HI-AWARE Working Paper 22

Climate Change Adaptation Strategies and Practices in the Lower Teesta Basin in 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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Climate Change Adaptation Strategies and Practices in the Lower Teesta Basin in Bangladesh

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Acronyms and Abbreviations

ADB	Asian Development Bank
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCCRF	Bangladesh Climate Change Resilience Fund
BCCSAP	Bangladesh Climate Change Strategy and Action Plan 2009
BCCTF	Bangladesh Climate Change Trust Fund
BLRI	Bangladesh Livestock Research Institute
BMD	Bangladesh Meteorological Department
BRAC	Bangladesh Rural Advancement Committee
BRDB	Bangladesh Rural Development Board
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
CARE	Cooperative for Assistance and Relief Everywhere
CBACC	Community-based adaptation to climate change
CCA	Climate change adaptation
CCAP	Climate Change Action Plan
CDSP	Char Development and Settlement Project
CEIP	Coastal Embankment Improvement Project
CLP	Char Livelihoods Programme
DAE	Department of Agricultural Extension
DECCMA	Delta's Vulnerability and Climate Change: Migration and Adaptation (a research project under CARIAA)
DRR	Disaster risk reduction
EBA	Ecosystem-based adaptation
FGD	Focus group discussion
GED	General Economic Division, Ministry of Planning, Government of Bangladesh
GoB	Government of the People's Republic of Bangladesh
GUK	Gana Unnayan Kendra, Dhaka
HI-AWARE	Himalayan Adaptation, Water and Resilience Research
HYV	High-yielding variety
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change

MoEFCC	Ministry of Environment, Forest and Climate Change, GoB
MoWR	Ministry of Water Resources, GoB
NAPA	National Adaptation Programme of Action
NWMP	National Water Management Plan
NWP	National Water Policy
PKSF	Palli Karmo-Sahayak Foundation
PRA	Participatory rural appraisal
RDRS	Rangpur–Dinajpur Rural Services
SDC	Swiss Agency for Development and Cooperation
TBP	Teesta Barrage Project
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

Glossary

Adhi	An income-generating system under which poor households lease in cattle or other livestock from usually better-off owners, and the two parties share the profits equally
Aus rice	An early summer rice variety
Boro rice	A winter rice variety
Cage culture	Fisheries in cages or nets floating in water
Chars	Islands or sandbars that form due to erosion and accretion processes during monsoon floods. Also, tracts of land surrounded by the waters of a sea, lake, or stream
Haor	A saucer-shaped wetland ecosystem
Khas land	Land deemed to be owned by the government and available for allocation according to governmental land distribution priorities
Kochuripana	Water hyacinth
Pen culture	Fisheries in a pen-shaped closed water body
Sorjan	An integrated adaptation approach for fisheries and agriculture
T. Aman	Transplanted Aman, a late summer rice variety
Upazila	Sub-district

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Summary

This study aims to deepen our understanding about local climate change trends, adaptation approaches and strategies of the government, NGOs, and other actors, and emerging adaptation practices in key impacted sectors in the Lower Teesta basin in Bangladesh. This region, regarded as one of the important food baskets of the country, has been experiencing varied changes in climate variability (including temperature rises, heat stress, low and erratic rainfall, and prolonged droughts), falling groundwater levels, and climatic extremes such as frequent and devastating floods, riverbank erosion, and thunderstorms. These climate change and other stressors are hurting sectors such as agriculture, water, sanitation and health, fisheries, food security, regional infrastructure, housing, and the livelihoods of common people in general.

The study examines in detail adaptation practices in six key social and economic sectors – agriculture, fisheries, livestock, housing and habitats, energy, and water. Methodologically, it is based on consultations with communities and other concerned actors, published literature and relevant documents including national policies and strategies on climate change adaptation, sectoral policies and plans, scientific papers, and the grey literature. Numerous adaptation practices adopted in different sectors are discussed, including the introduction of drought-tolerant and flood-tolerant crop varieties, the livestock-leasing adhi system, raising the level of the house plinth, maize and pumpkin cultivation in sandy soil, and rainwater harvesting.

The Government of Bangladesh has prepared the National Adaptation Programme of Action (NAPA) and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), which have suggested a number of climate change adaptation and disaster risk reduction measures in different sectors relevant to the Lower Teesta basin. This study has identified various coping mechanisms and adaptation practices of varied communities, but concludes that they need further support from the government. It recommends the integration of local knowledge with scientific knowledge, resource allocation for the poor, technology transfer, and innovation for effective adaptation in the Lower Teesta basin.

1. Introduction

Climate change has been defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC 2007). There are clear signs that the impacts of climate change are already being observed worldwide, and that it adversely impacts livelihoods through its effects on natural resources and ecosystems that are highly exposed to climate change (IPCC 2014, p 1132). The impacts of climate change are also evident all over the world, including in Bangladesh (IPCC 2007, 2014). Human and material losses due to climate-induced impacts in Bangladesh are mostly in the form of water-related and other accentuated extreme events such as floods, cyclones, storm surges, salinity intrusion, heat waves, and cold waves.

Bangladesh is ranked the fifth-most disaster-prone country in the world, with a risk index[1] of 19.6 (World Risk Report 2017, p 56). Bangladesh experiences the summer monsoon from June to August, with its northwestern region experiencing less rainfall compared to the rest of the country. However, in recent years, there has been a growing trend of a fewer number of rainy days providing the same amount of, or more total rainfall, with changes in its spatial and temporal patterns (Syed & Amin 2016). In sum, there appears to be more intense rainfall over shorter periods of time (Waslekar et al. 2013, p 96). As a result, climate change is also affecting the natural water balance and water availability in many ways, and hence all the economic and social sectors dependent on it. The impacts of climate change in these areas therefore affect lives, livelihoods, assets, and infrastructure – including people's homes – significantly.

Historically, because of its location in the foothills of the Himalayan mountain system, the Teesta basin has been experiencing frequent extreme climate events, including flooding. The Teesta river is characterized by chars, the local name for the islands or sandbars that form due to erosion and accretion processes during the monsoon floods, which have rich, fertile soils good for agriculture. However, in recent years, floods have put a layer of sand on the topsoil of agricultural fields, which adversely affects farming (Syed et al. 2017). Flooding during monsoons causes enormous riverbank erosion and destroys infrastructure, and is responsible for recurrent damage on farms, all of which also adversely impacts the economy here. Hence it is clear that adaptation to climatic impacts is required to sustain the lives and livelihoods of the people in the region.

VCCCAR (2018) summarizes the definitions of adaptation from multiple sources. For example, the United Nations Framework Convention on Climate Change (UNFCCC) defines 'adaptation' as actions taken to help communities and ecosystems cope with changing climate conditions. The Intergovernmental Panel on Climate Change (IPCC) describes it as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm, or exploits beneficial opportunities. The United Nations Development Programme (UNDP) calls it a process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented. The UK Climate Impacts Programme (UKCIP) defines it as the process or outcome of a process that leads to a reduction in harm or risk of harm, or the realization of benefits associated with climate variability and climate change.

[1] The World Risk Index calculates the risk faced by 171 countries worldwide on the basis of the following four components: (i) Exposure to natural hazards such as earthquakes, hurricanes, flooding, droughts, and sea-level rise; (ii) Vulnerability, dependent on infrastructure, nutrition, living conditions, and economic circumstances; (iii) Coping capacities, dependent on governance, preparedness and early warning measures, access to healthcare, and social and material security; and (iv) Adaptive capacities with respect to impending natural events, climate change, and other challenges. The index was generated by the Institute for Environment and Human Security of the United Nations University (UNU–EHS) in the years 2011–2016. For more information, see World Risk Report (2017, p 8).

The Government of Bangladesh (GoB) has adopted a few key policies – such as the National Adaptation Programmme of Action (NAPA) (MoEFCC 2005) and the Bangladesh Climate Change Strategy and Action Plan 2009 (BCCSAP) (MoEFCC 2009) – to address climate change-related issues. These two national policy documents have formulated strategies and actions in key thematic areas to address the impacts of climate change on ecosystems, people's lives, and livelihoods. The government's developmental efforts overlap a great deal with adaptation measures towards the sustainable use and development of the country's water resources. In this context, the National Water Management Plan (NWMP) of Bangladesh (MoWR 2001, p 48) was taken into consideration, along with other key national policies and priorities. The NWMP has been developed as a guide to implementing the National Water Policy (NWP) (MoWR 1999). Both the NWMP and NWP recognize climate change as a determining factor for future water supply and demand. Moreover, recent policies on agriculture, water resources and other natural resources have taken into consideration these policies as guidelines even as they recognize that climate change is increasingly a reality for the people of Bangladesh to grapple with.

This study attempts to deepen our understanding of adaptation approaches, strategies, and practices in the context of the Lower Teesta basin in Bangladesh, where agriculture is the main livelihood practised, along with fishing. There are also small entrepreneurs and innumerable wage labourers. Rice, wheat, jute, sugarcane, maize, potato, and tobacco are the major crops in the Lower Teesta basin of Bangladesh, which is regarded as one of the important food baskets of the country.

This study also briefly discusses the national, regional, and international interventions regarding existing policies, strategies, and action plans. The implications of various policies adopted at the national level are not found very satisfactory at the field level, since their integration by sectors and ecosystems are not adequately addressed or not at all. However, the adoption of the Community-based Adaptation to Climate Change (CBACC) approach has been given priority over other initiatives. Hence, high-level research for innovation regarding CBACC options, new tools and technologies, and the improvement and promotion of tested, existing practices/options by sectors and ecosystems is necessary for the improvement of people's livelihoods in the study area.

2. Study Area and Methodology

The study areas are based in three villages in the Lower Teesta basin – Jharsingheswar village in Dimla upazila (subdistrict), Nilpahamari district; Char Dhubni village in Hatibandha upazila, Lalmonirhat district; and Panjarbhanga village in Kaunia upazila, Rangpur district (Figure 1). The Lower Teesta basin is located in northwest Bangladesh in the Rangpur division, and is a flat riverine floodplain. The basin straddles five districts, namely Kurigram, Nilphamari, Lalmonirhat, Gaibandha, and Rangpur, in Bangladesh. The study area lies between latitudes 25°18″ to 25°57″N and between longitudes 88°56″ to 89°32″E. This region is prone to frequent and recurrent floods and riverbank erosion. The main rivers flowing through are the Teesta, the Jamuneswari, the Karatoya, the Chikli, the Akhira, and the Ghaghat (BBS 2011).

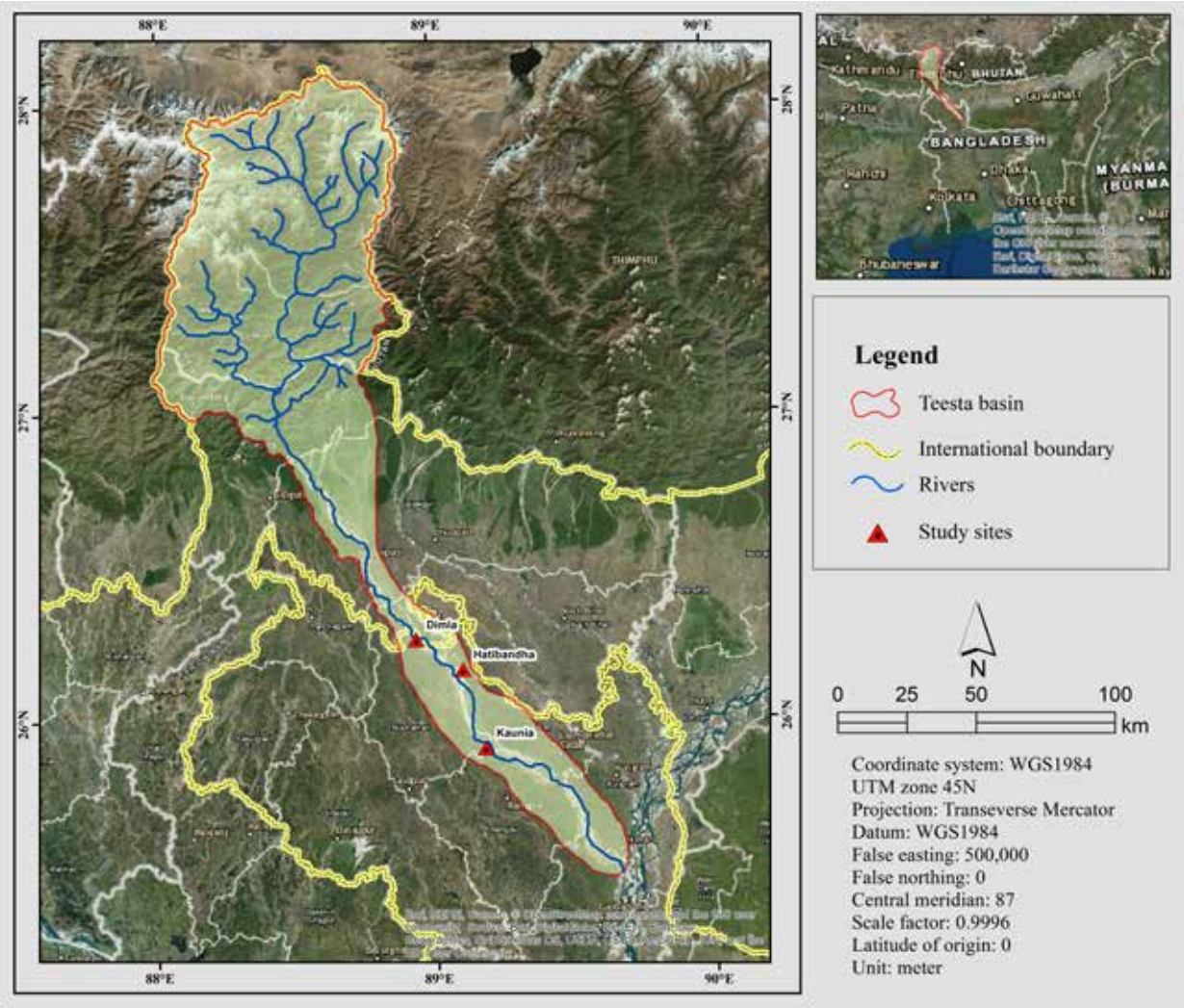

Figure 1: The Teesta Basin and location of the three study sites

Source: Adapted from background images, Google Earth.

The Teesta river is 414 km long, with the longest stretch (199 km) in India, another 94 km along the Indo-Bangladesh border, and the final 121 km in Bangladesh. It flows from southern Jalpaiguri (India) into three channels – Karotaya to the east, Punarbhaba to the west, and the Atrai through the centre. Hence the name Teesta; it derives from Trisrota (three currents/rivers) (Islam 2016). Its total catchment area is 12,159 km^2, distributed between

mountains and hills (8,051 km^2, with 6,930 km^2 in Sikkim and 1,121 km^2 in West Bengal) and plains (4,108 km^2, with 2,104 km^2 in West Bengal and 2,004 km^2 in Bangladesh). The river basin is home to around 30 million people, 2% of whom are in Sikkim, 27% in West Bengal; and 71% in northwest Bangladesh (Waslekar et al. 2013, p 96). Around 78% of the population in the Teesta river basin is rural while 22% is urban (Waslekar & Futehally 2013). The rural areas of the region are underdeveloped on both sides of the border, with the people being highly dependent on the river and its ecosystems for their very survival.

In the Lower Teesta basin in north-western Bangladesh, 69% of the people are directly or indirectly involved in agriculture, while around 11% are self-employed (BBS 2014, p 657). The area has a total population of approximately 14 million, 51% male and 49% female. The average literacy rate is 48% (BBS 2011). Rangpur division has the highest poverty rate (30.1%) and the least economic opportunities in Bangladesh (BBS 2011). It has the country's lowest mean monthly household income, at USD 99 (1 US$ = 84 BDT). Rangpur district itself is heavily populated, and is largely poor and underdeveloped compared to other regions of the country. The people are highly dependent on the water from the Teesta river for their agriculture, fisheries, and other livelihood purposes (Waslekar et al. 2013), but the river often has little water in stretches during the dry season (November to May). During those times, the tiny river course divides villages into the mainland and chars, in which a good number of families affected mainly by riverbank erosion live. During the monsoon, most of the chars are inundated by seasonal, long-term floods. Hence farming is practiced in chars only during the dry period (the rabi cropping season). Groundwater is available 4–6 m deep in the riverbed and the chars, and 7–12 m deep in village areas (Syed et al. 2017).

The average annual rainfall measured at 236 stations of the Bangladesh Water Development Board (BWDB) for the period 1980–2009 was 2,306 mm (MoDMR 2014, p 39). No substantial changes in the trend in annual rainfall were observed for Bangladesh as a whole. However, there are large variations in rainfall at the seasonal and regional scales. Rainfall during the pre-monsoon season shows a significant increasing trend; trends in rainfall for other seasons at the country level remain unchanged.

There are some regional variations in monthly rainfall trends as well. Inter-annual rainfall variability for most months is increasing, as are the number of rainy days in a year. The duration of consecutive non-rainy days also shows an increasing trend. The 7-day, 3-day and 1-day maximum rainfall in a year in the far northwestern part of the country indicate that the rainfall intensity there is increasing. This finding is further supported by the rising trend in the number of days in a year with more than 50 mm and 100 mm of rainfall (MoDMR 2014).

The long-term mean annual rainfall at Rangpur and Dinajpur stations of the Bangladesh Meteorological Department (BMD) are 2,154 mm (62 years mean, 1954–2015) and 1,857 mm (68 years mean, 1948–2015), respectively. An increasing trend in annual rainfall of 4 mm/yr and 5 mm/yr was observed at Rangpur and Dinajpur stations, respectively (Hassan et al. 2018). However, if one were to consider the trend line over a more recent period, 1980–2015, decreasing trends in annual rainfall of 13 mm/yr and 9 mm/yr are observed at Rangpur and Dinajpur, respectively.

The methods used in this study include scrutinizing the literature on current adaptation strategies in different sectors in Bangladesh. It also includes primary information derived through participatory research approaches, namely focus group discussions, community profiling, ethnography, key informant interviews, and case studies with different social, economic, and gender groups during 2016 and 2017. People of different age groups shared their views regarding climate change in the three study villages in the Lower Teesta basin mentioned above, Jharsingheswar, Char Dhubni, and Panjarbhanga.

3. Climate Change Impacts and Vulnerability in Key Sectors

3.1. Agriculture

Agriculture is deeply interconnected with weather and climate, the main drivers of agricultural production and determining factors in the overall variability of food production (Selvaraju et al. 2011). The agricultural sector plays a vital role in the economic development of Bangladesh in terms of its GDP contribution (15% in 2016) and the labour force it employs (47% in 2010) (CIA 2017). Its share of the GDP has sharply declined over the years though, from 26% in 1997, to 20% in 2006, and further to 15% in 2016 (BBS 2005; CIA 2017; MoA 2007), mainly because of industrial growth and the expansion of the services sector. However, its real contribution, in terms of volume of produce, has trebled in recent decades.

The major crops grown in the Lower Teesta basin in Bangladesh are rice, jute, wheat, maize, tobacco, and potato. Fertile alluvial soil and tropical weather with seasonally variable rainfall have given rise to a rich tradition of agriculture throughout the year. An overwhelming proportion of the total water withdrawal in the country – 88% of the 35 km3 in 2008 – is used in agriculture (FAO 2011).[2]

Agriculture is also a most climatically vulnerable sector, as its productivity depends heavily on key factors such as temperature and rainfall. Extreme climate events, such as floods, droughts, riverbank erosion, cold waves, and heat waves are the biggest factors in adversely affecting the yields of crops, vegetation, and fruits (IPCC 2007, 2014). All these kinds of extreme events – and others such as flash floods, cyclones, storm surges, thunderstorms and hailstorms, salinity intrusion, and tornadoes – have devastating impacts on the agricultural sector in different parts of Bangladesh. This section briefly presents some key impacts in the northwestern region of Bangladesh.

Bangladesh is located downstream of three major river basins and experiences floods every year, in the form of both flash floods and seasonal long-stay floods. These tend to inundate an average of 26,000 km^2, or 18%, of the total area of Bangladesh, annually (FFWC 2015, p 100). Economic losses from the four 'extreme' floods in the country have been as follows: USD 0.6 billion in 1974, USD 2.2 billion in each of the two consecutive floods of 1987 and 1988, and USD 3.5 billion in 1998 (Shehabuddin 2000). Flood damage cost the country 4% of its GDP in 1987 and 1988, and 6% in 1998 (BUP 1999), which is quite large. One study by Mirza (2011) found that Aman rice is damaged to the extent of 10%–100% during the monsoon due to 3–15 days' flooding at different cropping stages.

At the other end of the hydrological spectrum is the occurrence of droughts. Agricultural production is governed by moisture supply from rainfall and soil storage, and erratic rainfall and dry soils adversely affect yields. Many cropping seasons experience damage caused by droughts, whose damage is significantly higher than the damage caused by floods (MPO 1987a). As a consequence, irrigation or supplementary irrigation during three cropping seasons became very popular among farmers and helped them achieve increased crop yields (MPO 1987b). Risks of poor yields in the main staple crops are particularly important for smallholders, who tend to consume a large part of their own produce.

These climatic changes are occurring in an already prevalent social context of acute deprivation and risk. These include: insecurity of land tenure, uneven access in terms of quantity and quality of agricultural inputs such as fertilizers, seeds, and pesticides, and in access to markets (Gitz & Meybeck 2012). These existing socioeconomic

[2] Other than agriculture, 10% was used by municipalities and 2% by industry (FAO 2011).

and livelihood challenges get exacerbated by extreme climate events such as floods and droughts repeatedly impacting people's lives, livelihoods, and assets. For example, livestock that are already weakened due to lack of feed during a drought would be more susceptible to infections and be more vulnerable from food scarcity during floods. Also, risks faced by producers not only compromise food security directly, but also indirectly, as they constrain agricultural development by preventing investment and access to credit, resulting in reduced economic activity.

In the Lower Teesta basin in Bangladesh, during and following extreme events, work opportunities decrease and short-term, mid-term, and long-term migration increase. Approximately 80%–85% of the households in Panjarbhanga village in Kaunia upazila are directly or indirectly involved in agriculture. Farmers mainly produce paddy, maize, wheat, onion, garlic, pepper, mustard, tobacco, potato, and jute, among other crops. But there is hardly any agricultural work available during the monsoon, as the land goes under water. This is, therefore, the most difficult time for daily wage labourers as they hardly have any savings to speak of. They normally receive BDT 200–300 (USD 2.5–3.5) per day, which is not sufficient for their expenses. Though women do similar farm-related jobs, they get about half the wages that men do. During this lean period, men migrate for work to places such as Dhaka, Tangail, Savar, and Chittagong. They work there as labourers in garment factories, or as rickshaw pullers, or as daily agricultural labourers. This temporary labour migration creates income and livelihood opportunities for poor people, especially day labourers and fishers.

However, the men having to migrate has made the position of women who have stayed back in the villages even more vulnerable because the women have to run the family and arrange meals for all in the home in absence of male members of the family. Other vulnerable groups include marginal farmers, sharecroppers as well as landless agricultural wage workers, indeed anyone forced into short-term economic migration. When they are forced to migrate due to climate impacts such as floods or riverbank erosion, they do not get access to infrastructural and institutional support in their new locations.

3.2. Fisheries

Primary data and group discussions with people from the three study sites make clear that the hydrology, ecosystems, and fishing are severely affected by higher temperatures, river erosion, excessive sand deposition (sand casting on the paddy fields and the riverbed), braiding of the course of the river, and the establishment of embankments. In recent times, the riverbed has contained little or even no water in some stretches during the dry season (November–May) and conversely, has a healthy water flow only during the monsoon. This has adversely affected livelihoods that are dependent on fishing. In the course of a group discussion, members of a fisher community explained that the lack of water in the Teesta has meant that indigenous fish varieties and their abundance have reduced considerably. According to them, they used to catch more fish in the river barely 7–8 years ago than they are able to nowadays.

The ecosystem and vegetation are also affected by the dryness of the Teesta. Several focus group discussion (FGD) reports show that earlier fishers could catch 3–5 kilogrammes of fish in two hours, whereas nowadays it is difficult to get 1 kg of fish from morning till noon. This has resulted in decreased earnings per household on average. Most of the people who used to make their livelihood from fishing have been compelled to switch to wage labour, rickshaw pulling, or some other menial profession, which they don't like doing. According to the villagers,[3] the Teesta Agreement[4] has to be made effective without further delay; its current inoperability results in insufficient water levels in the Teesta, and is responsible for the shortage of fish catch and greater vulnerability of the fishing community.

[3] These FDGs were conducted in December 2016.

[4] The Teesta Agreement was negotiated in 2011 and is supposed to be signed by the governments of both India and Bangladesh; however, unfortunately it is still not signed. The unsigned draft negotiated agreement is available at http://waterbeyondborders.net/wp-content/uploads/2017/06/Teesta_Draft_37_Meet.pdf. For more information, see Chowdhury (2017).

3.3. Livestock

Rearing livestock constitutes an important part of the coping mechanisms for the people of the Lower Teesta basin in dealing with disasters. Livestock not only fulfil consumption needs, but also help financially in precarious times to meet urgent needs. However, people have difficulty finding fodder and shelter for their cattle during floods or periods of heat stress. During floods, the sheds for livestock get inundated and the cattle get infested with waterborne or other diseases, or suffer from malnutrition. Procuring fodder – in the form of straw or grass – and drinking water for livestock is extremely difficult during floods. Similarly, during droughts, grass does not grow well and the procurement of fodder is a problem. Cold waves make livestock more susceptible to disease as well. The poor are then compelled to sell their livestock at such times – particularly during floods or droughts – which means the loss of an important household asset, and what's more, they are typically forced to do so at throwaway prices.

3.4. Housing and Habitats

The main impact of floods on the housing sector is the washing away of entire houses or the partial damage they suffer. This is mainly due to the fact that many of these structures are made of fragile raw materials, such as mud, leafy thatching material, or corrugated iron sheets. As a result of this destruction, people become homeless and are particularly vulnerable to many social and environmental risks for long periods of time. Notably, the structures damaged or destroyed during floods include not only homes, but also hospitals, clinics, rural roads, educational institutions, and cultural sites significant for people's lives such as mosques and temples (Dewan 2015).

This study finds that villagers in the Teesta basin experience floods and riverbank erosion every year. During and even after the floods, villagers have to live on embankments, in relatives' homes, or in other houses on higher ground. As the locals from Haibatkha village said, a good number of houses, roads, vast lands, and other infrastructure are swallowed by riverbank erosion every year. The vulnerability of women and children increases during floods and riverbank erosion in the 2–3 months during the monsoon or the post-monsoon period. Women and adolescent girls are the worst sufferers, because they cannot use any sanitation facilities and have to go outdoors. Schools and colleges are both unreachable and unusable during floods; if they survive, these structures are used for shelter rather than for educational purposes.

3.5. Energy

This study finds that people in the Lower Teesta basin area are largely deprived of access to electricity from the national grid. Some villages have access to grid electricity, while other areas do not; many households also cannot afford it. The use of electricity for irrigation is common in different parts of the area, mainly in flood-protected areas. However, some areas are not covered by rural electrification programmes. Consequently, irrigation pumps are run using diesel, which is an expensive input. And as most marginal farmers here have to buy water from the owners of the irrigation machines, this makes them even more vulnerable, as the high cost of irrigation is something they can ill afford. And as this area is drought prone, farmers need to depend on irrigation water even more for their crop production than in other areas of the country. The lack of affordable and quality (uninterrupted) energy supply makes poor farmers most vulnerable, as their production gets affected by the inadequate irrigation. Areas that have grid power coverage experience over ten hours of power outage almost every day. This sometimes affects the crop so badly that farmers cannot even get the returns on their investment.

The use of improved stoves, biogas, or solar power is still to be introduced in many areas. As a result, households depend on biomass (tree branches, twigs, dry leaves, straw) and agricultural residues (rice husk, dried chili/eggplant, etc.) for cooking. In this region, women are solely responsible for cooking and managing lamps for the family. Cooking in a traditional manner by burning biomass, cow dung, and agricultural residue produces huge fumes, which make them vulnerable to respiratory diseases and eyesight problems. Additionally, due to extreme

events like floods and riverbank erosion, the affected houses are inundated for months on end, which makes cooking difficult for women.

3.6 Water Resources

Increasing water scarcity, compounded by reduced water availability and its poor quality because of pollution and contamination, combined with increasing demands for water for different uses (domestic, agricultural, industrial, energy-related) is already affecting the livelihoods of hundreds of millions of people worldwide and aggravating water-related problems (IPCC 2014).

The low flows of the Teesta river during the dry season causes enormous harm to its riverbed and riverbanks. The low flow causes surface water scarcity and enhances the use of groundwater. It reduces navigability, and contributes to the decline of indigenous fish species. In the Teesta basin, the unilateral withdrawal of Teesta's water by India upstream limits irrigation water availability during the dry season in the Teesta barrage irrigation command area in Bangladesh. Conversely, during the monsoon season, sudden and huge flows cause flash floods and the deposition of sand on the riverbed and floodplains, damaging agriculture on the latter.

The Teesta, which had once been a heavy-flowing, mighty river even during the dry season, now has become an area with uncountable shoal islands. The inter-relationship between surface water and groundwater resources of the floodplain suggests that the changes in the rate of the Teesta's water flow makes accessing groundwater more difficult (Waslekar et al. 2013). Local people at Dalia say they used to find groundwater at depths of 6–9 metres (m) 15 years ago. This has now fallen to 21–23 m in winter (the dry season). Local people notice that each year, when installing a new tube well, they have to go even lower to access groundwater. On analysing groundwater observation wells of the Bangladesh Water Development Board, no permanent decline in groundwater tables was found in the Lower Teesta basin. However, the maximum depth of the groundwater table has increased in many places in recent years, due to the increased abstraction of water for irrigation, as well as increased base flow to the river. In the dry season, many farmers who are using hand tube wells (HTWs) are unable to get water as the groundwater table goes deeper than the suction limit of the HTWs (≤6 m).

Falling water tables, and thus water shortages during the dry season, and the unavailability of clean and safe drinking water during floods, has made people in the region more vulnerable than in the past. The poor are more vulnerable now as they are financially incapable of installing deep tube wells or a lined water supply system to get water for drinking or irrigation. Women and children of the family are particularly vulnerable as they mostly collect drinking water for the family. Having to collect drinking water from afar and having to cross sandbars barefoot under the scorching sun in summer increases their workload and stress. The over-exploitation of groundwater for irrigation during the dry season, due to the scarcity of surface water, could reduce water levels even further. This would make this area even more drought-prone in the future.

At the other extreme, flash floods deposit a layer of sand on agricultural land (termed sand casting), sometimes over 1m thick. This prevents farmers from using their agricultural land for farming anymore. Removing these sandy layers is too expensive and laborious a task for farmers, and thus they often abandon that land. During floods, most of the tube wells also go under water and become unusable. This makes people more vulnerable as they do not get pure drinking water; therefore, they are forced to drink water from unhygienic sources. In these varied ways, flash floods drive people out of their livelihoods, adversely affect agricultural production and, ironically, cause water scarcity for domestic use.

One serious issue that came up during discussions at Gajoldoba barrage on the Teesta in Jalpaiguri district was the poor quality of drinking water. Almost all the locals expressed concern about its poor quality, which was mainly due to the high concentration of iron content in the groundwater. As a result, villagers reportedly suffer from stomach problems and kidney stones.

4. Climate Change Adaptations in the Lower Teesta Basin

Human life and livelihoods are constantly affected by climate change impacts, and proper climate change adaptation is crucial. It bears mentioning that adaptation requires technological advancement and infrastructural support, hence financing climate change adaptation is important, and is a challenge for Bangladesh. This section looks at adaptation to climate change in six key sectors – agriculture, fisheries, livestock, housing, energy, and water – in the Lower Teesta basin.

4.1. Types of adaptation

Theoretically, there are several types of climate change adaptation (CCA), namely anticipatory, autonomous, planned, private, public, reactive (Levina & Tirpak 2006, p 25), and ecosystem-based adaptation (EBA) (Olivier et al. 2013). Anticipatory adaptation takes place before the impacts of climate change take effect. Autonomous adaptation is not necessarily a response to climate change directly, but is triggered by ecological, economic, and welfare changes in existing human systems, which is the result of private adaptation, initiated and implemented by individuals, households, or private companies. Planned or public adaptation is usually directed by the collective needs of people, but implemented mainly by the government. Reactive adaptation takes place after the impacts of climate change have been observed (Levina & Tirpak 2006, p 25). EBA is an approach that reduces climate change-induced vulnerabilities and increases the resilience of the vulnerable group, by using biodiversity and ecosystem services as part of an overall adaptation strategy (Olivier et al. 2013, p 2).[5]

People at risk in the Lower Teesta basin (in the char lands and in the floodplains) are taking coping and adaptation measures with their limited resources and knowledge. They are adopting measures in agriculture, water, sanitation, health, and rural infrastructure, to cope with the impacts of floods, erosion, drought and heat stress, cold, and fog. Bangladeshi farmers mostly practice two types of adaptation, autonomous and planned. Annual inundation or waterlogging for long periods is a common phenomenon, and so farmers opt for autonomous adaptation (Leichenko et al. 2010). In the context of combating floods, it refers to various adjustments in cropping patterns, changing crop varieties, managing soil and irrigation systems, and changing planting schedules and tillage practices. For example, in agriculture, farmers are changing their cropping patterns and introducing new crops such as maize, potato, and pumpkin; cultivating drought-tolerant crops and those that consume less water; or planting short-duration crops such as potato and tomato. They are also undertaking technological innovations in water management, drought management, and irrigation. In these efforts, they are aided by government departments like the Department of Agriculture Extension (DAE), the Bangladesh Rural Development Board (BRDB), and the Bangladesh Water Development Board (BWDB).

4.2 Government strategies and approaches

The IPCC, in its Fifth Assessment Report (AR5), proposed strengthening institutions at the local, regional, and national levels to support agriculture and gender-oriented policy as adaptation to climate change in the agricultural sector (IPCC 2014). Bangladesh has already implemented many CCA and disaster risk reduction (DRR) projects.

[5] An example of ecosystem-based adaptation could be a collaborative restoration of infrastructure that may reduce the impacts of floods or river erosion.

One of the key programmes was NAPA 2005 (MoEF 2005), which had a number of thematic areas. These included research and knowledge management, agriculture, fisheries and livestock, health, building climate-resilient infrastructure, disaster management, livelihoods, biodiversity, and policy and institutional capacity-building. Another notable achievement is the formulation of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 (MoEF 2009). The main themes of the BCCSAP are: (i) food security, social protection, and health; (ii) comprehensive disaster management; (iii) infrastructure; (iv) research and knowledge management; (v) mitigation and low-carbon development; and (vi) capacity-building and strengthening institutions.

The Government of the People's Republic of Bangladesh defines climate finance as "…the flow of funds toward activities that are aimed to help societies in developing resilience to adapt to climate change impacts" (Bjornestad et al. 2016, p 120). It has pioneered funding mechanisms for implementing the BCCSAP through establishing two funds: the Bangladesh Climate Change Trust Fund (BCCTF), which is completely funded by the Government of Bangladesh; the other is the Bangladesh Climate Change Resilience Fund (BCCRF), whose initial contributors were the governments of Australia, Denmark, the European Union, the United Kingdom, and the United States.

The Government of Bangladesh has prioritized key sectors for CCA. These sectors are water, agriculture, fisheries, livestock, human health, ecosystems and forests, infrastructure, and urban centres (Huq et al. 2004; Rawlani & Sovacool 2011). Since 60,000 people are affected each year by riverbank erosion in Bangladesh (Mutton and Haque 2004), the government emphasized river dredging and reclaiming lands from braided rivers and in the coastal region. It has taken initiatives to protect river-based water resources under an annual development programme scheme. According to a recent report of the Planning Commission, under the annual development programme, several adaptation initiatives were taken in 2015–2016 (GoB 2016, p 10). The Char Development and Settlement Project (CDSP) is one of them, which focuses on CCA in northern Bangladesh. Coastal embankment improvement (CEIP) is another project; this focuses on CCA in southern Bangladesh. The government is strongly supporting an inclusive floods and riverbank erosion risk management investment programme, for which a huge amount of investment has been proposed until 2019, with collaborative donations from the Asian Development Bank (ADB).

Among the other initiatives of the Government of Bangladesh, there is some focus on char areas of northern Bangladesh. According to the accomplishment report of the Sixth Five Year Plan, one of the projects titled 'Making markets works for the Jamuna, Padma and Teesta chars'[6] was initiated, and has been implemented since May 2013, by the Swiss Agency for Development and Cooperation (SDC), in collaboration with Rural Development Academy, Bogra. The focus of the project is the agricultural sector, in which growth potential, market demand, the involvement of women, and DRR were considered through consultations with stakeholders. The project intended to provide the char dwellers with better agricultural opportunities through market access, improved business services, and increasing job opportunities in ten northern districts of Bangladesh.

4.3. Strategies and approaches by NGOs

Both national and international non-government organizations (NGOs) are playing active roles in various economic and social sectors, with the aim of reducing people's vulnerabilities. NGOs mainly focus on community-based

[6] A detail description may be found at
https://www.enterprise-development.org/wp-content/uploads/M4C_Project_Overview.pdf;
https://www.swisscontact.org/nc/en/projects-and-countries/search-projects/project-finder/project/-/show/making-markets-work-for-the-jamuna-padma-and-teesta-chars-m4c.html
https://beamexchange.org/practice/programme-index/108/
http://innovision-bd.com/portfolio-posts/making-markets-work-jamuna-padma-teesta-chars-m4c-project/
http://rda.portal.gov.bd/sites/default/files/files/rda.portal.gov.bd/page/7a081bdc_a314_461c_ab7e_2dc020af3206/160508_M4C_RDCD_PG%20Database_Details_May%202016.pdf

interactions regarding CCA and DRR. A number of NGOs are implementing adaptation projects with support from BCCTF. They include the Palli Karmo-Sahayak Foundation (PKSF), Rangpur–Dinajpur Rural Services (RDRS) in northwestern Bangladesh, and Gana Unnayan Kendra (GUK), which focus on the Rangpur division (RDRS 2017, p 104). RDRS and GUK are implementing adaptations in agriculture, fisheries, water sanitation, and alternative livelihoods in the Lower Teesta basin of Bangladesh. It is imperative to note that a major portion of the work of NGOs consists of post-disaster activities, in providing relief and aid (Younus 2017). A recent contribution of NGOs is implementing the use of participatory studies or participatory rural appraisal (PRA), a method by which local priorities, perspectives, and a bottom-up approach are given prominence (Younus 2017). According to the United Nations International Strategy for Disaster Reduction (UNISDR), the main positive functional attributes of NGOs are their capacity for working through grassroots-level, and higher, operational flexibility since they are mostly free from bureaucratic structures (Islam 2016). A detailed discussion on the contribution by NGOs to DRR is presented later in this study, in the subsections on sector-wise adaptation activities.

4.4 Sectoral adaptations to climate change

4.4.1 Agriculture

4.4.1.1 Development of new crop varieties by BARI and BRRI

Agriculture is one of the sectors most impacted by climate variability and extreme events in Bangladesh. Hence, both public sector organizations and the private sector are promoting or adopting various adaptation measures. Prominent among them are governmental agricultural research organizations such as the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Agricultural Research Institute (BARI), which play a major role in developing varied rice varieties that are resilient to droughts and floods (BRRI 2016, p 33) (Table 1).

Table 1: Climate-resilient crop varieties developed

Name and description of crop varieties	Significance
T Aman genotype: BR9159-8-5-40-13-52 and BR9159-8-5-40-14-57 variety	Possible to produce yields within 142 days
Advanced line BR9390-6-2-2B and BR10260-2-19-2B, developed for shallow-flooded deep water areas	Farmers of shallow-flooded deep water areas will get greater yields (4.0–4.5 t/ha) than local deep water rice
Shallow flood-tolerant rice (research ongoing)	Development of rice varieties suitable for shallow-flooded deep water environments, having water levels up to 1 m
BRRI dhan51 and BRRI dhan52	Suitable varieties for the Rangpur Teesta adjoining region. Applying 30 kg/ha of additional fertilizer within 15 days of submergence during the vegetative stage would result in farmers getting more than 1–1.5 t/ha additional grain by adopting this technology
BRRI dhan62	Can mature within 99 days. Suitable for flood conditions in Rangpur region
BRRI dhan48 and BRRI dhan55	Farmers can grow more rice with less water if they use BRRI dhan48 and BRRI dhan55 as a Braus variety in a 'Potato-Braus-T. Aman' cropping pattern in Rangpur region
BRRI dhan56, BRRI dhan57, and BRRI dhan62, used in Rangpur region	A total of 32,431 kg grain was produced, from which 4,702 kg were retained as seeds of the study area
BRRI dhan56 and BRRI dhan57 (research still ongoing)	Drought tolerant varieties

BRRI dhan66	High-yielding, drought-tolerant rice variety for T-Aman season. BRRI dhan66 can yield 4.5 t/ha of grain in a duration of 113 days
BRRI dhan65	Drought tolerant rice variety. The grain yield potential of BRRI dhan65 is 3.5 t/ha in a duration of 99 days

Source: Adapted from BRRI (2016).

This study has found many adaptation practices that are being undertaken in the Lower Teesta basin in Bangladesh. For instance, in Dimla, in Rangpur district, farmers cultivate short-duration rice varieties such as chikonhori and BRRI-33. Chikonhori is the most popular variety among local farmers, and has been over the last 10 years. Paijam, malshiraj, BR28, and BR11 used to be the most popular varieties, but farmers do not cultivate these nowadays due to their relatively low yields. Paijam and other local varieties are more vulnerable to climatic variability than chikonhori. In an FGD in May 2017, a female farmers' group mentioned that chikonhori and BRRI-33 varieties cultivate within three months during the monsoon. Normally, 2.3–3 tonnes of paddy can be produced per hectare using the chikonhori and BRRI-33 varieties, according to the local people.

4.4.1.2. Enhancing maize cultivation through BARI

Maize, locally called bhutta, and cultivated during the dry (rabi) season, has become a popular cash crop in the Teesta region. Higher profits and its relatively low water requirement are the key reasons for the rapid adoption of maize, as an adaptation measure. Women are also participating in maize farming and contributing to household income, either on their own land or as wage earners. Table 2 presents some of the popular varieties that have been developed by BARI and disseminated by the DAE.

Table 2: Drought-tolerant maize varieties developed by BARI

Variety	Significance
BARI hybrid maize–2, BARI hybrid maize-5	High-yielding, drought-tolerant varieties
BARI maize-5, BARI maize-7	Drought tolerant varieties
BARI hybrid bhutta-12	Drought tolerant, with less irrigation water needed
BARI hybrid bhutta-13	Drought-tolerant, with less irrigation water needed

Sources: Banik et al. (2012); Independent (2016).

4.4.1.3. Pumpkin cultivation in sandy areas

Riverbank erosion is an adverse consequence of climate change. It accumulates sand in char areas during the monsoon. Nowadays, poor farmers are cultivating pumpkins (Figure 2), which requires less irrigation water, on the sandy soil of chars. This practice was started through public and private collaboration. A British-funded NGO, Practical Action Bangladesh, is assisting landless families from char areas through the dissemination of technical knowledge about pumpkin cultivation. Practical Action Bangladesh supports farmers in identifying suitable sandbars, learning digging and composting techniques, and pumpkin seeding. According to their recent estimates, Practical Action has reached out to 750 farmers, of which 150 are female. This process has proved to be profitable for the adopters (Practical Action 2018).

Figure 2: Large pumpkins grown on sandbars

Source: Practical Action (2018).

According to the DAE, during 2015, around 5,000 landless peasants were engaged in pumpkin cultivation on 2,800 hectares (ha) of sandy land over 32 villages in four upazilas of Rangpur district, in the river basins of the Teesta and the Dharla (Roy 2015a).The HI-AWARE research group also found that pumpkin farming has become popular among local communities in char areas of the Teesta, because of its relatively low production costs and the need for less water for cultivation. Earlier, no crops used to be cultivated before Aman cultivation, and hence farmers missed out on potential earnings. Nowadays, many farmers plant pumpkins in the sandy land, become financially solvent as a consequence, and rise out of poverty in the process.

However, there is still much more to do, particularly to establish markets and value chains for the pumpkins produced by the farmers. In many instances, farmers produced huge amounts of pumpkin, and ended up with a pile of pumpkins at home in the absence of any market or buyer. This becomes a huge burden for them during disasters, especially during periods of flooding. Presently, both the public and private sector have given special attention to this adaptation approach, which can be replicated in other char regions of the country.

4.4.1.4. Utilizing flood waters for growing vegetables

People in floodplains have been creating floating gardens in water bodies for long. They establish floating beds with alternate layers of water hyacinth, bamboo, and mud, completing the bed with a top layer of mud (Figure 3). Numerous studies have also shown that the water hyacinth (locally called kochuripana), interspersed with bamboo, soil, and cowdung can be used to construct a raft. Locals grow vegetables in these floating beds. What is relevant for this study is that this could be a solution in a situation of flooding as well. The raft is covered by soil and cowdung and it should remain as floating matter above the flood water. A new raft needs to be built each year, but the old one can be used as fertilizer during the dry season.

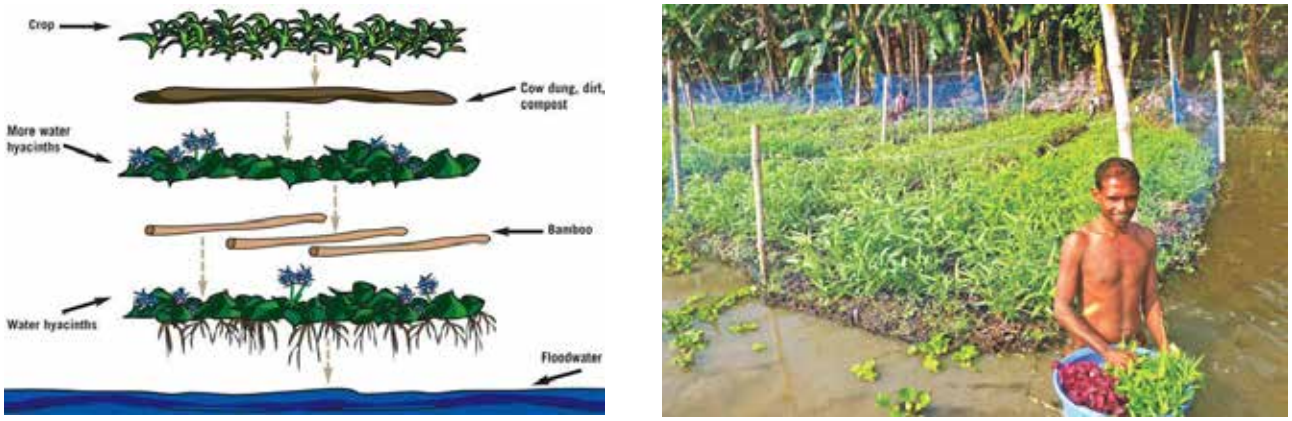

Figure 3: Construction of a floating garden (left); Vegetables grown on some floating gardens in Balapara village, Aditmari upazila, Lalmonirhat (right)

Source: Photograph from Roy (2015b).

4.4.1.5. Community-based maize cultivation through the 'contract' system

Drought has become a widespread and critical impact of climate change. This has made maize cultivation popular (Ali et al. 2008), as the crop needs relatively less water. This research shows that in Dimla, one of the study areas, drought-tolerant maize varieties have become popular and been adopted by most farmers. Mirakel, Elite, and Super-45 are three varieties currently being adopted by maize farmers. These three varieties produce 9–10 tonnes/ha of maize, which can yield a market price of USD 300–350 over a six-month duration. There are some other varieties of maize as well, namely Bumper-91 and Bumper-20.

However, most of the farmers here are very poor, and do not own the land to cultivate maize. Hence they lease in land, paying BDT 3,000–4,000 per bigha[7] for maize cultivation on a six-monthly basis. This land is typically owned by rich landowners, who are part of the local elite, chairmen or members of the union parishad (local government body) of the village. All the cultivation and harvesting work is done by men and women both.

Though maize cultivation could be a boon during times of drought, the vulnerability of poor landless farmers is high because of two reasons: one, on account of having to take a loan at high rates of interest from moneylenders who are the only source of lending for them. Two, the number of farmers needing land has exceeded the amount of land available. The consequent emerging competition for leasing in land is making the landless farmers more vulnerable each day, as their probability of getting a piece of land for cultivation is decreasing over time.

4.4.2. Fisheries

Climate extreme events can lead to water scarcity, which eventually contributes to a decline in fisheries production in Bangladesh (Shaw et al. 2013). Droughts have a severe impact on fisheries, in that they tend to reduce egg production, breeding performance, egg hatching, and larval dispersion, especially in the pond fishing subsector (Halim et al. 2017). The major adaptation practices in the fisheries sector in Bangladesh are the following:

4.4.2.1. Ditch and dyke system

The Government of Bangladesh has, in the context of the occurrence of extreme events, recommended various adaptation options for the sustainable development of aquaculture under the priority project, NAPA. For instance, the 'ditch and dyke' system can be an effective adaptation option for fish cultivation during the dry season in

[7] 1 bigha = 0.33 acres. Conversely, marginally over three bighas equals an acre in this part of Bangladesh.

Bangladesh (Alam et al. 2013). 'Ditch' in this context means a narrow channel dug in the ground, in which fish can be cultivated. It is considered a useful system, particularly during the dry season when fish are unavailable in rivers. Though this system has been implemented by coastal communities in Hatiya, Nokhali, Borguna, and Patuakhali, among others, it can also be effective in drought-prone areas as well (Shaw et al. 2013). On the other hand, 'dyke' is used for seasonal vegetables, improved fruit varieties and forest trees for adaptation purposes as well. The ditch system can be an additional or alternative source of income for fishers. Moreover, it facilitates rainwater harvesting, which can be helpful during the dry season in providing regular water supply to the adopted community (Shaw et al. 2013).

4.4.2.2. Integrated approaches to fisheries and agriculture

Sorjan, or floating agriculture (Amin 2017; Hoque et al. 2016), and fish culture in rice fields (Ahmed & Garnett 2011; Galib 2010; Halwart & Gupta 2004; Hossain 2008), are the most widely-used examples of an integrated approach to fishing and agriculture. This is mainly practised during the monsoon, post-floods, when the flood water stagnates in low-lying lands or wetlands.

The sorjan system, or 'vegetable–fish' cultivation, is an adaptation technique whereby vegetables are cultivated on raised a platform/loft (Figure 4). Under this method, adopters also breed indigenous fish varieties in the water, such as tilapia, koior, and other freshwater fish species, a strategy that is effective at the small scale. It requires low input costs, and contributes an important source of protein for the marginalized. It needs to be replicated on a wider scale in Bangladesh, in the light of new science (Hoque et al. 2016).

Figure 4: Sorjan system
Source: Amin (2017).

The production of fish in rice fields is almost as old as the practice of rice or paddy cultivation itself. The combined culture of rice and fish is also known as paddy-cum-fish culture (FAO n.d). Integrated rice–fish farming can play an important role in increasing food production as the integrated farming system is better than rice monoculture in terms of resource utilization, diversity, productivity, and the quality and quantity of the food produced (Ahmed and Garnett 2011).

4.4.2.3. Pen and cage culture

Pen culture in this context refers to fisheries in a pen-shaped, closed waterbody. Cage culture is fisheries in cages or nets floating in water. Through these, fish can be stopped from escaping into the open floodwater. Most inland freshwater fish species can be cultured in pens and cages.

In 2015–16, the area under pen culture fishing in Bangladesh was over 7,500 ha, with a production of over 13,000 metric tonnes (MT) of different fish species (DoF 2017, p 124). An example of cage culture can be found in Mahananda river in Chapai Nawabganj district (Mukta 2017) (Figure 5a). An example of pen culture carried out by the Department of Fisheries is in Boral river in Bagatipara upazila of Natore district in northern Bangladesh (Islam 2010) (Figure 5b).

Figure 5: Fish cultivation in net cages set in the Mahananda river, Chapai Nawabganj district (left); Fencing for pen culture in the Boral river in Bagatipara, Natore (right)

Sources: Figure 5a (Hassan 2015); Figure 5b (Islam 2010).

4.4.2.4 CBACC in fisheries in the Lower Teesta basin

From the FGDs and several case studies that have discussed this, it is found that various types of nets, boats, big bowls, and cycles are major assets for the fisher community. However, not all of the fishers have such equipment, and income levels vary, depending on the availability of resources. Nonetheless, the fisher community has a good mutual understanding among themselves, and share their fishing equipment, either free or rented, with each other. Members of the fisher community also supplement their income through short-term migration, working as wage earners, or by leasing in agricultural land. As short-term migrant workers, they usually go to urban areas nearby and work as rickshaw pullers or day labourers, to earn some money during the dry season.

4.4.3 Livestock

4.4.3.1 Developing high-yielding fodder crops under government initiatives

Earnings from livestock constituted 1.7% of Bangladesh's GDP during 2015–16, and are growing at 3.2% annually. About 20% of the people are directly involved in this sector in Bangladesh (DLS 2017, p 1). Therefore, livestock plays a major role in the livelihoods of millions, and in Bangladesh's economy.

However, the lack of adequate fodder has been constraining the development of livestock and it becomes more acute during periods of disaster. The Government of Bangladesh has begun to initiate strategies to ensure fodder for livestock. For instance, growing high-yielding perennial fodder crops such as Napier grass, Jumbo grass and Para grass on embankments, roadsides, and other underutilized areas (MoP 2013, p 143). Conducting research on unconventional green grasses in hilly or char lands will also contribute, indirectly in the long run, to overcoming the

shortage of fodder, and hence help in livestock protection. Furthermore, agricultural scientists have been working on developing effective fodder varieties that are suitable for haor (a saucer-shaped wetlands ecosystem) and salinity-prone areas. High-yielding fodder has been used to feed livestock, to generate a greater production of poultry (BLRI 2016, p 9). Apart from research activities, building shelter for livestock facing floods or river erosion is one of the common coping mechanisms by the government for livestock preservation (MoP 2013).

4.4.3.2 Relocating cattle to safe places

This study found several coping and adaptation approaches taken at the community level, especially for the preservation and protection of livestock. These are mainly: (i) relocating cattle on raised plinths; (ii) using riverside sand to raise the plinth; (iii) keeping the livestock on the nearby embankment during floods or when facing river erosion; and (iv) collecting fodder and leaves from distant areas during periods of disaster.

The villagers tend to collect and store straw, banana peels, and steamed rice as food for livestock before floods hit. Many people store sufficient dry rice straw as fodder during floods if their house is high enough. These activities of collecting and storing varied kinds of fodder are largely carried out by women. It has been seen that during periods of disaster, not everyone is capable of protecting their livestock from floods or riverbank erosion. Therefore, they send their livestock to a relative's home as a protective option if the relative lives in a flood-free area. Alternatively, they sell them, albeit at a low price.

4.4.3.3 Adhi system

Adhi is an income-generating system of poor people who are too poor to own their own livestock. Under the Adhi system, they lease in cattle or other livestock from usually better-off owners of livestock. Eventually, both the owner and the borrower get 50% of the profits each. This thus provides some extra income, mainly to women. This system is widely used and easily available, hence is considered a female-friendly source of earning for underprivileged families.

4.4.4 Housing and habitat

There are a number of projects that have been initiated in the housing and habitat sector, by both the government and NGOs. The first governmental initiative, for cyclone-affected people mainly, was the Asrayan project,[8] the first phase of which was implemented during 1997–2001, and the second phase during 2002–2010. The beneficiaries numbered about 140,000 households in both phases. This project was implemented mainly by building cluster houses on government khas land,[9] largely for the landless and homeless. At present, the housing project Asrayan-2 is being implemented by the government, under which it plans to build homes for 250,000 households during the period 2010–2019. Until 2017, more than 158,000 houses had been built.

Regarding adaptation measures specifically, raising the level of the house plinth is one of the most significant adaptation options in flood-prone areas. The convergence between CCA and DRR is evident, and has been implemented under housing adaptation, with the collaboration of the public sector and the private sector.

The government focuses on protecting people living on char lands as these lands are exposed to flooding and riverbank erosion. For instance, the Chars Livelihoods Programme is one of the collaborations led by the Government of Bangladesh[10] and implemented through many NGOs in the northwestern, flood-prone riverine islands. Under this programme, in 2010–2016, 78,000 households have benefitted from a flood-free housing structure by raising

[8] More information on this project may be obtained from http://www.ashrayanpmo.gov.bd/

[9] Khas land refers to government-owned fallow land, to which nobody has property rights

[10] The CLP is also funded by UKAid and Australian Aid; more information may be obtained from http://clp-bangladesh.org/

plinths at least two feet (60 cm) above the normal flood level (CLP 2014a, 2014b). This would also allow access to safe drinking water and sanitation throughout the year (CLP 2014c, p 1). Raising the housing platform was also a measure carried out by many NGOs such as CARE Bangladesh, OXFAM, Concern Worldwide, Solidarity International, and Islamic Relief (Watt and Alam 2013, p 96). A large number of beneficiaries reported that raising the platform of their homes was an effective adaptation option, following which they could survive and protect their assets relatively better.

However, NGO initiatives are mainly concentrated on people who have land for their houses, but there are a large number of people who don't own any land, or who have lost all their land to riverbank erosion. In their case, the Government of Bangladesh distributes khas land[11] to them, but this tends to be inadequate. The distribution of khas land[11] therefore needs to be improved, and made free from political interference.

Figure 6: Commonly-built houses with raised plinths in the Teesta basin floodplain and chars

Photo credit: Abu Syed.

The Char Development and Settlement Project in 2009 especially targeted people living in char areas in Noakhali and Chittagong districts, and was financed by the Government of Netherlands and the International Fund for Agricultural Development (IFAD). There were four phases of this project, from 1994 to 2017. The main concerns of this initiative were: (i) protection from climate change; (ii) providing climate-resilient infrastructure; (iii) land settlement; (iv) livelihoods support; and (v) providing technical assistance (IFAD 2015).

NGOs have made a significant contribution in improving housing, and providing housing materials and related help to disaster-affected people, by helping construct their homes, providing food and basic survival materials such as cloth, soap, medicines, water-purifying tablets, sanitary napkins, and so on. For instance, the Bangladesh Rural Advancement Committee (BRAC) has recently been providing support to 50,000 farmers in northeastern haor areas, in Kishoreganj, Sunamganj, Habiganj, and Netrokona districts. A USD 1.9 million emergency flood relief programme was launched in April 2017 after early flash floods (BRAC 2017).

A number of projects related to housing improvements, aimed at building the resilience of communities, have been implemented by NGOs (SKSFoundation 2016). In June 2015, approximately 2.6 million people in 29 upazilas were affected by flash floods after the tropical storm Komen hit.[12] More than 200,000 households needed emergency assistance in affected areas in Cox's Bazar, in southeastern Bangladesh (UNDP 2016b). UNDP initiated an owner-driven approach to raise the level of houses in Cox's Bazar areas. The selected beneficiaries were trained to raise the earth filling and plinths 60 cm above the highest flood level (UNDP 2016a, p 19).

[11] Land which is deemed to be owned by government and available for allocation according to government priorities.

[12] More information on Komen can be obtained from https://en.wikipedia.org/wiki/Cyclone_Komen.

In 2010, the international NGO Practical Action Bangladesh built cluster houses in Bogra, Gaibandha, and Sirajganj districts as a part of DRR. Cluster housing means establishing a group of houses in a particular location, which are built two feet above the highest-recorded flood level. The advantage of cluster housing is that it can be built at relatively low cost by using locally available materials. Homes for 135 households were built thus, at low cost, and included space for cooking, vegetable gardens, and access to safe drinking water and sanitation. It received a very positive response from the beneficiaries. This holistic approach to housing can be an effective adaptation option for people in the Lower Teesta basin, especially for those affected by riverbank erosion and flooding (Practical Action 2010). However, Matin and Taher (2001) have mentioned that, besides rehabilitative materials such as seeds and fertilizers, cash grants and interest-free loans for rebuilding homes ought to be distributed as a component of essential relief as well.

4.4.5 Water Resources

4.4.5.1 Teesta barrage project, groundwater use, and new technologies

Surface water irrigation, supported by the Teesta barrage project (TBP), is one of the important initiatives taken by the Government of Bangladesh in the northwestern region as part of water management adaptation. However, the insufficient availability of water in the Teesta during the dry season has made the area drought-prone (Islam 2016). Therefore, at present, the main objective of the TBP is to provide supplementary irrigation to grow Aman rice during the monsoon. During the dry (boro) season, groundwater withdrawal for irrigation in this large area has been substantial, which is not sustainable in the long run (Wahid et al. 2007). However, the silver lining is that, each year, the groundwater regains its full level following recharge during the monsoon, and hence there is no permanent groundwater decline. Nonetheless, seasonal decline persists, and hand-held tube wells do not work in many areas where the groundwater table falls below six metres. This occurs even at the beginning of the dry season. The community needs new technologies such as the Tara pump, piped water supply, and other technologies that can withdraw water from below 6 m, in order to ensure safe drinking water for all.

4.4.5.2 Using shallow machines for irrigation

Using a 'shallow machine' or portable diesel pump for irrigation is a notable water adaptation measure. Not every farmer owns a shallow machine due to economic deprivation. However, the households belonging to lower economic strata can rent such a machine to irrigate their lands. Typically, they can do so by paying its owners BDT 60–80/hr.

4.4.5.3 Rainwater harvesting

Rainwater harvesting can be a useful water adaptation technique in the Lower Teesta basin. People in rural areas throughout Bangladesh traditionally harvest rainwater during the monsoon for their household use. It is a common practice particularly in the coastal zone, in saline and arsenic-prone areas, such as in Satkhira, Khulna, and Bagerhat districts, where people store rainwater in large earthen pots, plastic tanks, or concrete tanks for later use during the dry season (Shaw et al. 2013).The Government of Bangladesh could take initiatives to make people further support and use rainwater harvesting technologies as an alternative or supplementary source of safe household or drinking water.

[13] The Tara pump has been developed by the government's Department of Public Health Engineering. Due to the falling groundwater table, a large number of No 6 suction pumps became inoperative, in different parts of Bangladesh, particularly in the dry season when the water table is below 6 m. To deal with this problem, the Tara pump was developed based on the principle of a displacement pump. The pump is submerged in the water and connected by a handle through a piston rod. It can yield water within a 15-m water table. For more information, visit https://www.dphe.gov.bd/index.php?option=com_content&view=article&id=75&Itemid=83.

4.4.6. Energy

The lack of access to electricity and unhealthy cooking practices followed by using traditional stoves are the main problems regarding energy access in the Lower Teesta basin. Women face many critical impacts of climate change, in terms of water and sanitation. The lack of fuelwood increases their suffering while cooking. As a result, women mostly use dried tree branches, cow dung, maize residue, and other agricultural residues as fuel for cooking.

Besides, people store fuelwood in separate sheds at a raised level. Raised or portable earthen/cement stoves are commonly used for cooking. Many families instal solar systems for lighting the house. They are nowadays relatively less expensive in the market, compared to earlier. However, these are not sufficient to meet people's needs; they need access to the national electricity grid for the full use of household goods such as televisions and refrigerators.

4.4.7. Alternative livelihoods as a form of adaptation

Short-term migration is one of the most commonly practised adaptation approaches by people from most sectors. Farmers, agricultural labourers, and fishers more or less all adopt this approach, based on their necessity and availability of resources. During lean periods, little or no work is available for wage earners. They seek agricultural and non-agricultural work outside their own area, migrating, for example, to Dhaka, Rangpur, Bogra, and other big cities, or near them. They go in search of work like doing agricultural labour, paddy transplanting, harvesting, cleaning and weeding of fields, and domestic work. Or they work in steel rolling mills, brick kilns, pulling rickshaws, and other kinds of hard labour. Often, they need to wait 2–3 days to get hired for a job. In the case of agricultural labourers, they do not get paid on a daily basis. They get paid a lumpsum at the end of the cropping season.

Work in the fisheries sector is changing rapidly – and has become a huge issue – in the Lower Teesta basin area due to the decrease in water levels in rivers and ponds. As a result, temporary or short-term migration has become a common coping and adaptation mechanism for fishers.

An 'adaptation matrix' is one in which most adaptations practised overall in different sectors have been listed (Table 3).

Figure 6: Adaptation matrix in the Lower Teesta basin

Sector	Sectoral adaptations
Agriculture	Climate-resilient rice and maize varieties (short duration, demanding less water, flood-tolerant, etc.)
	Community-based maize adaptation through 'contract/lease' system
	Distribution of drought- and flood-tolerant seeds by the Department of Agriculture Extension, Government of Bangladesh
	Growing pumpkins and other cash crops like squash in sandy areas, led by local people
	Enhanced homestead gardening for cash crops or regular vegetables grown on elevated land
	Use of pesticide/fungicide for crops before the disease strikes (like late blight in potato)
Fisheries	Short-term migration
	Community sharing of fishing equipment
	Using various nets through mutual collaboration
	Ditch and dyke system
	Sorjan system
	Small-scale, homestead pen culture
	Use of calcium carbonate and other appropriate chemicals (for example, rotenone, fertilizers, caustic soda, chlorine liquid, antimicrobials, potassium permanganate, dipterex, copper sulphate, formalin, sumithion, malachite green, methylene blue, and malathion) in appropriate doses in ponds to protect fish from disease, or for preparing the ponds
Livestock	High-yielding fodder crops
	Building elevated shelters
	Relocating cattle to safer places during floods, such as the nearby embankment or relatives' homes
	Storing sufficient dry rice straw and other fodder
	Adhi system
Water management	Teesta barrage project and deep tube well project by the government
	Using shallow machines for irrigation
	Raised platform for tube wells, for drinking and sanitation
	Storing rainwater in big bowls or plastic pots
	Installing one deep tube well for every 4–5 families
Housing	Raising the level of the house plinth by one's own or community-based initiatives using sand, soil or clay
	Building disaster-resilient cluster houses
	Construction of trees and bamboo bushes around the home
	Distribution of khas lands among the poor and women of char areas
Energy	Making portable cooking stoves by using soil for use during floods or when coping with river erosion
	Storing maize stover, dry leaves, twigs or branches as fuelwood
	Building a separate shed on a raised place to store fuelwood
	Collecting dry branches and twigs for cooking
	Raising the kitchen plinth, using sand, soil, and clay
	Installing a solar system

4. Conclusions

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

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

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

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