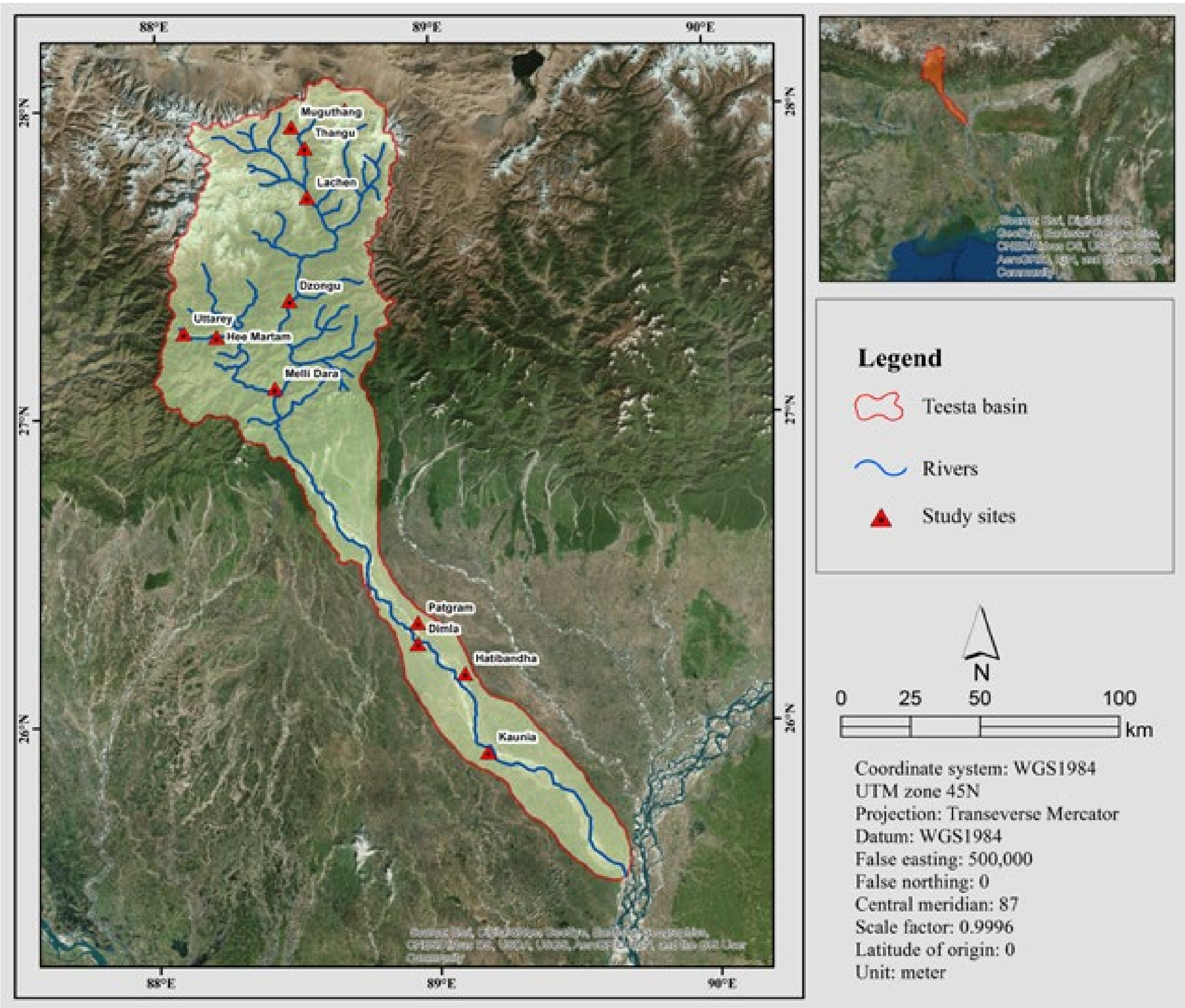
This working paper provides qualitative and quantitative assessment of critical moments in the Teesta River basin in India and Bangladesh. The objective of the assessment was to identify and document the periods/moments when people and their livelihood systems are perceived to be most vulnerable to different climate risks and hazards. Critical moments may be a tool for easy communication about vulnerable populations and for emergency response and adaptation planning and management for a wider community.

2. Methodology

2.1 Study area

The Teesta River basin extends from Sikkim in India in the eastern Himalayas through West Bengal (Darjeeling, Jalpaiguri, Cooch Behar, Uttar Dinajpur, Dakshin Dinajpur, and Malda districts), to the northern Rangpur division in Bangladesh (Lalmonirhat, Nilphamari, Rangpur, Kurigram, and Gaibandha districts), where the river joins the Brahmaputra at an elevation of 23 masl before it flows into the Bay of Bengal after meeting with the Ganges and the Meghna. Khang-Chen-Dzonga, the third highest mountain in the world, is the highest point in the basin although the river originates from the Pahunri (or Teesta Kangse) glacier at above 7,068 masl. Within a distance of 414 km, the Teesta River crosses an elevation of more than 7,000 metres, hence, the average slope is about 1.7% which may be considered as a moderate slope due to which, flash floods and riverbank erosion are recurrent phenomena in the downstream. Historically, the Teesta was part of the Ganges River system and flowed south from Jalpaiguri in West Bengal as three separate rivers, the Karatoya, Purnabhaba, and Atrai, or Trisrota, until it changed its course after a flood in 1787 and shifted southeast to join the Brahmaputra.

Figure 1: Locations of study sites in Teesta basin of which upstream (three sites) and midstream (four sites) areas are in Sikkim, India and downstream (four sites) areas are in Bangladesh. The background image is downloaded from Google Earth; the light green transparent shade marks the Teesta basin boundary.



In this study, the Teesta River basin is divided into three strata based on elevation: high mountain or upstream areas, >1,500 masl; mid-hills or midstream areas, 500-1500 masl; and plains or downstream areas, <500 masl. The upstream areas include Uttarey (Lower Simphok, Hoiley Dara) and Lachen in Sikkim. Sikkim is regarded as a prosperous state with high development indices (GOS, 2015). Lachen is a self-administrated region of Sikkim by a traditional institution called Dzumsa and is located in the North District of the State, bordering the Tibetan plateau. The midstream study sites include settlements in the West and North districts of Sikkim. The sites in West Sikkim include Martam and Hee; and Hee-Gyathang, Dzongu in the North District. The downstream sites include villages in Rangpur (Kaunia), Lalmonirhat (Hatibandha and Patgram) and Nilphamari (Dimla) districts in Bangladesh. Figure 1 shows the study sites at different elevations.

2.2 Qualitative data collection by participatory methods

The critical moments study utilized a mixed methods approach to identify stress periods. This was achieved through the use of both quantitative and qualitative survey methods. The quantitative survey was aided through the AkvoFlow application while qualitative critical-moments assessment follows a participatory research approach adopted by Groot et al. (2017) which includes focus group discussions (as shown in Figure 2), case studies, and key informant interviews. The participants included farmers, fishermen, day labourers, women, community leaders, and NGO representatives, among others. The qualitative assessment was guided by the following research questions:

Figure 2: Focus group discussion for qualitative assessment of critical moments in Kaunia, Rangpur, Bangladesh (Photo: Fahim Haque)

1. When are people's lives most affected by climate hazards? How do these periods of stress vary across social groups and socio-political contexts as also within households?

2. What specific climatic conditions and other drivers (such as biophysical and socio-economic circumstances) cause these periods of stress? How are such conditions experienced by the most vulnerable?

3. What strategies have people adopted to cope with critical moments? To what extent do people perceive these strategies as effective? What would they like to do, ideally?

2.3 Quantitative data collection by structured questionnaire

2.3.1 Sample size and sampling design

To determine the sample size for the study sites in Teesta basin, Cochran's sample size formula (Cochran, 1977) was used.

$$n = D \times \left[\frac{Z^2 \times (p) \times (1-p)}{e^2} \right] \qquad \text{Eq. 1}$$

where = sample size; = percentage of households picking a choice (expressed as decimal = 0.5); expresses an estimate of variance; = Z-value (1.96 for 95% confidence interval); = margin of error (0.06); and = Design effect (1.50). Simple random sampling is the most appropriate method to ensure statistical robustness. This study follows a stratified random sampling method which may result in the loss of statistical robustness in the sampling procedure. The design effect is basically the ratio of the actual variance, under the sampling method actually used, to the variance computed under the assumption of simple random sampling. A design effect '1.50' has been used to compensate the loss of statistical robustness.

Using the Eq. 1, a sample size of 402 households was determined for Teesta River basin. The number of actual surveyed households is higher than the determined sample sizes in midstream and downstream areas of the river basin; however, in the upstream, a lesser number of households was surveyed due to low population in the surveyed villages (Table 1).

Table 1: Distribution of sample size across settlements

River basin	Altitude	Target districts	Selected settlements within districts	Actual surveyed households	Sample size as determinded by Eq 1
Teesta (India and Bangladesh)	Upstream	West Sikkim (India)	Gumpa Dara	35	134
			Simphok	49	
	Midstream	West Sikkim (India)	Hee Gaon	70	134
			Martam	37	
		North Sikkim (India)	Hee-Gyathang	59	
	Downstream	Rangpur (Bangladesh)	Panjarbanga	126	134
		Nilphamari (Bangladesh)	Purba Chatnai	32	
		Lalmonirhat (Bangladesh)	Char Dhubni	79	
Total				**487**	**402**

A stratified sampling technique was adopted to survey the sampled households. In the Teesta basin, three strata, e.g. upstream, midstream & downstream, were established in view of significant differences in terms of socioeconomic, climatic and biophysical factors (Table 1). In each stratum, districts and study settlements within districts were selected purposively in view of their high vulnerability to climate change induced impacts. For data collection, households were selected through random route procedure. In some areas, particularly in the mountains, list of households and their serial numbers were not available to researchers. In such cases, random route sampling was the most appropriate method to target the households.

The data and findings of the study may not be truly representative at river basin level and for different altitudes, e.g. upstream, midstream and downstream due to purposive selection of districts and settlements within districts, limiting the scope for generalization of the study findings at river basin, and altitude levels. Rather, this study may be treated as quantitative case study with evidences from upstream, midstream and downstream areas of the river basin.

2.3.2 Data collection tools

A standardized questionnaire was prepared to collect data from households. The questionnaire was digitalized in a mobile/tablet based application 'Akvo-flow'. Predesigned survey forms, which had undergone multiple iterations had been input into the Akvo-flow application running on Android-enabled smartphones. This helped in avoiding transcribing mismatches and enabled the user to upload the data directly onto a central server where data could be readily accessed. The survey laid stress on the factors most affecting people and their livelihoods. These factors include a range of biophysical and socio-economic factors that induce conditions of vulnerability and how shocks are then perceived. Intra-community differences in how these shocks are felt is witnessed due to differences in the socio-economic structure of the households.

The survey enumerators were trained on the use of Akvo-flow and data collection in a training workshop. In April-May 2017, the questionnaire was pre-tested in all strata to make necessary corrections for ensuring consistency of questions and smooth data collection through electronic devices. The actual survey was administered from June-September 2017 in all study sites. Enumerators were guided to select the respondents in households based on their age. Respondents with more than 25 years of age were interviewed because the questionnaire contained a number of questions about perceptions of past events (recall data of the situation of 5 to 10 years ago).

3. Key socio-economic characteristics

Teesta River basin is densely populated with around 30 million people. However, intra basin differences in population is vast. In Sikkim, where the river originates close to the Indo-Tibet border, a mere 2% of the basin population live in the state because of its mountainous nature; 71% of the basin population lives in northwest Bangladesh which has an almost flat topography and the rest 27% in West Bengal in India, which comprises of hilly areas as well as plains. Around 78% of the population in the Teesta river basin is rural while the remaining 22% is urban (Waslekar et al., 2013). The rural areas in the region are underdeveloped on both sides of the border with the people being highly dependent on the river and its ecosystem services for their survival.

Results of household survey show that 90% households are male headed in downstream areas while there is quite large number of female headed households in the upstream (20%) and midstream (21%) areas. According to age group classification 60% of household members are in the 15-49 age range. The survey also revealed that around 44% and 18% of household members had the primary and intermediate education. Around 8% of the household members reported the bachelor level education, and only 3% reported Masters and above education. Importantly, around 24% members did not have any formal or informal education.

The upstream and midstream areas of the Teesta basin are inhabited by various ethnic groups such as Lepchas, Bhutias, and Nepalis. In the upstream, Lachen is an administrative region that is spread over a few hundred square kilometers and constitutes a considerable portion of the North District. This region is administered by a traditional governing body called the Dzumsa. Dzumsa is a 19th century (Acharya & Sharma, 2012; Bourdet-Sabatier, 2004) indigenous administrative system that is still in practice in Lachen and Lachung areas of North Sikkim. This system has been argued as a form of adaptive governance. It is an example of de-centralized governance and its origins, as usually cited in literature, was to help govern these regions which were largely cut-off from the rest of the Empire and the central authority (Bourdet-Sabatier, 2004; Sharma & Rai, 2012). It is not rare to find such customary institutions in India. In fact there are many examples from the North and South of India, while Dzumsa is the only 'officially' recognized customary institution (Chhetri, 2013), giving it an administrative legitimacy. Dzumsa was founded to help the locals, who were predominantly pastoralists, manage their natural resource pool. This later evolved as a more robust administrative institution after it was officially recognized giving it similar powers/roles as a local self-government such as Gram Panchayat (Acharya & Sharma, 2012). The availability of rangelands for grazing is crucial to sustain pastoralism and precipitation plays a crucial role in the access to these subalpine pasture lands. The subalpine meadows receive less snowfall, enabling grazing in the winter months. The Dzumsa regulates grazing and other natural resource management practices through customary law (Sharma, Tambe, et al., 2016).

In the midstream, most of the households in the studied settlements are involved in the cultivation of cash crops. Earlier, Dzongu in North Sikkim was a leading large cardamom growing area; however, in recent years, farmers from West Sikkim have created new centres for cardamom production through farm level innovation (Sharma, Partap, et al., 2016). The two areas differ in ethnicity; while West Sikkim field sites have mixed communities, Dzongu is a special reserve for the Lepcha, the original inhabitants of Sikkim[1].

In the downstream Jalpaiguri site, people around 20 years ago were engaged in regular traditional system of low-land agriculture, fishing, and wage labour in the nearby towns and Siliguri town, and marketing of agriculture produce for subsistence needs. However, after the completion of Teesta barrage at Gajoldoba, the situation changed and the area is affected by recurrent and severe floods degrading the agriculture land suitable for cultivation. The Bangladesh part of Teesta basin is densely populated of which 69% people are directly or indirectly involved with agriculture while 11% depends on business (BBS-GOB, 2014). Farming is the primary occupation

[1] Chogyal Palden Thondup Namgyal, the king of Sikkim declared Dzongu a Lepcha Reserve in the 1960s. In addition, the Supreme Court verdict of 10 February 1993 acknowledged the Lepchas to be Sikkim's 'original indigenous inhabitants'. The Government of Sikkim also granted them the status of Primitive Tribal Group in November 2006.

of the people living both in the Bangladesh and Indian parts of the Teesta in the downstream areas. Average land holding of the people in this area is less than one acre. However, most of the surveyed households in the downstream areas (60%) have no ownership of the agricultural land while this number is very low in upstream (11%) and midstream areas (17%). Rice is the main crop grown across the downstream area of the basin. This is the main rice producing zone in Bangladesh (Mondal, 2010). Average cropping intensity on the Indian side is 169%, and 200% on the Bangladesh side (BBS-GOB, 2012; FAO, 2013). Teesta basin is not among the industrially developed regions in Bangladesh and India, while Saidpur, in Rangpur division, is an important commercial hub with growing medium and heavy industries especially crockery, fertilizer, oil from recycled tires, light engineering, metal works and agricultural tools furnished with an airport (Waslekar et al., 2013).

Table 2: Major income sources/livelihoods of surveyed households in Teesta basin

Income sources	%HH reporting income sources (upstream, midstream, downstream)	Percentage of households reporting on income categories (IR69 = US$1) per annum				
		<US$870	US$870 – 1740	US$1740 – 3480	US$3480 – 5220	>US$5220
Agriculture and forest produce	65 (64, 79, 56)	13	12	19	11	45
Livestock and fishing	22 (13, 16, 30)	36	22	14	17	11
Formal salary	18 (38, 24, 6)	6	6	13	17	58
Casual labour	18 (18, 8, 26)	34	17	12	13	24
Rent and business	14 (21, 5, 18)	7	13	15	15	50
Remittances	5 (0, 6, 6)	17	22	31	17	13
Transfer payments or subsidies	4 (6, 3, 3)	12	19	31	19	19
Income from tourism	3 (16, 1, 0)	7	21	36	0	36

Table 2 shows the present sources of income and livelihoods of surveyed households in the Teesta basin as a combined value for upstream, midstream and downstream areas. It shows that the major income sources are agriculture and forest produce, livestock and fishing, formal salary, casual labour, rent and business, remittances, transfer payments or subsidies, and tourism where many HHs have more than one income sources. In upstream of Teesta, agriculture and income from formal salary are the major sources of income in both upstream (64% and 38%) and midstream areas (79% and 24%) in which most (45% and 58%) households have incomes of >US$5220 per annum. Livestock (pastoralism) and fishing, rent and business, casual labour, and tourism are also important sources of income of people there. Horticulture and floriculture are the major types of agriculture in the mid -hills of the Teesta River basin. In the downstream areas, agriculture (56%), and livestock and fishing (30%) are major sources of livelihood. During the survey, households were asked about their income in the last five years whether it is increasing, decreasing, or has remained unchanged. In case of agriculture and forest produce, 48% reported that it has decreased. In case of casual labour, people reported that their income has decreased due to recurrent floods in the downstream areas due to crop damage (49%). However, in livestock and fisheries, 41% households reported that income has increased compared to last five years mainly due to increase of livestock rearing activities at the household level although fishing activities have decreased in the downstream areas.

4. Climate change critical moments

4.1 Perception and long-term trend of climate change

Our study shows that a majority of the surveyed population across elevations perceive an increase in average temperature (Figure 3). However, perceptions regarding average rainfall do not depict a linear narrative. The data suggests that a majority of the respondents from the upstream regions of the basin perceive an increase in average rainfall and erratic rainfall as opposed to ten years earlier. However, in the midstream regions, respondents reported a reduction in average rainfall. Nonetheless, erraticity was perceived to have increased (80% at the basin level). In the downstream areas, the data shows that average rainfall has increased (49%). However, the erraticity of rainfall has increased across elevations, irrespective of the boundaries.

Figure 3: Perception of weather variability and climate change current situation compared to 10-20 years ago in Teesta basin in percentage values of respondents; alphabets A to H are different climatic conditions i.e., A - annual average temperature; B - average temperature in summers; C - average temperature in winters; D - erratic events of rainfall; E - average annual rainfall; F - annual snowfall; G - annual hailstorm; and, H - number of dry days

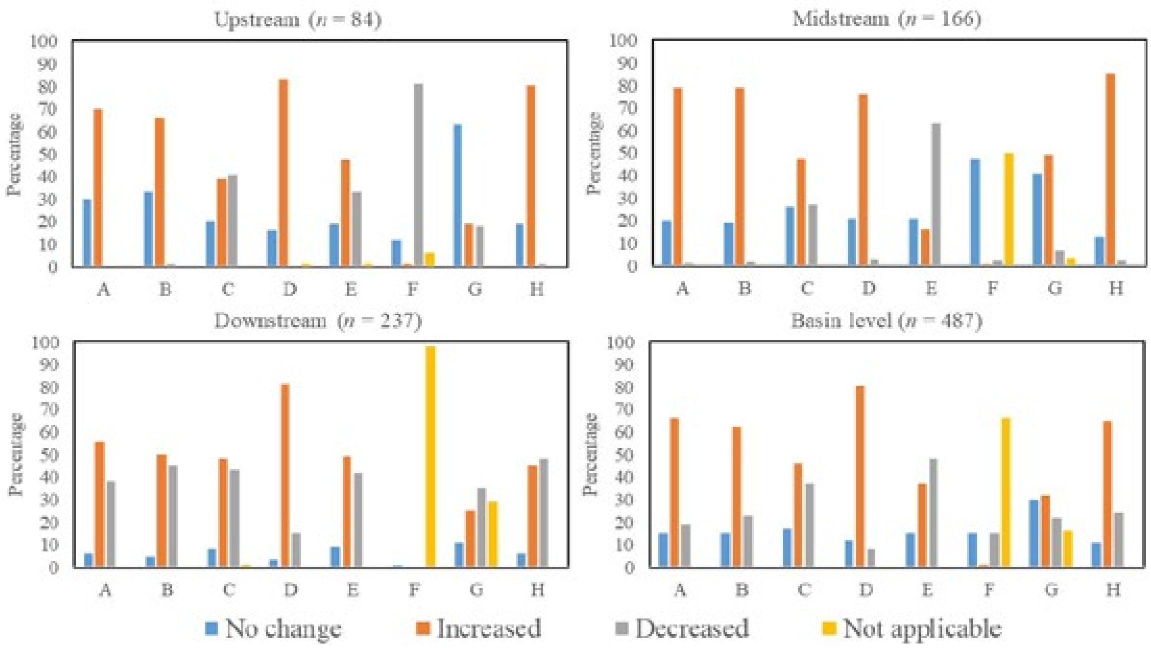
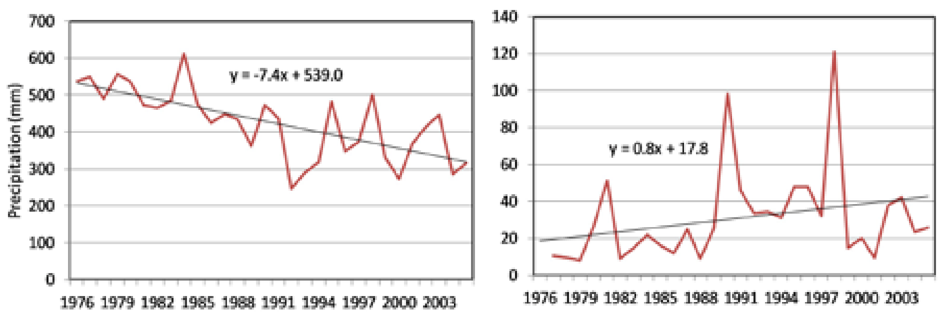
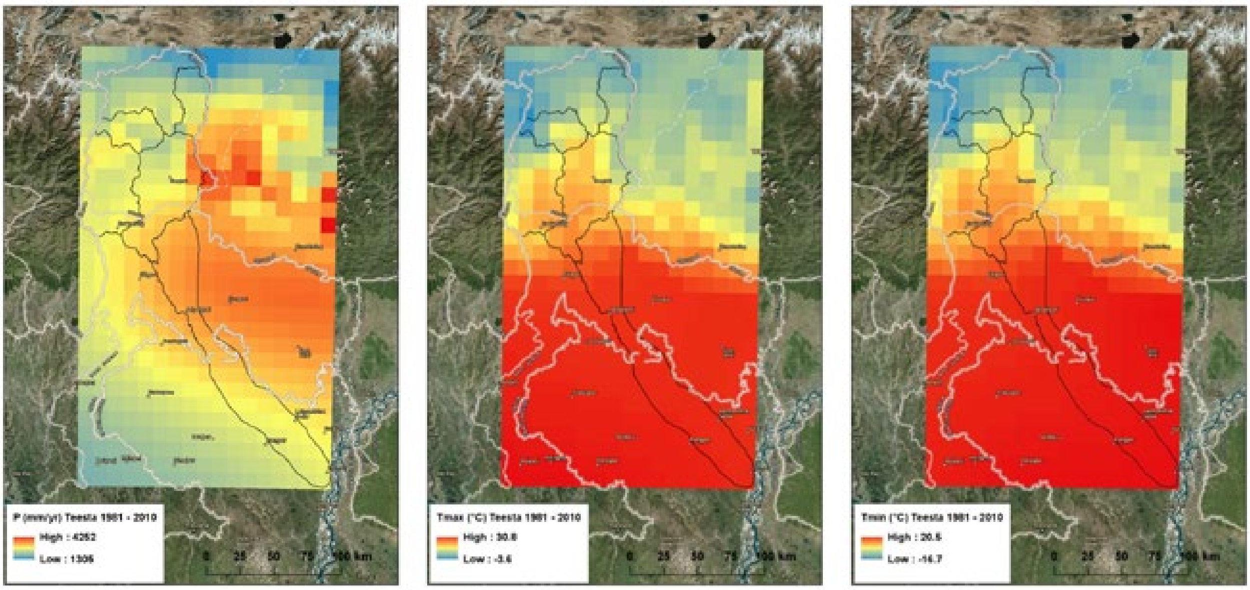


Figure 4: Precipitation in North Sikkim during monsoon JJAS (left) and dry season DJF (right) for years 1976 to 2005 based on gridded data for precipitation



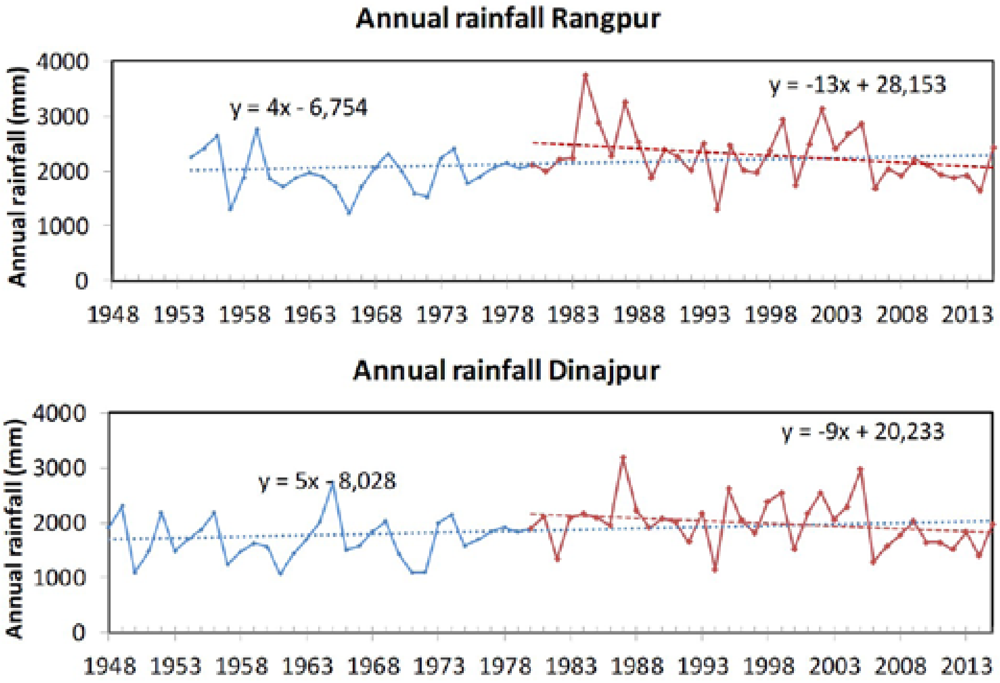
The gridded data analysis of 30-year (1976-2005) precipitation during monsoon (JJAS) and dry season (DJF) shows that there is a declining trend of monsoon precipitation of 7.4 mm/year while increasing trend can be observed for dry season precipitation of 0.8 mm/year. However, the dry season precipitation is more uncertain than the monsoon (Figure 4). Figure 5 shows the long-term average (1981-2010) annual precipitation, maximum and minimum temperature, using 10-km grids prepared by Lutz and Immerzeel (2016), where it can be seen that all three variables are highly variable in upstream, midstream and downstream areas within not so large area and distance. The impacts of these variables in upstream and midstream areas are large. For example, Tambe and Rawat (2009) identified degradation of temperate and subalpine forests in the midstream areas due to overgrazing of yaks and horses in winter as increased winter precipitation (snowfall) at alpine meadows in upstream areas forced grazing of yaks and horses to midstream areas.

Figure 5: Long-term (1981-2010) average precipitation (left), maximum (middle) and minimum temperature (right); adapted from Lutz and Immerzeel (2016)



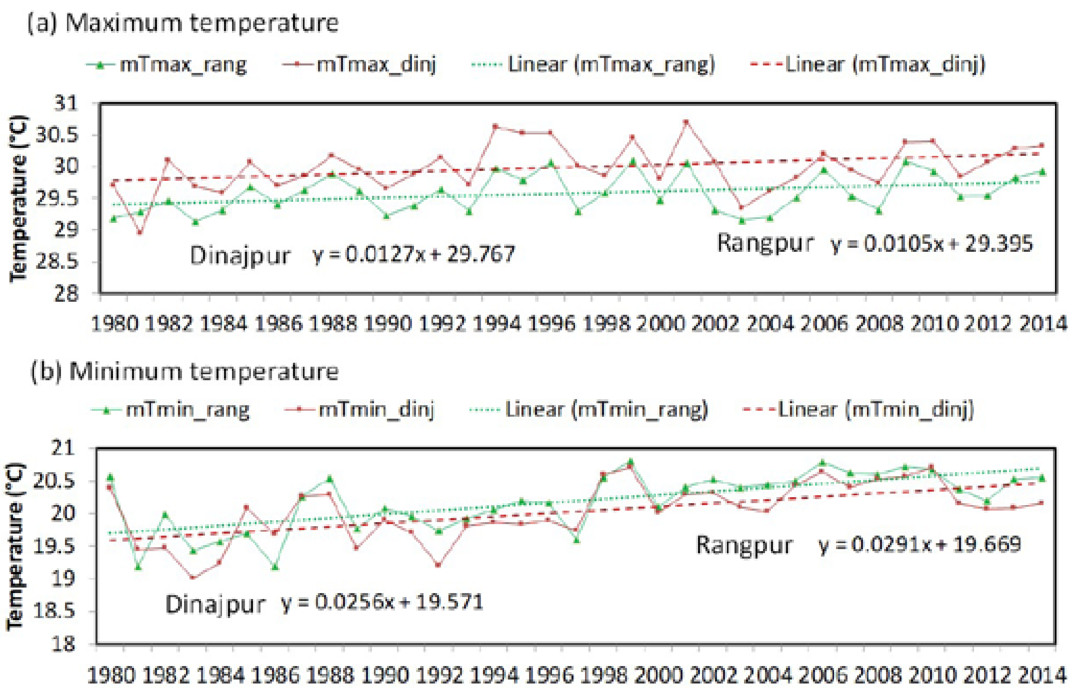
During focus group discussions, people observed that the incidence of irregular heavy rainfall in a short period of time has increased in recent years. The long-term mean annual rainfall at Rangpur and Dinajpur stations of the Bangladesh Meteorological Department (BMD) are 2,154 mm (62-year mean, 1954-2015) and 1,857 mm (68-year mean, 1948-2015), respectively. Rainfall trends with annual total rainfall of Rangpur and Dinajpur stations in mm are presented in Figure 6. It shows an increasing trend of annual rainfall of 4 and 5 mm.y-1 at Rangpur and Dinajpur stations respectively when the trend line is drawn with the available dataset (since 1954 for Rangpur and 1948 for Dinajpur). Conversely, if the trend line is drawn since 1980 (as little missing data is recorded after 1980), both trends of annual rainfall at Rangpur and Dinajpur stations show decreasing trends of annual rainfall of 13 and 9 mm.y-1 respectively.

Figure 6: Trends of annual total rainfall (mm) at Rangpur and Dinajpur stations of BMD; trend line after 1980 is drawn as since 1980 little missing data is recorded



The trends of annual mean maximum and minimum temperature for Rangpur and Dinajpur stations of BMD is shown in Figure 7. It shows that there are increasing trends of both maximum and minimum temperature at Rangpur and Dinajpur stations (Figures 7a, 7b). However, larger increasing trends of minimum temperature (0.29 and 0.26 °C per decade at Rangpur and Dinajpur, respectively) are observed than the maximum temperature (0.11 and 0.13 °C per decade at Rangpur and Dinajpur, respectively). This decrease in amplitude, where the difference between maximum and minimum temperature is decreasing, may have adverse impacts on agriculture and other livelihoods.

Figure 7: Trends of annual mean maximum (a) and minimum (b) temperature at Rangpur and Dinajpur stations of BMD



4.2 Perception of natural hazards and extreme events

The study areas suffer from multiple climatic and natural hazards including floods, riverbank erosion, drought, landslides, water scarcity, erratic rainfall, heat and cold waves, and heavy wind/storm. Table 3 shows households' perception of natural hazards and extreme events in the Teesta River basin. In the upstream region, the major stress period is the dry winter from November to January. The last few years have witnessed reduced to almost no winter rainfall. The increase in temperature in April-May also causes springs to dry up leading to reduced flow in local streams. Water scarcity, erratic rainfall, and landslides are major climatic hazards in this area.

Across the mid-elevation, intense rainfall during July-August causes landslides and mudslides. The major stress period here is during the lean season from November-April. Opinions vary on the driest months but respondents across all sites felt that winter rainfall had reduced drastically. The increase in temperature in April-May, also causes springs to dry up leading to reduced flow in local streams. Frost occurs in the high-elevation of West Sikkim. Earlier intense frost used to set in as early as December and continue through January but now severe frost is mostly limited to January, with some frost in December.

In the downstream, floods occur every year in the Teesta floodplains in Bangladesh, including flash floods and seasonal longer-duration floods which inundate large areas. The occurrence of floods has several implications on the lives and livelihoods in these areas. Most of the annual rainfall in the plains and upstream occurs during the monsoon (July-September). The water flow from the upstream areas, which is dependent on rainfall patterns (erratic or normal), is the main cause of both flash and seasonal floods in these areas because river water comes very quickly from large upstream areas as compared to rivers in the surrounding areas. In the downstream areas, riverbank erosion is a regular and recurring phenomenon for areas adjacent to the Teesta River, largely caused by river dynamics particularly flooding. Large-scale riverbank erosion occurs during pre-monsoon (April–June) and post-monsoon (September–October) periods. Post-monsoon erosions are more severe than pre-monsoon. People complained that dams in the upstream of the river mainly at Gajoldoba (India) and Dalia (Bangladesh) have decreased the flow of the river during dry season, creating erratic water releases during monsoon that are driving riverbank erosion processes in the downstream areas with no flood control structures.

Table 3: Perception of natural hazards and extreme events in Teesta River basin; Q1 - Perceived change in hazards/ events; Q2 - Frequency of hazards/events; Q3 - Intensity of hazards/events; IC – increased; DC - decreased

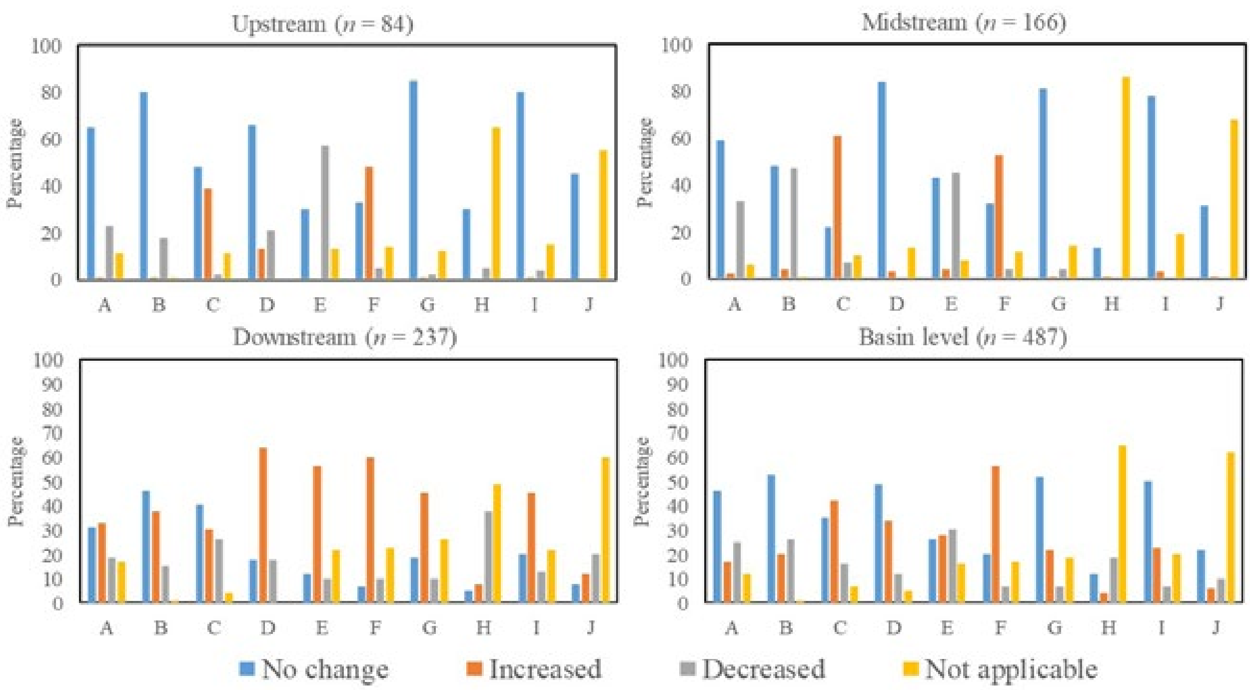
Natural hazards or extreme events attributed to environmental/ climate change	Upstream (n=84)						Midstream (n=166)						Downstream (n=237)					
	Q1		Q2		Q3		Q1		Q2		Q3		Q1		Q2		Q3	
	Yes	No	IC	DC	IC	DC	Yes	No	IC	DC	IC	DC	Yes	No	IC	DC	IC	DC
Cold waves													5	91	27	9	45	0
Drought	8	80	100	0	100	0	27	65	89	0	89	0	23	72	27	47	31	53
Erosion							1	92	0	0	0	0	16	80	54	35	54	35
Erratic rainfall							1	92	100	0	100	0	0	95	100	0	0	100
Extreme rainfall	51	37	42	7	51	5	54	38	58	4	76	0	10	85	83	4	75	8
Flood							1	92	100	0	100	0	78	18	55	32	52	30
Forest fire	2	86	0	0	0	0												
Hail	25	63	0	0	14	0	26	66	67	2	84	0	8	87	35	35	35	30
Landslide	31	57	42	8	50	0	22	70	58	3	78	0						
Heat waves													1	95	50	0	50	0
Outbreak of diseases													3	92	86	14	71	29
Pest attack on diseases	7	81	67	17	100	0	15	78	88	0	83	4	5	91	73	0	73	0
Storm/ snow storm	1	87	0	100	0	100	1	92	0	0	0	0	27	68	60	25	55	25
Thunderstorm													5	90	67	17	67	8
Water logging	1	87	0	0	100	0							3	92	38	13	38	13
Water scarcity	4	85	67	0	67	0	1	92	0	0	100	0						

In the downstream areas, riverbank erosion, flooding, and sand casting during the wet season, combined with drought and water scarcity during the dry season, create enormous pressures and force people out of their farming and other livelihood practices. This causes social, cultural and psychological stresses on people, particularly women, children, elderly, and the disabled. Here, drought is a frequent climatic stress during the dry period (March-May). The areas experience frequent water scarcity during this dry period due to low river flow and high groundwater withdrawal for irrigation, which severely impacts domestic water supply sources of shallow hand tube wells that go dry when groundwater table goes below 7-8 m from the surface. Drought also causes water shortages for livestock, fisheries and forestry sub-sectors, daily livelihoods and sanitation, and damages pre-monsoon crops. The soil type is mainly sandy with high conductivity and low soil moisture holding capacity. As a result, the soil dries up quickly and causes drought conditions. Frequency of heavy rainfall in the pre-monsoon season, late onset and breaks in the monsoon, and early monsoon withdrawal has increased in recent years. Erratic monsoon patterns have also reduced agricultural production in these areas due to short-time flooding and drought conditions. Over the last few years these areas have also experienced some severe cold waves that have caused serious disruption to livelihood and distress to the affected people. During cold waves the areas experience rapid fall in temperature with cold winds and dense fog in January-February resulting in a large rise in respiratory illness, and in some cases death. April and May are the hottest months in the study areas. A number of moderate to severe heat wave days occur in these months. People have been experiencing higher temperatures and greater frequency of extreme temperatures (especially heat waves) in recent years and perceive this as climate change.

4.3 Perception of climate change impacts

The perception of households about climate change impacts is presented in Figure 8. It shows that at the basin level there is large impact of climate change on lives and livelihoods of the whole basin mainly in terms of low water availability for both domestic use and irrigation, drying up of fresh water sources (springs, wells, ponds etc.),

Figure 8: Perception of households about impacts of climate change compared to 10-20 years ago in Teesta basin in percentage values of respondents; alphabets A to J are different impacts of climatic variability and change i.e., A - water availability for domestic use; B - water availability for crops and animal; C - drying up freshwater sources; D - occurrence of sickness in humans; E - crop productivity; F - incidence of disease/pests in crop; G - livestock productivity; H - fish production (capture); I - incidence of livestock diseases; and J - degradation of pasture land



crop production losses due to lack of water, and increase in pest attacks, decrease of fish capture, and impacts on human health. In the upstream and midstream areas, the substantial impacts are mainly drying up of spring water sources, decrease of crop productivity, increase of pest attacks, while in the downstream areas, there are major impacts on human health due to increase in heat and cold waves, increase in crop and livestock diseases, and decrease in fish captures. However, the results also show that both crop and livestock productivity has increased (56% and 45% perceptions, Figure 8) in the downstream areas, which may be due to large-scale adaptation measures in these sectors. For example, uncontrolled groundwater extraction for crop production in the rabi season (October - March) has increased production for the time being but this may not be sustainable if the groundwater table declines. Similarly, livestock production has increased due to large demand for livestock that are sacrificed during the Muslim festival of Eid-ul-Adha.

4.4 Critical moments in sectors

4.4.1 Upstream areas

Agriculture - Potato

Potato is the major crop in the Lachen and Thangu (Figure 9) study sites. There are very few crops that grow at this altitude due to lack of water for irrigation, so the few crops grown here are rain-fed. Potato is grown from late March through September. At lower elevations, potato is sown in January-February but at this elevation the sowing time is extended mainly due to the elevation at which it is grown and to obtain suitable temperatures for sowing and growth of the crop. Respondents noted that hailstorms during growing season affect the generation of the crop and impact yield. However, hailstorms are not frequent during late March, i.e., the sowing season and hence no major impacts have been observed. However, if hailstorms do occur during this period, they cause considerable losses. Apart from hailstorms, sub-optimal rainfall is also a concern for optimal growth. It was pointed out in discussions that less rainfall during the sowing time – late march to early April – influences the crop productivity negatively. Another critical stage for the growth of the potato crops is during the pre-harvest season of late June to July. Hailstorms are a hazard during this period, but the impact is far greater than in March as hailstorms are more likely to occur during this period and inflict heavy damage on the crop which would otherwise be harvested in less than a month. The FGDs pointed this out as a major concern for the people in the region. Crop damage of 84% of potato was reported by the surveyed households during the last 12 months of the surveyed time (Table 4). Since all the potato that is produced is used for consumption/self-sustenance, no issue of marketing is observed.

Figure 9: A potato growing farmland at Thangu (4,200 masl), North Sikkim (Photo: Ghanashyam Sharma)

Agriculture – large cardamom

Large cardamom (Ammomum subulatum) is one of the major cash crops promoted in Sikkim (Partap et al., 2014). In the high altitudes the main large cardamom variety grown is Chibey Ramsai or Ramsai. This variety has smaller size and is often referred to as chotadana. The crop is grown in both agroforestry and under open farming conditions. The main sowing period begins in June–July. The crop is harvested after 1–3 years in late September to October depending on altitude. The crop is harvested after 1 year if the plant is grown by vegetative propagation through suckers, while it takes three years if it grows from seed. Most of the farmers in the area grew their large cardamom through suckers. Flowering of large cardamom starts in March in the lower altitudes and ends by May in the higher altitudes. The major stress period is the dry winter from November through February. The last few years have witnessed reduced to almost no winter rainfall. This has led to drying up of large cardamom plants leading to crop loss. Increased temperature during April–May directly also leads to wilting and drying of the crop, while it is difficult to irrigate with low water availability. Villagers have observed that if the temperature is high the chances of pest and disease infestation in large cardamom increases. According to the farmers the impact of hailstorms on agriculture varies, depending on where it falls. If hailstones fall directly on the large cardamom flower it can cause damage like breakage and the moisture can lead to rotting of the flower, eventually leading to decreased yield. However, if it falls on the leaves or surrounding areas they can be beneficial as it provides much needed moisture in the dry season (April–May). Earlier intense frost used to set in as early as December and continued till January. Now severe frost is limited to January and some frost occurs in December. Farmers observed that in 10-20 years ago, the frost used to last for 7-10 days, but in recent days it lasts for only 2-3 days. The impact of frost on large cardamom is limited to damage to leaves; however, it provides moisture to the plant. Shade plants like titepati (Artemisia vulgaris) are grown to protect cardamom from frost and hailstone injury (Sharma, Joshi, & Gurung, 2017). In all, 58% and 60% of surveyed households reported extinction of native cardamom varieties during the last 10 years and production losses in the last year, respectively (Table 4).

Table 4: Attributed impacts (% of surveyed households) of climatic stresses in agriculture in upstream areas of the Teesta basin

Crops cultivated in last 12 months	Extinction of traditional/ native crop varieties during last 10 years (n=84)	Production loss in last 12 months (n=84)
Cardamom	58	60
Potato	8	84
Maize	4	22

Livestock - Agro-pastoralism

A major source of livelihood for the community in Muguthang is yak rearing. Beyond Thangu, a village that is located some 25 km downstream, close to the scenic Chopta Valley, yak rearing is a major source of livelihood. The high alpine meadows are optimal for the grazing needs of the countless yaks that dominate the landscape (See Figure 10). Hence, changes in the access to grazing lands, or changes in the quality of the grazing lands can negatively impact the livelihoods of people. During December–January, grazing is mainly affected by heavy snowfall and corresponding low temperatures (Table 5). Therefore, there have been instances of grazing pastures not being available for yaks. In the past, extreme cold has also led to the death of yaks. Grazing lands are also affected by water shortage during March–June, negatively impacting the quality of rangelands and availability of fodder for grazing. Another critical hazard for the yaks is increasing incidences of windstorms in November, which combined with low temperatures lead to sub-optimal temperatures for grazing and impact the health of yaks.

Yak cheese is considered as a delicacy and is in considerable demand in the lower and mid elevation areas in Sikkim. Marketing of yak-based products, other agriculture products such as cabbage, or potato is heavy rainfall, and is influenced greatly by landslides, as these products are marketed to lower regions and involves transportation through treacherous terrain and landslide prone regions. Further the months of July-September bring heavy rainfall to the region, further increasing the frequency and magnitude of this risk.

Table 5: Calendar of yak rearing and critical moments in the upstream of Teesta basin in Sikkim, India

Yak rearing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grazing	Snowfall ←										Wind storm	Snowfall →
Milking						←		→				
Cheese preparation						←				→		
Fodder collection			Water shortage	←					→			
Dung collection			Water shortage ←	→								
Fodder supplement	Snowfall ←		Water shortage →									

Figure 10: Yaks grazing in an alpine meadow in North Sikkim, India (photo: Ghanashyam Sharma)

Forestry and bio-diversity

The summary of impacts of weather/ climatic stresses/ hazards on ecosystem services provided by forests to the community in the upstream of Teesta is presented in Table 6. A large number of households reported a decline in the number of species and production of wild vegetables, wild fruits, medicinal plants and other non-timber forest products, while little or no change was reported for timber and fuel-wood trees from the forest.

Table 6: Impacts of weather/ climatic stresses/ hazards on forest ecosystem services in the upstream areas

Forest ecosystem services	Extinction of forest species in last 10 years observed by HH (n=84)	Production loss in last 10 years observed by HH (n=84)
Wild vegetables	25	31
Timbers	9	9
Medicinal/aromatic plants/herbs/ shrubs/grasses	33	27
Other non-timber forest products	18	18
Wild fruits	40	60

The livestock composition in the upstream areas has changed in recent times. It was reported that in an upstream area like in Gurudongmar-Tsho-Lhamu area of North Sikkim, during last 15 years 10 sheep herds have reduced to only one sheep herd with only 150 sheep. One of the reported reasons for this drastic decline was the outbreak of an epidemic during 2013–14 that killed a large number of sheep. In Sikkim, recently, there has been many cases of zoonotic diseases such as FMD (foot and mouth disease), avian influenza (bird flu), canine and feline distemper, rabies and swine flu (ENVIS, 2018). It is also documented by Sharma, Tambe, et al. (2016) that during 32 years period a drastic decrease of sheep has taken place in North and West Sikkim i.e., more than 70,000 sheep in 1977 reduced to only 2,311 in 2009 due to an outbreak of epidemic disease followed by heavy snowfall in 1995-96.

Tourism

Tourism is an important source of livelihood in West Sikkim. Hiking and trekking are popular sources of income generation. The main periods of tourism according to interviews coincide with major school and public holidays in Sikkim. Although tourists visit throughout the year, the major inflow is during May–June and October–November. A critical stress period for tourism is during June–August, when heavy rainfall results in landslides that affect both communication and transportation. The respondents observed that the lack of all-weather roads causes large losses to tourism. Also, the lack of connectivity to modern banking facilities like ATMs in remote places like Uttarey impacts the inflow of tourists.

4.4.2 Midstream areas

The following sections cover the critical moments observed for specific crops and livestock that are relevant for the region.

Agriculture - large cardamom

Similar to upstream areas, large cardamom is one of the major cash crops in the mid-elevation areas of Sikkim (see a sample photo in Figure 11). The main varieties locally grown are Sermena, Golsey and Bharlang. Sermena is a high quality variety with larger seed and pod size and often sold as badadana. The crop description and related critical moments for large cardamom cultivation are given in the earlier section on upstream areas. Only additional information for the midstream areas is provided here. The major stress period is during the lean season from November–May. Opinions on the driest months vary but respondents across sites agree that winter rainfall has reduced drastically. This has led to drying up of the crop and crop loss. In Dzongu, one of the problems is unpredictable onset of monsoon as early as May which impacts agricultural planning for cardamom sowing. Across the mid-elevation sites, intense rainfall in July–August causes landslides and mudslides. This can lead to loss of agricultural land including cardamom. Similar to upstream areas, large number of surveyed households reported both extinction of native cardamom varieties (53%) during last 10 years and production losses (40%) in the last year (Table 7).

Figure 11: Large cardamom agroforestry at Hee-Bermiok, West Sikkim (Photo: Ghanashyam Sharma)

Agriculture - other crops

Table 7 shows the perceptions of surveyed households on the impact of climatic stresses on agriculture in midstream areas. It shows that besides cardamom, there are impacts on other crops e.g., rice, vegetables, millet, beans, ginger, maize and tobacco, resulting in extinction of many local/native crop varieties in the last decade and crop production losses in the last year.

Table 7: Attributed impacts (% of surveyed households) of climatic stresses on agriculture in midstream of Teesta basin

Crops cultivated during last 12 months	Extinction of traditional/ native crop varieties observed by HH during last 10 years (n=166)	Production losses during last 12 months observed by HH (n=166)
Cardamom	53	40
Ginger	7	14
Maize	11	16
Rice	50	50
Vegetables	0	33
Millet	33	33
Beans	50	50
Tobacco	11	0

4.4.3 Downstream areas

Climatic change-related erratic rainfall, increased flooding and extended droughts pose significant threats to agricultural communities in the downstream areas of the Teesta basin (See hazard calendar, Table 8). There are two broad cropping seasons in the downstream areas of the basin: (i) kharif: crops are grown in the spring or summer season and harvested in late summer or in early winter; and (ii) rabi: crops are sown in winter and harvested in the spring or early summer. Farmers produce a wide variety of crops e.g., maize, potato, winter vegetables, chili, and tobacco, among others. The critical moments faced by the agriculture sector are summarized for these two cropping seasons.

Agriculture - kharif season

Aman is the main crop during kharif season (April–September), which is exposed every year to flooding risks (Table 9). By area coverage T-aman (transplanted aman) is the single largest crop in these areas. Farmers cultivate high yielding varieties of T-aman rice. Farmers reported that T-aman production has been consistently increasing for the last 10–12 years. The seeds are sown from mid-Baishakh through mid-Jaistha (the entire month of May) when it needs irrigation or it is sown in low lying areas where moisture still exists. After 20–25 days, the seedlings are transplanted in the field. T-aman is harvested during early to late-Vadro to mid-Kartik (September–October).

In recent years, the downstream areas have experienced flash floods in April which cause huge damage during early stage of sowing of T-aman. Farmers reported that they do not get the expected T-aman production in an early flooding year. If the flood comes after 30 days of transplantation, the standing paddy survives. T-aman can also sustain post-monsoon flooding. Floods in August lead to the complete inundation of matured rice crops just before harvest. Apart from these large-scale damages, even minor weather events can devastate T-aman production. T-aman is mainly rain-fed while supplementary irrigation is provided if there are long gaps between rainfall events. Inadequate rainfall in May–June delays land preparation and transplantation of T-aman. Due to the delayed onset of monsoon in recent years, farmers have had to irrigate fields which greatly increases the production costs. Erratic rainfall and heavy winds during sowing at pre-monsoon (April–June), and storms with heavy winds before harvesting in the post-monsoon (September–October) reduces yields of T-aman.

Agriculture - rabi season

Maize is a major cash crop in the sandy and barren char lands in the rabi season (October–March). Maize cultivation has become popular in the region and is contributing largely to the economy of the area. Since the irrigation water requirement of maize is low, it is cultivated instead of boro rice during the rabi season. Potato is a prominent crop in terms of production and internal demand in the country and potato cultivation has become popular over many years. However, the area planted with local varieties has declined as farmers grow more productive high yielding varieties. Different varieties of winter vegetables give relatively more profit than other rabi crops. Farmers grow cabbage, cauliflower, gourds, beans, eggplant, cucumber, tomato, carrot, and radish. However, in char lands, chili may be affected due to fog and cold wave during weeding and flowering and early floods during harvesting (Table 10, Figure 12). Many farmers in the downstream of Teesta River basin have been cultivating tobacco for the last several years. However, this is ultimately threatening cereal crops as their cultivation has reduced in that time span during the rabi season. Harvest of tobacco takes place during February–March. Farmers said that they cultivate tobacco to get more profits as the tobacco companies encourage them by providing necessary inputs, cost-free seedlings and incentives with an assurance of lucrative prices.

Table 8: Hazard calendar in lower Teesta basin in Bangladesh; the months of the Bengali calendar are presented along with corresponding period in the Gregorian calendar; normally each Bengali month starts at middle of one Gregorian calendar month and ends at the middle of next month

Crop	Baishakh (Apr - May)	Jaistha (May – Jun)	Ashar (Jun – Jul)	Shrabon (Jul – Aug)	Vadro (Aug – Sep)	Aswin (Sep – Oct)	Kartik (Oct – Nov)	Agrahayan (Nov – Dec)	Poush (Dec - Jan)	Magh (Jan - Feb)	Falgun (Feb - Mar)	Chaitra (Mar - Apr)
Flood												
Riverbank erosion												
Drought												
Erratic rainfall												
Heat wave												
Cold wave												
Heavy wind/ storm												

Table 9: Crop calendar of major crops and critical moments in the downstream of Teesta basin in Bangladesh; S - sowing; P - planting; W - weeding; F - flowering; H - Harvesting; I - irrigation

Crop	**Baishakh (Apr - May)**	**Jaistha (May – Jun)**	**Ashar (Jun – Jul)**	**Shrabon (Jul – Aug)**	**Vadro (Aug – Sep)**	**Aswin (Sep – Oct)**	**Kartik (Oct – Nov)**	**Agra-hayan (Nov – Dec)**	**Poush (Dec - Jan)**	**Magh (Jan - Feb)**	**Falgun (Feb - Mar)**	**Chaitra (Mar - Apr)**
Rice (T-*aman*)	ERRATIC RAINFALL			FOOD		HEAVY WIND/STORM						
Maize	H STORM							S	W/I FOG AND COLD WAVE	W/I	F/I	H
Potato								P/I	W/I FOG AND COLD WAVE		F/I	H
Green chili	H STORM							P	W/I FOG AND COLD WAVE	W/I	F/I	H
Winter vegetables								P	W/I FOG AND COLD WAVE	F/H/I	F/H/I	H
Tobacco								P	W/I FOG AND COLD WAVE	W/I	F/I	H

Table 10: Critical moments and adaptations in agriculture in the downstream of Teesta basin in Bangladesh

Crop	Stress moments	Climatic hazard condition(s)	Risk related to climatic condition	Other factors leading to vulnerability	Coping strategy in place	Potential adaptation measures
Transplanted aman rice	Early stage of sowing and transplantation	Flood/Flash flood	Damage to seedlings Delays transplantation Destruction of standing crops	Sand deposition makes the field uncultivable Because of economic crisis, cannot involve day labourers	Replantation Borrowing loan	Late variety of T-aman Effective flood early warning
		Drought	Prevents land preparation Damage to standing crops Reduce yields		Irrigation	
		Erratic rainfall	Damage to standing crops			Agro-information service
		Late monsoon onset	Delays transplantation		Irrigation	Seasonal forecast
	Matured and harvesting period	Flood	Destroys the standing crop Plants are flattened and get rotten	Loan increases.	Early variety vegetables after recession of floodwaters and then regular crops on their lands to recoup crop losses incurred	Effective flood early warning
		Heavy wind/ storm	Affects flowering of paddy causing severe damage to crop Reduced yields			
Maize	Flowering period	Fog and cold wave	Reduce yields Disease outbreak	Insect attacks	Use of pesticides	Agro-information service
	Before harvesting	Northwester and hailstorms	Damage the corn cobs	Market price	Early harvesting	Short rotation variety
Potato	Weeding and flowering	Fog and cold wave	Late blight - plants rot	High price of input (seeds, fungicide)	Spraying of fungicide	Weather information based alert of late blight
Green chili	Weeding and flowering Harvesting	Fog and cold wave Early flood (like in Figure 10)	Damaged due to fog Reduced yields			
Winter vegetables	Weeding and flowering	Fog and cold wave	Do not grow well	Insect		

Poultry and livestock	Jaistha - Vadro	Flood	Animals die Scarcity of fodder	Have to sell in low price	Sell the poultry and livestock in low price	Raise plinth of shed High yield fodder
	Baishakh – Jaistha	Heat stress	Animals die Diseases outbreak		Veterinary treatment	

Figure 12: A chili field destroyed by floodwater at Khalishakaloa village in Kurigram district, 2017 (Photo: Star-Country-Desk (2017))

Table 8 shows the hazard calendar for downstream areas of Teesta basin while Table 9 summarizes the crop calendar corresponding with major critical moments in the agriculture sector. Table 10 shows the detailed impact of critical moments for each crop stage and the adaptation practices or potential adaptation practices.

Rabi crops are hampered mainly due to fog and cold waves during winter (mid-December to mid-February), and hailstorms and northwester during summer in *Baishakh - Joistha* (April - May) (Table 9). Hailstorms and Norwesters cause major damage to maize and vegetables. These areas have also been experiencing severe cold waves with heavy fog for the last few years. Fog and cold waves largely reduce the yield of *rabi* crops. Potato cultivation is highly exposed to cold waves and late blight disease outbreak during this time can have devastating effects on potato production. Cold wave and fog also reduce yields of other winter crops.

Table 11: Attributed impacts (% of surveyed households) of climatic stresses in agriculture in downstream areas of Teesta basin

Crops cultivated in last 12 months	Extinction of traditional/ native crop varieties during last 10 years (n=237)	Production loss in last 12 months (n=237)
Rice	43	46
Maize	41	54
Potato	44	44
Jute	18	24
Onion	0	30
Peanut	50	100
Garlic	0	50
Wheat	100	100
Chili	0	20

The attributed impacts of climatic stresses on agriculture in the downstream areas is presented in Table 11. It shows the extinction of traditional/native varieties during the last decade and estimates of production losses for rice, maize, potato, jute, onion, peanut, garlic, wheat and chili in the last year.

Figure 13: Tomato and other climbers affected due to drought at Jalpaiguri (Photo: Ghanashyam Sharma)

Non-agricultural livelihoods

Fisher communities are substantially dependent on fish availability and favourable weather conditions for fishing (Table 12). They constitute a distinctive group of people who are geographically located in areas by the river. These communities are particularly vulnerable to climatic stressors because fishing utilizes resources in a natural environment under little human control. Fishers reported that the daily fish catch was reducing and attributed this to reduced flows in the Teesta River, particularly during the dry season. They also reported that in recent years, the daily catch reduces close to zero from Chaitra to Joistha (mid-March to mid mid-June). Another stress moment for the fishing communities is the monsoon. During this season there is water everywhere, but it is very difficult to catch fish due to strong currents. Water flow or river currents are very strong during the months of Ashar and Shrabon (mid-June to mid-August). Strong winds are another factor affecting fishing during this period. Fishermen have to stop fishing during those days.

Daily wagers are considered the poorest and most vulnerable group in the study area. A larger proportion of households living below the poverty line earn their living as daily wagers. Landless daily wagers are most vulnerable to climatic risks as these pose an additional burden besides chronic poverty and food insecurity. Landless wagers mainly work in the agriculture sector, and disruptions in the labour market occur when there are crop damages. If there is a flood, crop damage and temporary disruptions in the labour market, daily wagers' households reduce their food consumption. Erratic rainfall also affects the need for and availability of labour, and thus the income of agricultural daily wagers. Each year, from Shraban to Vadro (mid-July to mid-September), agricultural daily wagers and small-scale farmers face a period of hunger as little labour is required in the fields before the actual harvest of T-aman rice.

Table 12: Critical climate-stress moments in non-agricultural livelihoods

Activities	Stress moments	Climatic hazard Condition(s)	Risk related to the climatic condition	Other factors leading to vulnerability	Coping strategy in place	Potential adaptation/ coping measure
Fishing	Dry season	Unavailability of water	Reduced catch size	Heat stress	Work as day labourer Short term migration to cities	Livelihood diversification
	Monsoon (Ashar and Srabon)	River currents too strong for fishing in this period	Unable to go for fishing Reduced catch size	Siltation occurred; catch amount got reduced for four months at least	Operating boats	Livelihood diversification
Daily wage selling	Flood		No work, no income			
	There is no work in the monsoon months	No/little cultivation of T-aman which farmers do on their own as there is high risk of crop damage so farmers do not want to employ day wagers		Low wages	Some take loans to survive Seasonal migration	

Health and sanitation

Climatic stresses have direct and indirect impacts on human health and sanitation in the study areas (Table 13 and 14). Water resources are threatened by different climatic factors that increase health risks. The areas are affected by vector- and water-borne diseases during floods and heat waves. Participants in the FGDs reported an increase in incidence of diarrheal diseases, skin diseases, and drowning in recent years. They also reported fever and headaches as second order health problems due to climatic factors. Most participants in the FGDs clearly mentioned that the incidences are frequent during the pre-monsoon (April–June) period. Extreme floods also claim human lives. The results of the household survey in Table 15 show that many health issues have increased during the last decade due to climatic stresses. Remarkable increases are water borne, lung and gastro related diseases. Besides, death toll by drowning has also increased significantly during last decade.

Table 13: Critical moments in health and sanitation

Stress moments	**Climatic hazard condition(s)**	**Risk related to the climatic condition**	**Other factors leading to vulnerability**	**Coping strategy in place**
Pre-monsoon	Flood	Shortage of safe drinking water Damage of WASH infrastructure Outbreak of water-borne diseases Death toll of human lives	Malnutrition Lack of access to basic health facilities and services	Raise the plinth of toilet and tube well collect drinking water from tube wells in elevated road once a day by boat
	Heat wave	Outbreak of vector borne diseases Tiredness Excessive sweating Headache Death	Less productivity	Drink more water Take bath If tired take rest in the shade then work again.
Post monsoon	Flood	shortage of safe drinking water WASH infrastructure damage Inaccessibility of basic health facilities outbreak of diseases Toll of human lives	Malnutrition Inaccessibility of basic health facilities	Raise the plinth of toilet and tube well Collect drinking water from tube wells in elevated road once a day by boat
Winter	Cold wave	Outbreak of diseases Fever Death		

Table 14: Health attributed impacts of weather/ climatic stresses/hazards

Health aspects/issues	Increase in frequency of health issues in last 10 years	Loss of life due to climate induced health issues in last 10 years
Water borne disease	10	64
Heart related disease	4	61
Diabetes	11	63
Others e.g., drowning	32	68
Vector borne disease	0	65
Lung related disease	25	25
Gastro related disease	25	50

Critical moments in habitat

Flood and riverbank erosion lead to loss of land and houses, and to the forced displacement of individuals and communities at least temporarily (Table 15). Several thousand hectares of floodplain are lost to riverbank erosion and this leads to thousands of people becoming landless and homeless every year. These people are forced to move to other places and these movements are usually large scale. In most cases, the displaced return to their place of origin in the long run.

Table 15: Critical climate stress moments in habitat

Climatic hazard condition(s)	Risk related to the climatic condition	Other factors leading to vulnerability	Coping (potential) strategy
Riverbank erosion	Loss of thousands of hectares of land Loss of homes, property and infrastructure	Death and injury Disruption of economic production, education, communications and sanitation facilities Poor erosion management.	Relocate landless individuals and families Erosion management activities by government
Flood	Substantial damage to housing and property Lack of food and fuel wood	Disruption to agriculture, including destruction of crops Disruption to livelihoods Sedimentation	Raise homestead plinth Flood resistant housing Portable cooking stove for cooking Conserve dry food and fuel-wood Multipurpose flood shelters

5. Response strategies

5.1 Upstream and midstream areas

In the upstream areas, there are no clear coping/adaptation measures to deal with the loss in potato crop due to extreme/unexpected weather during the sowing and pre-harvest seasons. However, the Lachen Dzumsa sets a sowing season every year for the Lachen area. This decision on sowing time is taken by the 'Pipon' (head of Lachen), prior to which he calls for a meeting in Lachen town – the seat of the administrative arm of the Dzumsa. When the dates are announced, people from Thangu, Muguthang and other regions travel to Lachen. Sowing is done only during these specified dates by Dzumsa to ensure equal or no distortions in produce and the timings are observed. In the context of grazing, the Dzumsa plays a crucial role in maintaining the quality of the rangelands. They employ a rotational grazing method to ensure time for rejuvenation of already grazed pasture lands. This also ensures that there is no competition for rangelands amongst herders. The herders have to obey the rotational grazing rules set by the Lachen Dzumsa and sub-pipon of Dzongu. The herders who disobey the instructions related to movement of animals other than on the specified dates are fined by the Dzumsa.

In the midstream areas, the main adaptation measure for the growing water scarcity is the use of drip and sprinkler irrigation systems if financially feasible. Otherwise manual watering is done by the farmers. Overflow from drinking water tanks are used at night for irrigating cardamom. Springshed management is another major adaptation option emerging in the area to revive dying springs (Figure 14). This is done by creating trenches and water harvesting structures in the spring recharge zone under the Dhara Vikas initiative. Farmers also tend to mix varieties of large cardamom to increase diversity and reduce loss.

Figure 14: Spring revival initiative at Chibo-Pashyor in Kalimpong, India by TMI India and ICIMOD (Photo: Ghanashyam Sharma)

In general, the household survey data shows that very few respondents were using adaptation strategies i.e., 24 out of 84 respondents in upstream areas, and 12 out of 166 respondents in midstream areas (Table 16). The major adaptation strategies documented are use of modern technology for sowing, planting and harvesting; improved irrigation techniques; use of organic fertilizer; mixed cropping; adjustment of timing of sowing; change in cropping pattern; change in cropping cycle; introduction of new crop/ variety; local seed; rain water harvesting;

and disease management. The more specific adaptation strategies are use of improved innovations of cardamom. farmers for sowing, planting and harvesting; improved irrigation techniques; use of organic manure such as cow dung; intercropping with kerau (field peas), rahari dal (kidney bean), mas dal (black gram), bakulla (broad bean), Masyam dal (rice bean), bodi (cow pea), bhatmas (soybean), aduwa (ginger), chilli, etc., planting of suitable shade trees such as alder (Alnus nepalensis), planting of other species to avoid frost such as titepati (Artimesia vulgaris), bilaune (Maesa indica), periodic gap filling, uprooting of diseases plants etc. (Sharma, Joshi, Gurung, et al., 2017). Traditional farmers of cardamom have learnt to adjust with the timing of new cardamom plantation, management of the farms for careful weeding, manage suitable cropping pattern, introduction of adaptive and improved cardamom cultivar such as Seremna in Hee-Bermiok-Uttarey area, or Dzongu Golsai in Dzongu area in North Sikkim; rain water harvesting; and disease management, and diversification of agricultural practices. This implies that as an adaptation strategy farmers are engaged in innovative climate-smart agricultural practices to revive cardamom and increase production and productivity while also integrating suitable intercropping. A number of these adaptation strategies are already being practiced although at limited scale. Government agencies and NGOs can help upscale them to build the resilience of communities living in these areas.

Table 16: Result of household survey of adaptation strategies for major crop (cardamom) in upstream and midstream areas

Adaptation strategy for cardamom cultivation	Upstream (n=24)	Midstream (n=12)
Use of modern technology for sowing, planting, and harvesting	63	17
Improved/more irrigation	46	25
Use of organic fertilizer	13	8
Mixing compatible cropping	8	
Adjustment of timing of sowing	4	8
Change in cropping pattern		17
Change in cropping cycle	4	8
Introduction of new crop/varieties	4	8
External support	4	
Started local seed	4	
Rain water harvesting		8
Disease management		8

5.2 Downstream areas

If floods occur early during the kharif season (April-September), replantation of T-aman is the main adaptation strategy. Many farmers also use late and high-yielding variety of T-aman (e.g., SWARNA, BRRI dhan51, BRRI dhan52, BINA 11, and BINA 12). However, to do so, farmers need to take loans at high rate of interest from local seed and fertilizer agents. In the rabi season, maize cultivation in the char lands is the most preferred adaptation in these areas. Sand deposition due to floods drastically inhibits crop cultivation on chars, making it very difficult to grow staples on such barren and degraded land. Char farmers have now switched to cultivating maize, peanut, onion and potato, crops that offer better profit margins. Even the high-yield boro rice has been replaced by maize due to sand deposition on chars. Farmers here urged for adequate support from the government in terms of market creation and financial support to move towards sustainable maize farming practices. Mixed and relay culture is also practiced by a good number of farmers as it is more profitable than mono cropping. Many farmers intercrop maize with potatoes and early maturing vegetables. Peas are also intercropped with maize because they do not compete for sunlight, nutrients or space. In the rabi season, new improved rice varieties (e.g., short rotation) were observed to be used. In chars, sandbar cropping like pumpkin was supported by many NGOs in the areas. However, due to lack of market access and transportation (as pumpkins are quite large), pumpkin was not successful in the remote chars. In addition to pumpkin, some other crops like squash, cabbage, lettuce, parsley, capsicum, strawberry, melon, and onion are being cultivated on a trial basis. Among these crops, squash, capsicum and strawberry are preferred by the community as these are high value crops. However, the seedlings of these crops are not available in the areas. In the rabi season, all the farming is made possible because of availability of portable pumps for irrigation which is used to withdraw very shallow groundwater.

Fishers work as daily wagers during the dry season as there is little or no fish available in the Teesta River. However, they earn lower wages since do not have the skills of regular wage earners. Short-term labour migration is one of the most practiced coping strategies of agricultural daily wagers in the context of climatic risks. They can use their agricultural skills and take benefit from the labour shortages in the other areas of the country. Depending on the availability of work and the wages being paid, wagers move back and forth several times in a year.

In the habitat sector, people normally relocate to a new place nearby if riverbank erosion or floods hit frequently. A small number of people raise their homestead plinth; however, it is difficult for them to raise the plinth without support from external sources. Portable cooking stoves and conserving dry food and fuel-wood are other adaptation practices.

In the health and sanitation sector, raising of plinth level of toilet and tube well is the most widely practiced adaptation measure in the area. People take shelter on elevated areas like embankments; however, multi-purpose flood shelters are required and these can be supported by the government. During heat waves, people normally drink more water and take bath more frequently e.g., twice/thrice in a day; however, lack of drinking water due to drying up of tube wells may worsen the situation.

Table 17 summarizes the adaptation strategies for major crops rice and maize and other crops in general. A number of these adaptation strategies are already practiced in the downstream areas although in limited numbers. Government organizations and NGOs can help upscale them to improve the resilience of communities living in these areas.

Table 17: Result of household survey of adaptation strategies for major crops rice and maize in downstream areas

Adaptation strategy	For rice (n=39)	For maize (n=13)
Adjustment of timing	46	54
Introduction of new crop/variety	39	31
Use of organic fertilizer	36	31
Improved/more irrigation	31	15
Use of modern technology for sowing, planting, and harvesting	26	23
Improved harvesting system	23	23
Change in cropping pattern	18	15
Change in cropping cycle	10	23
Mixing compatible cropping	18	15
Improved storage system for harvested crop	10	
Use of traditional seed		15

6. Discussion and way forward

It is clear from the findings that there is no single critical moment for communities in the Teesta River basin. Rather, communities are experiencing series of critical moments that hit one after another during different periods of the year. The upstream, midstream and downstream represent different sets of vulnerabilities. Further there is a need to understand and identify impacts under short, medium and long term climate variability and change. Also, no single critical moment can adequately represent the complex system of the Teesta River basin as indicated earlier in this paper. For the emergence of some appropriate policy options in this complex scenario the following discussion may be helpful.

In the upstream areas of the Teesta River basin, agriculture is mainly rain-fed e.g., potato, large cardamom. Getting suitable temperature is most challenging for growing potato there due to high elevation. The other stresses for potato cultivation are during March due to hailstorm, April due to low rainfall, and July due to again hailstorm. Potato has no clear coping/ adaptation strategies. However, sowing time of potato is normally set by the local governing body, the Dzumsa, e.g., in Lachen Dzumsa.

In the upstream and midstream areas of Teesta River basin, large cardamom is developed and supported by the government as an adaptation in the mountain areas. However, lack of water for irrigation due to drying up of springs is a major stress along with other climatic stressors e.g., hailstones in April-May and frost in high altitudes in winter. Nonetheless, springshed management and spring revival by afforestation and artificial recharge by excavating small reservoirs or trenches and other water harvesting structures under Dhara Vikas initiative by the Government of Sikkim may be a fruitful adaptation for providing irrigation for large cardamom. Shade plants like titepati (Artemisia vulgaris) are also grown to protect cardamom from frost and hailstones injury. A majority of farmers do not depend fully on large cardamom; they also depend on silviculture (timber trees), livestock farming, and agroforestry systems including broom grass (Amliso) and other fodder species in Sikkim (Partap et al., 2014). Therefore, farmers may have alternative livelihood options if large cardamom is not profitable.

In the agro-pastoral sector of the upstream and midstream areas, yak rearing is a major livelihood strategy. However, heavy snowfall in December-January, and shortage of water in March-June affects grazing lands for yak, while high winds during November affect both grazing lands and yak health. The adaptations include management of grazing land by rotational method to ensure time for rejuvenation and prevent competition among herders (Sharma, Tambe, et al., 2016) . In the forestry sector, large number of households reported a decline of forest species and production of wild vegetables, wild fruits, medicinal plants and other non-timber forest products. Tourism is affected due to landslides in June-August.

In the downstream areas, floods and riverbank erosion are the most overwhelming hazards and constitute critical climate-stress moments. The lives and livelihood systems are vulnerable after each large flood due to disruption of agricultural production, education, communication and sanitation facilities. Besides, erratic rainfall, heavy winds during monsoon, drought, fog, cold waves, and heat waves during dry season have large impacts on the lives and livelihoods of the people of the study area.

The above research, findings and discussions lead to a number of summarized conclusions and indicate directions for several future policy approaches of actions and identification of a group of actors. Critical climate-stress moments is a useful tool and approach to communicate vulnerabilities of the communities and the challenges faced by them to achieve their sustainable livelihoods and opportunities. Given the complexities and heterogeneity in the livelihoods of communities it is necessary to recognize the changes in bio-physical parameters with differences in a number of factors including seasonality, altitude, quantity and quality of water flow.

Communities across elevations in the Teesta River basin are responding to these critical climate-stress moments at a limited scale with their parental and experiential knowledge. Upscaling of present practices and new adaptation actions with critical scientific and policy review are necessary for building resilience and improving the lives and livelihoods of communities in all areas of the Teesta River basin. Many adaptation actions that have been initiated by local communities and progressive farmers could be supported and upscaled with support from government and non-government organizations.

The three regions of Teesta River basin covered in this study have strong local government institutions and NGOs. Climate change is already a part of the development discourse in the region and communities as well as the development agencies and practitioners – local government, NGOs, scientific community, some well-informed civil society organizations – have all recognized and accepted the increasing stresses and impacts of climate change, climate variability, and some newly emerging extremes. The issue of critical climate-stress moments discussed in this paper is being recognized, albeit slowly by most actors, as a communication tool of vulnerability. This would aid disaster management and sustainable livelihoods of affected communities. Further, river basin management has been recognized as a modality for sustainable development considerations. Thus a group of four sets of key actors have been identified to facilitate maximum interactions between the communities and other key actors in each region.

This interaction is envisaged at two levels. First, interactions will be needed to be undertaken by policymakers, communities and other key actors within each region i.e. in (a) Sikkim, (b) West Bengal and (c) Bangladesh. Second, a set of interactions will be required between respective policy makers, communities and key actors across the three regions.

The four key sets of actors are:

(a) Communities representing the upstream, midstream and downstream areas their respective livelihood, geo-spatial and ethnic groups;

(b) Local Govt. institutes and NGO actors working in the Teesta River basin region;

(c) Key personnel and involved professionals in policy analysis and decision making process, climate change science, adaptation, impacts identification of climate vulnerabilities and extremes, those involved in working on critical climate stress moments or any disaster management component; and

(d) Professionals and managers of river basin management approaches in appropriate areas in Sikkim, West Bengal and Bangladesh and working for better convergence.

Higher and more intensive and integrated level interactions between the four groups of actors in each region is likely to offer better opportunities for enhanced adaptation, reduced risks, greater opportunities for sustainable livelihoods of communities and overall sustainable development.

If there are actors beyond those identified here, they should be included to meet the principles of inclusion and ensure a comprehensive representation. The principle to be followed is the SDG "Principle of leaving no one behind". Any innovative ideas should also be included to ensure strengthening the choice for the communities. Such an intensive interaction will hopefully enhance new policy approaches and help develop three regional action plans, one in each region to advance the integration process in the Teesta River region. The objective is to enable an enhanced integration process of sharing experiences, knowledge exchange, innovative adaptation, disaster risk reduction and overall sustainable community development.

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