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Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

Sultana, Mst. Rebeka

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Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

PhD Dissertation

By

Mst. Rebeka Sultana

Session: 2015-16

Department of Geography and Environmental Studies

University of Rajshahi, Rajshahi-6205, Bangladesh

September, 2020

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PhD Dissertation

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Session: 2015-16

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September, 2020

Dedicated

To

My Three Little Angels

ভূগোল ও পরিবেশবিদ্যা বিভাগ
রাজশাহী বিশ্ববিদ্যালয়
রাজশাহী-৬২০৫, বাংলাদেশ

DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES
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Declaration

I hereby declare that the thesis entitled "**Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh"** is the result of my own research work, under the supervision of Dr. Md. Zahidul Hassan (Principal Supervisor) and Dr. Shitangsu Kumar Paul (Co-supervisor), Professor, Department of Geography and Environmental Studies, University of Rajshahi, Bangladesh for the degree of Doctor of Philosophy.

I further declare that this thesis or any part of the thesis has not been submitted to any other universities for any degree.

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Certificate

We have the pleasure to certify that the thesis entitled “**Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh”** is a research work carried out by Mst. Rebeka Sultana. The analysis, explanations and Illustrations used in this research have conducted under our direct guidance and supervision. We are hopeful that the research will contribute in the field of Geography and Environmental Studies.

We also certify and recommend that the research is satisfactory for submission to the Department of Geography and Environmental Studies, University of Rajshahi as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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To whom it may concern

This is to certify that Mst. Rebeka Sultana is an Assistant Professor and PhD Fellow (session 2015-2016) of the Department of Geography and Environmental Studies, University of Rajshahi. '**Morphological Changes in Teesta River Basin: Impact and adaptation strategies in the Northern Bangladesh**' is the title of her PhD thesis. Mst. Sultana's thesis has been checked through plagiarism checking software and the similarity index of her thesis is found 4%, which is within considerable limit according to university rules. Therefore, her PhD thesis can be submitted for evaluation.

I wish her all success in life.

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Author

Abstract

Bangladesh is located at the foothills of the mighty Himalayas and the landscape of the country is formed with the morphological changes of the Ganges- Brahmaputra-Meghna river system. The Teesta is one of the main tributary of the Brahmaputra river which originates from the glaciers of Sikkim, India. The Teesta river flows through the north-eastern region of Northern Bangladesh which is considered as the soul of the entire region of Rangpur division. Physiographically, the region is recognized as Teesta Floodplain and designated as an important earthquake zone. Morphological Changes are recurrent incident in the study area. Aggradation and degradation processes of the Teesta river shaped different morphological features in the river basin. Flood, erosion, sediment deposition, channel migration are the main events causing river morphology change. All these fluvial-morphological hazards are responsible for distresses of thousands of people of the Teesta riverine community. The study area lies beneath the plains of the Himalayas and it is the inherent cause for flood and river bank erosion in the Teesta river basin. The unstable river bank and its changing morphology turned the region least developed economy and the area is known as "*Monga* prone area" ("Monga" refers to seasonal unavailable employment opportunity and reduction of purchasing capacity of essential goods which leads people to become starved) as well as the community is termed as "*Mofij*"(The poor people of Teesta river basin). Catastrophic flood, ruinous river bank erosion, recurrent channel shifting situation becomes part and parcel of everyday life of the community adjacent to the Teesta river bank. The Teesta riverine people are helpless, homeless and landless particularly the poor's are the most affected and vulnerable groups who are loosening their lives, property and livelihoods. Morphological change interrupts their normal life and they turn into poor, poorer and poorest.

The present research tries to investigate the morphological changes in Teesta river basin from 1975-2017, impacts of such changes and adaptation strategies of the community. Highly affected seven unions of Teesta river basin have been selected purposively to conduct the study. Both qualitative and quantitative data and information has been collected from primary and secondary sources. The study demonstrates the morphological changes of the river through satellite images. Satellite images have been collected from USGS Earth Explorer. Questionnaire survey has been carried out within 381 households. Besides, Focus Group Discussion, Key Informant Interview and Case Studies have been carried out to collect necessary data and information. Statistical and mapping analysis and interpretation has been conducted through SPSS, Microsoft Excel, ERDAS IMAGIN and Arc GIS software.

The findings of the study indicate that during the study decades the left bank of the Teesta river is more erosion prone and the right bank is more deposition prone. The study result also revealed the bank line shifting and diversified landscape development in the Teesta river basin. The study result shows change in occupation; change in farmer type; homestead displacement; standing crop loss; damage of livestock, poultry and trees; loss of income; loss of land; dropout from secondary school; absence of household members for job search; and insufficient food consumption are the impacts of river morphology change on local community. Besides, the study explored the impacts of flood, river bank erosion and sediment deposition on environment.

The study identified that the Teesta riparian community adopted indigenous adaptation strategies towards coping with river morphology change. Likewise, they accepted institutional supports to reduce river morphology change induced vulnerability. The study explored that eating habit change, starvation, indigenous food making techniques, take shelter in relatively safe and high land, community based flood and erosion protection initiatives, reduction of expenditure, livelihood diversification, income intensification, agricultural intensification, borrowing tendency, acceptance of precaution strategy are the major adaptation strategy of the community adjacent to Teesta river basin.

The community of Teesta river basin directly and the confluence zone population of the river indirectly impacted by the morphological changes. From the field survey it has been focused that the Teesta river is the source of livelihood of the river basin community and it is also the major cause of their poverty. The community of Teesta river basin is susceptible to food security and its agriculture is disturbed by floods in the monsoon, loss of cropped land for erosion, and also newly formed char lands are unable to produce food crops. The people inhabited adjacent to the Teesta river never fulfill their basic needs properly. They are homeless during erosion and flood, take their meals once or twice daily, sometimes they becomes starved to minimize economic cost and proper education, health care facilities are beyond their dreams. Though there are lots of issues regarding river morphology change in the Northern Bangladesh, it took less attention by the policy makers. Mitigation of river induced adversity, disaster impact minimization and enhancing the adaptation capacity of the community needs greater attention from government and non-government sectors to reduce the vulnerability of the victim. River and watershed management, mitigation of Teesta river water dispute, effective water governance, proper monitoring, documentation, research, planning and implementation of laws and regulations, adoption of indigenous coping strategies will change the destiny of the Teesta river bank community and the riverine environment as well. Therefore, the study suggests both institutional and community action will enhance the resilience of the victim to combat multi hazards. Moreover, the study also recommends creation of income generation source in the study area and rehabilitation of the river displaces will make the community more resilient towards river morphology change.

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List of Acronyms

BADC	Bangladesh Agricultural Development Corporation
BANCID	Bangladesh National Committee of the International Commission on Irrigation and Drainage
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCM	Billion Cubic Meter
BDT	Bangladeshi Taka
BIRBO	Bangladesh Integrated River Basin Organization
BMD	Bangladesh Meteorological Department
BRAC	Bangladesh Rural Advancement Committee
BWDB	Bangladesh Water Development Board
BWP	Bangladesh Water Partnership
CEGIS	Centre for Environmental and Geographic Information Services
CFD	Computational fluid dynamics
CLP	Char Livelihood Program
CRP	Char Rehabilitation Program
DEM	Digital Elevation Model
DL	Danger Level
DMB	Disaster Management Bureau
ENSO	El Nino Southern Oscillation ENSO
FAO	Food and Agricultural Organization
FAP	Flood Action Plan
FCC	False Color Composite
FCSPI	Flood Coping Strategies Practice Index
FFW	Food For Work
FFWC	Flood Forecasting and warning Centre
FFWRS	Flood Forecasting and Warning Response System
FGD	Focus Group Discussion
GBM	Ganges-Brahmaputra-Meghna
GCM	General Circulation Model
GIS	Geographic Information System
GOB	Government of Bangladesh
GPS	Global Positioning System
GUK	Gono Unnayan Kendro
GWP	Global water partnership
HDM	Hydrodynamic Model
HYV	High Yielding Variety
HMS	Habitat Modification Score
HQA	Habitat Quality Assessment
IGA	Income generating Activities
IRR	Institute of River Research
IWM	Institute of Water Modeling
IWRM	Integrated Water Resources Management
JRC	Joint Rivers Commission
JSKS	Jhanjira Shomaj Kollan Songhtha
KII	Key Informants Interview

LISS-PAN	Linear Imaging Self-Scanning Sensor-Panchromatic
MRD	Multi-purpose River Basin Development
MYA	Million years Ago
MSL	Mean Sea Level
MSS	Multi Spectral Scanner
NAM	Nedbor Afstromnings Model
NEMAP	National Environment Management Action Plan
NDWI	Normalized Difference Water Index
NGO	Non-Government Organization
NRMCC	National River Morphology Change Cell
NWMP	National Water Management Plan
NWP	National Water Policy
OMS	Open Market Sales
OLI TIRS	Operational Land Imager Thermal Infra-Red Scanner
OXFAM	Oxford Committee for Famine Relief
PH	Potential of Hydrogen
PFI	Planform Pattern Index
POPY	Peoples Oriented Program Implementation
PWD	Power Development Board
PKSF	Palli Karma Sahayak Foundation
RBO	River Basin organization
RDRS	Rangpur Dinajpur Rural Services
RMC	River Morphology Change
RS	Remote Sensing
SHARP	Self Help And Rehabilitation Program
SPARSO	Space research and Remote Sensing Organization
SPSS	Statistical Package for Social Science
SRDI	Soil Resources Development Institute
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
TGD	Three Gorges Dam
TR	Test Relief
TRF	Teesta River Floodplain
TM	Thematic Mapper
TRB	Teesta River Basin
UNDP	United Nations Development Programme
UNO	Upazilla Nirbahi Officer
UP	Union Parishod
UTM	Universal Transverse Mercator
USAID	United States Agency for International Development
USGS	United States Geological Survey
VGD	Vulnerable Group Development
VGF	Vulnerable Group Feeding
WARPO	Water Resources Planning Organization
WFM	Work for Money
WL	Water Level
WWC	World Water Council

Chapter One
Introduction

1.1 General Background

The mighty Himalayan mountainous belt is the home of diversified river channels which flows through the continent of Asia. The south Asian countries are blessed for these rivers. Most of the rivers of the Himalayan region are trans boundary rivers and average annual 1060 BCM (Billion Cubic Meter) of water is conveyed through these rivers but the lean period such flow is 159 BCM (BWP, 2002). The Ganges-Brahmaputra-Meghna (GBM) basin occupies 7% catchment areas in Bangladesh, 63% in India, 19% in China, 8% in Nepal and 3% in Bhutan (Ahmad, 2001). These trans- boundary rivers transport a huge amount of sediments in the downstream. The rivers of Bangladesh carry 2.4 billion tons of sediments in each year that accelerates the river bed and causes flood (Sikder, 2008; Choudhury, 2009; Rahman, 2010). The Ganges-Brahmaputra river system transports more than a billion tons of sediments per year (Milliman and Syvitski, 1992). Regular flood causes fine sediment deposition in the floodplains from suspended sediment loads and irregular flood accumulates more sediment in the banks than the river valley within decades or centuries (Middelkoop, 2006). These sediments form a wide variety of landforms such as floodplain, back swamp, sandbar, natural levee etc. Sediment transportation depends upon water flow, water discharge, rainfall, run off and different anthropogenic factors. Mining activities, dam construction, deforestation are the factors responsible for increasing and decreasing sediment loads. (Meade, 1988). The major rivers of Bangladesh has the tendency of channel migration resulting formation of deep scour hole that is filled with sediment deposition after flood (Mohiuddin *et al*., 2007). Any unevenness in sediment transportation system causes river bank erosion, channel shifting, sand bar formation and other geomorphological changes in the river valley. Flood, sediment deposition, bank erosion and channel shifting are the determinants of river morphology change. Meander cut off and channel migration, sediment supply to the floodplain causes river planform[1] pattern change (Constantine *et al*., 2014). Besides, aggradation and degradation of a river channel causes change in hydraulic geometry which are governed by river energy, channel characteristics and water discharge (Mugade and Sapkale, 2015).Thus river morphology took greater attention from the geomorphologists, geologists, geographers, river engineers, environmentalists and researchers from various fields. Though, Bangladesh is a motherland of rivers and the inhabitants of the country somehow directly and indirectly influenced by the rivers, except the Ganges-Brahmaputra-Meghna, the rest of the rivers has not paid much devotion by the country’s researchers. The Teesta is the fourth largest river of Bangladesh. Every year the community of Teesta river basin becomes victim of river morphology change. Therefore, the present research tries to investigate the morphological changes occurred in the Teesta river, impact of such changes and adaptation strategies of the community.

---

[1] Planform pattern refers to the form, type, and pattern of river.

The Teesta is an erratic river (Sheikh, 1995). It is one of the major rivers of northern Bangladesh. The Teesta valley is an active floodplain of Bengal basin. It is an important physiographic subunit which covers the former administrative districts of greater Rangpur and Dinajpur. The Teesta is an alluvial river with a combination of sinuous and braided stream channel pattern. The Teesta is an unstable and young river with its course shifting characteristics (Islam *et al*., 2004). Teesta took greater attention from the Bangladeshi and Indian government for its trans-boundary status and it is become more popular for geo-political issues. The Teesta river basin of Bangladesh portion had been formed from the Teesta floodplain soil which was carried through the Teesta river, its tributaries and distributaries. The Teesta floodplain area possesses low lying topography through fluvial deposit of the river. The Teesta river slope is 0.47-0.55m/km and it is highly vulnerable to flooding every year (Rahman *et al*., 2011). Hence, this floodplain is affected by flash flood as well as normal flood due to heavy rainfall. Recurrent flood modifies river channel, valley bottom and the ecological characteristics of floodplain (Gupta, 2010). The Teesta river is affected by intensive human intervention due to different development and construction activities in the upper stream.

The upstream of the Teesta river is located in different regions of West Bengal and in Bangladesh the river flows through the districts of Nilphamari, Lalmonirhat, Kurigram, Rangpur and Gaibandha. The entire region is accompanied by the fluvial-morphodynmics of the Teesta river. The behavior of Teesta river depends upon its flow regime and morphological characteristics. Channel morphology and topography is influenced by water discharge and channel characteristics (Chakraborty and Hait, 2014). The historical channel shifting process expresses the Teesta as a dynamic river. Channel shifting, bar development, meander cut offs are regular morphological events occurred in the river basin due to its alluvial characteristics. Shift in channel position occurs in the alluvial rivers for its susceptibility of erosion and sediment deposition (Schumm, 1985). The present research deals with the erosional and depositional status along with bank line shifting through satellite images of different decades. Thus, the present study tries to investigate the morphological changes occurred in the Teesta river basin and its impact in the Northern Bangladesh. The study will also illustrate the causes, consequences and coping strategies of the inhabitants of the study area for river morphology change. The research will explore how altering river morphology made the local people to adopt different adaptive measures to combat with the changing morphological characteristics.

1.2 Statement of Problem

Bangladesh is a flood prone country for its geographical location and hydro-meteorological condition. There exists strong relationship between flooding and geomorphological features of an area**.** Flood is governed by geomorphological parameters as well as meteorological conditions (Yeasmin, 2009; Haq, 1992). Bangladesh occupies eight million hectare of flood vulnerable land which covers 35% of total land area of Bangladesh (Hassan *et al*., 2007). The catchment area of Teesta river is about 2,750 sq. km in Bangladesh (Sheikh, 1995) which is affected by various fluvo-morphological hazards. Flash flood is very common in the river basin area, which are natural as well as manmade phenomena. As a result, every year the communities of the Teesta river basin area are affected by severe flooding. In rainy season all the sluice gates of the Gazoldoba barrage of West Bengal of India opens up which creates flash floods in Bangladesh (Islam, 2016). Sometimes flash flood occurs in the months of September to November (*Aswin-Kartik*[2]) and the farmers become enable to harvest their ripen paddy. These unexpected flash flood causes river morphology alteration. Deforestation in the catchment areas of Bangladesh aggravates flooding situations (Choudhury, 2009). The danger level of Teesta river at Dalia point is 50m above MSL (Mean Sea Level), minimum water discharge is 4,000 cusec and maximum water discharge is 35,000 cusec[3](Rashid,1977). In the monsoon the water level of Teesta reaches the danger level which causes damage to property and livelihood of the river basin communities. Agricultural land and homestead inundates crops, domestic fowls and utensils swept away, health and food insecurity occurs due to floods in Teesta every year.

Erosion is a frequent phenomenon as well as endemic hazard in Bangladesh and about 5% floodplain of the country is affected by river bank erosion (Rahman, 2010). All the major rivers of Bangladesh is erosion prone and about 30-40% of people lives in the river banks (Islam *et al*., 2014). Every year millions of families adjacent to river bank become homeless and helpless for ruinous bank erosion in Bangladesh. The shifting behavior of river not only impacts the rural population but also influences on the urban centers and about 5% floodplain of Bangladesh is affected by river bank erosion (Islam, 2003). The Teesta river bank is highly susceptible to erosion owing to scouring in the bank. Every year extreme erosion occurs in both the banks of Teesta river. As a result the victim land owners of the study area shifts house and change their livelihood options. River bank erosion is a dominant problem which creates dislocation of thousands of local people (Islam, 2006). The effect of river bank erosion and flood causes one million population displacements perennially (Elahi and Rogge, 1990). Moreover, the sediments produced from bank erosion of Teesta are buried in the river bed and reduces the valley depth which is the inherent cause of further flooding. River bank erosion and sediment load are the key factors for decreasing trend of depth of river bed and water depths (Promny and Vollmer, 2011).

The characteristic feature of Bangladeshi rivers is gradual shifting of channels. The annual channel shifting varies between 60m to 1600m in the rivers of Bangladesh (Rahman, 2010). The Teesta river always shifts bank line and thus it changes its morphology. River channel change is mostly influenced by water flow force towards the bank and the bank materials ability to erode or stay in stable situation (Gupta, 2012). Bank material is an important aspect of channel pattern change (Eaton *et al*., 2004). Another cause of channel change in alluvial river is sediment deposition which impacts on river bed uplifting. Sediment deposition in river bed causes river height rise and it is an important reason for river course change (Chakraborty and Datta, 2013). In wet season Teesta is in bank full stage and the basin community is affected by flood and river channel shifting. Imbalanced water flow in dry and wet season causes channel shifting in the Teesta river. Channel shifting process depends upon the hydrology, lithology, climatology and of course human interventions. Flow characteristics of river, tectonic activity, slope aspects and lithological condition are the causes of river channel shifting (Ramkumar, 2009). A number of projects are initiated in the upstream of Teesta in India which accelerates channel shifting. Construction of embankment elevates river bed (Rogers *et al*., 1989). From field survey it has been noticed that massive floods significantly causes river course shifting but non-severe floods also effects on channel migration. Change in river morphology effects on the landscape, hydrology, ecology surrounding the entire basin area and also the riverine communities.

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[2] *Aswin-Kartik* are the two Bengali months. *Aswin* is a month of Autumn season and *Kartik* is a month of Late-Autumn season.

[3] A unit of water flow which means one cubic foot per second.

The downstream of Teesta river in Bangladesh faces another problem of sedimentation. Siltation, erosion and char formation on the Teesta river bed are well known (Islam, 2006). Teesta brings huge sediments from the upstream and releases in the Brahmaputra. The Ganges, Brahmaputra, Meghna rivers has unstable channels with braided and meandering pattern and 10-20 kilometer width along with high rate of sediment loads (1-2.4 billion ton) annually (Brammer, 1990). Land slide and soil erosion causes sediment deposition. Large amount of water discharge causes land slide, soil erosion in the upstream of Teesta causes sedimentation and flash flood in the downstream river channel morphology (Chakraborty and Dutta, 2013). The river bed is covered by alluvial floodplain soil. Moreover the barrages and embankments in the Teesta river is one of the major cause for increasing siltation and char formation. Human activities such as river training have strong influence on floodplain sedimentation (Middelkoop, 2006). Moreover, flood and size of sediment particle influence on sediment accumulation in river bank and bed. Sediment deposition rate in the floodplain depends upon over bank spilling, grain size, settling velocity of particles and local sediment concentration (Middelkoop, 2006). The river has stable *char*[4], shoal[5], and unstable *char* in the river bed. The formation of mid channel bar and point bar is very common in Teesta river valley. The river basin community lives in the unstable bar, mid channel bar and point bar and continuously affected by flood, river bank erosion and channel shifting. All morphological activities of the Teesta river impacts both its physical as well as human environment which causes livelihood and homestead damage. Formerly (before dam and barrage construction) Teesta was a youthful river. But now it is a dead river with numerous *char* in the river valley for its huge sediment load and water discharge anomalies.

Human interference directly influences on morphology of a river system. Deforestation in the upstream catchment and cultivation in the floodplains increases fluvial action (Prokop and Sarker, 2012). River bank stabilization, hydraulic structure construction, water diversion channel has significant impact on water discharge, sediment transportation, channel geometry and riverine ecosystems (Wohl, 2006; Wiejaczka *et al*., 2014). The water flow of Teesta river decreases in dry season in Bangladesh. Recently water withdrawal of Teesta in India for irrigation and industrial sector during the summer delimits water availability in Bangladesh (Rahman, 2013). The Teesta river water flow decreased 88% in Bangladesh due to Gajoldoba barrage operation in India (Afroz and Rahman, 2013). Both the hydrology and morphology of Teesta river are changed due to human interference. Dams and barrages on Teesta hamper natural flow of the river and sediment carrying capacity (Bari and Haque, 2016). Sedimentation causes river bed uplifting, channel shifting and braiding pattern change. The capability of sediment discharge of a river on flood plain decreases for embankment construction which tends to the river to deposit its load to bed and rise in river beds (Mallick, 2016). The dams and barrages in the Teesta river impact on water release. As a result Teesta is diverting its channel in the lower catchment. The older and newer *char* formed in the Teesta river shaped the river as braided pattern. This braided pattern and morphological changes occur through moribund river channels. Prominent manmade infrastructures on the Teesta river are: Teesta barrage at Lalmonirhat district in Bangladesh, Teesta Barrage Project at Gajoldoba in Jalpaiguri district and Rangit Hydroelectric Project in India. Moreover, several dam, water diversion and hydroelectric projects are ongoing involved in the Teesta river. Downstream water inadequacy, river bed siltation, char land, floods are the impact of dams and barrages in the Teesta river (Khan and Islam, 2015). The anthropogenic impact on Teesta river morphology intensifies the vulnerability of the environment, culture and economy of the agrarian society of the study area.

---

[4] *Char* refers to river islands formed with sedimentation process.

[5] The submerged ridges or bars are typically knows as *Shoal*.

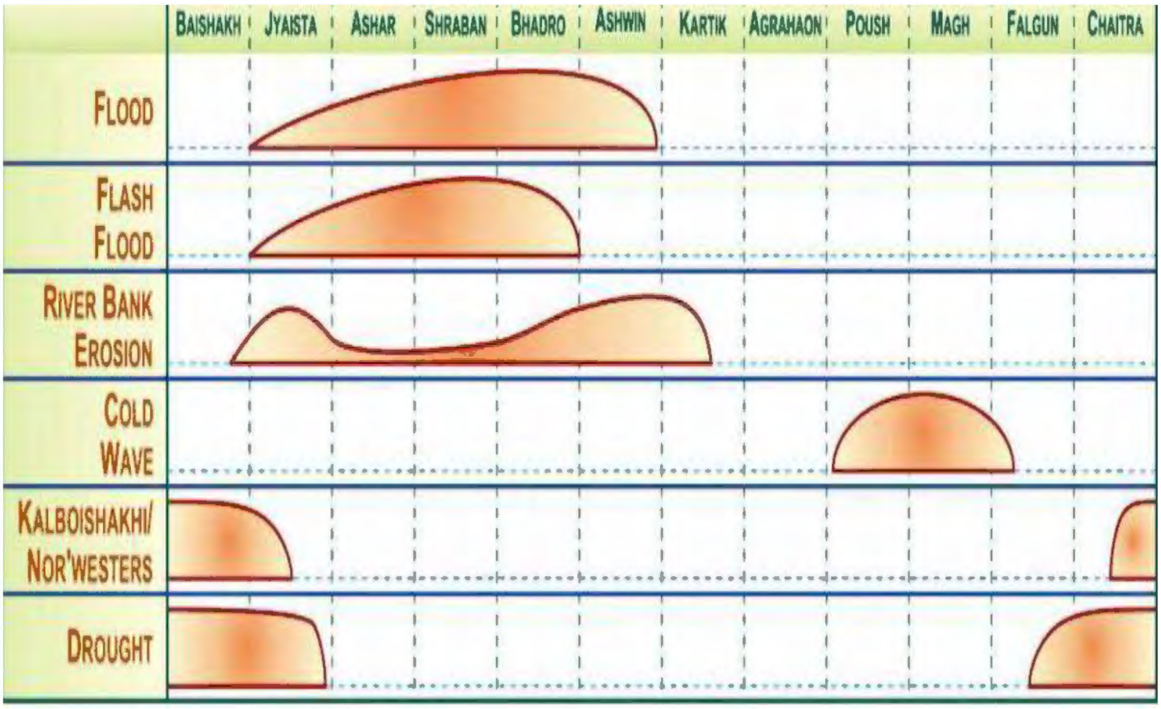
The River morphology changes in the summer which effects on crop production. In the dry season the portrait of the study area is totally different. In the Bengali months of *Falgun-Chaitra*[6](mid-February to mid-April), *Baishakh-Jaistha*[7] (mid-April to mid-June) the entire basin area turned into a drought prone zone. The north western Bangladesh as well as the Teesta River Floodplain (TRF) are mostly drought prone (Murshid, 1987). In that period the river mostly dries up and water flows only in few channels and farmers suffer for irrigation water. Crop burning is very common in the dry season which effects on production and livelihood of farmer and fisherman. Transportation accessibility decreases in the season and from the remote char a person comes in main land walking after 3 to 4 km distance. Most of the days, the riparian community severely affects by sand blow in their homestead from the river bed. In both the seasons (dry and wet) the Teesta river morphology impacts on the life and livelihoods of the riparian communities. Moreover active landscape formation and altering ecology are also the after effects of Teesta river morphology change.

---

[6] *Falgun-Chaitra* are the Bengali months consist of the Spring season.

[7] *Baishakh-Jaistha* refers to the two Bengali months of hot Summer season.

The Teesta basin is a multi-hazard zone for its fluvo-geomorphological and meteorological conditions. The study area is occupied by different hazards associated with the Teesta river throughout the year. The seasonal hazard calendar of the study area has been depicted in Figure 1.1. The multi-hazards of Teesta river basin cause immense damage in the agricultural sector. Most of the people of the study area involved with agricultural activities. Every year flood, bank erosion, sand deposition in agricultural field and river channel shifting cause substantial damage in agricultural production such as paddy, jute, maize, tobacco, nut, sugarcane, potato and different types of vegetables. The Teesta river morphology change directly and indirectly effects on the socio-economic activities of the community adjacent to the Teesta floodplain. Factors affecting the marginalization of rural peasants are bank erosion, channel migration and flood (Elahi and Rogge, 1990). River morphology change impacts on occupation, homestead, agricultural land, household asset, infrastructure and environment of the study area. River course shifting causes multiple displacements of riparian communities and damages personal as well as social infrastructures (Hutton and Haque, 2004).Therefore, household displacement, migration, occupation change, occupation conversion are important issues regarding river morphology alteration. To cope with changing river morphology the river victims adopt different adaptive measures for their survival.



Source: Shafie and Rahman, 2009

Figure 1.1 Multi-hazard calendar of Teesta river basin

1.3 Research Questions

The followings are the research questions:

1. What is the condition of erosion and deposition from the year 1975-2017 in Teesta river basin?
2. Why and How the river morphology changes?
3. What types of erosional and depositional landforms are produced by Teesta river?
4. What is the perception of local people regarding river morphology change?
5. What is the impact of river morphology change on human being and natural environment?
6. What are the adaptation strategies of the riparian communities to combat the adversities of changing river morphology?

1.4 Objectives

The present research tries to investigate the morphological changes of the lower reach of the Teesta river and the impacts of these changes. The adaptation strategies of the riparian community will also be depicted in the research. The specific objectives of the research are:

1. To detect the morphological changes of Teesta river from 1975-2017 through river bank erosion and deposition
2. To identify the geomorphological features produced by the river reach.
3. To evaluate respondent's perception about river morphology change.
4. To investigate the impacts of morphological changes on the local people as well as on the environment of the study area.
5. To depict the adaptation strategies of Teesta riparian communities.

1.5 Conceptual Framework

Bangladesh is severely affected by geomorphological hazards such as flood, erosion, sedimentation and river channel shifting. Climate change issues effects on glaciers which causes flash flood, abnormal flood and high velocity of water discharge. All these events effects on increasing sedimentation, lateral river bank shifting, bank failure and river avulsion mechanisms. River morphology change occurs in two ways: either it changes through natural causes or it also changes through human intervention. When both the two causes effects on a river system, then the river abruptly changes its morphology. River morphology change causes alteration in the planform dynamics of river and impacts on the surrounding environment as well as river bank dwellers socio-economic activities. The severity of Teesta river morphology change effects directly to the basin communities but its indirect impact influences the whole country. Therefore, people try to cope with the adverse condition through changing eating habit, occupation, homestead and all sorts of their everyday lifestyle. The conceptual framework of the present research is

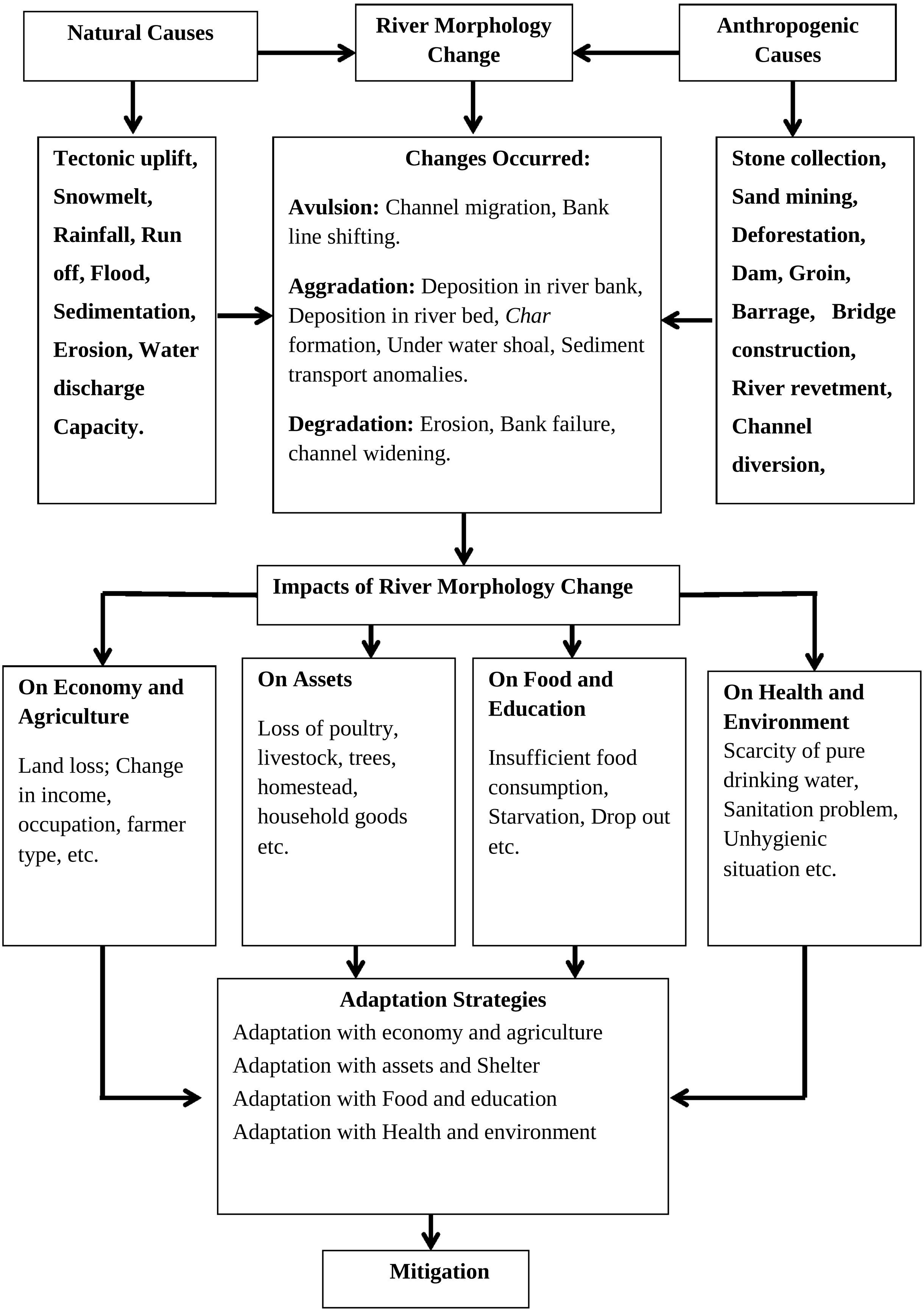

Natural Causes
River Morphology Change
Anthropogenic Causes
Tectonic uplift, Snowmelt, Rainfall, Run off, Flood, Sedimentation, Erosion, Water discharge Capacity.
Changes Occurred:
Avulsion: Channel migration, Bank line shifting.
Aggradation: Deposition in river bank, Deposition in river bed, Char formation, Under water shoal, Sediment transport anomalies.
Degradation: Erosion, Bank failure, channel widening.
Stone collection, Sand mining, Deforestation, Dam, Groin, Barrage, Bridge construction, River revetment, Channel diversion,
Impacts of River Morphology Change
On Economy and Agriculture
Land loss; Change in income, occupation, farmer type, etc.
On Assets
Loss of poultry, livestock, trees, homestead, household goods etc.
On Food and Education
Insufficient food consumption, Starvation, Drop out etc.
On Health and Environment
Scarcity of pure drinking water, Sanitation problem, Unhygienic situation etc.
Adaptation Strategies
Adaptation with economy and agriculture
Adaptation with assets and Shelter
Adaptation with Food and education
Adaptation with Health and environment
Mitigation

Figure 1.2 Conceptual Framework of the study

1.6 Justification of the Study

Morphological change is a recurrent event for the riparian community of Teesta river basin in the northern Bangladesh. Agricultural productivity of the entire region mostly depends upon the Teesta river water and floodplain soil. On the other hand, every year river morphology alteration causes huge damage of crop production. In the dry season, decrease in water flow from the upstream, controls the river morphology which determines the fate of the basin community. Again in monsoon, flood, bank erosion, river course shifting and sedimentation also effects on their life and property. Bank line shifting for erosion, creates casualties of thousands of people and their livelihood. As a result, the basin communities remain homeless, helpless and they became poor, poorer and at last poorest. These disastrous events also impose obstacle in natural ecosystem and the river morphology changes its landforms in different ways. River morphology alteration not only hampers on local communities everyday life and natural environment, but also destroys transport network, religious infrastructures (*Masjid*[8], *Mandir*[9]), school, collage, *hat-bazaar*[10] etc. within a few seconds. Therefore, it is highly significant to study the morphological change and its related issues influencing in the Teesta river basin area and the riverine community. The present study has explored the Teesta river bank erosion, sediment deposition and channel migration through satellite image processing since last four decades. The impact of morphological change occurring in the area adjacent community and their adaptation strategies has been also portrayed by field survey.

1.7 Scope of the Study

The study reveals a door to the researchers who tries to investigate the morphological changes of a riparian environment. It emphasizes on the morphological change, its causes, consequences and adaptations of the river basin communities. The scope of the study is as follows:

- The findings of the research will provide a large scale historical and present river born changes in a riparian environment.
- Morphological changes of Teesta river basin, miseries and coping strategies of the river basin community have been bought to the light in the study. The future researchers of physical geography and human geography will get insights from the present study.
- The study will help to endorse awareness among the community adjacent to the river basin about the morphological changes.
- It will deliver a guideline to the policy makers to take suitable footstep for the river basin management.

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[8] *Masjid* is the formal place of prayer of Muslim community to pray five times every day.

[9] *Mandir* refers to the place of worship of the Hindu religious community.

[10] *Hat* is rural market opens once or twice in a week and *bazaar* means the daily market.

1.8 Limitation of the Study

The limitations of the present study are:

- The characteristics of the Teesta river becomes barrier to investigate the morphology of the basin. The foremost limitation of the present study is, constrain of data collection regarding rainfall, discharge and sediment of the catchment area as the Teesta is a trans-boundary river.
- The regional office of BWDB (Bangladesh water development Board) in Rangpur has not able to provide data of hydrology and morphology of Teesta River. So, the researcher has to collect data from the head office of BWDB. But there is also shortage of data for a comprehensive research on river morphology change. Sedimentological data deficiency is a limitation of the study. Dearth of morphologist, sedimentologist and hydrologist in BWDB becomes a constraint for researchers to collect data.
- The Landsat images have not been illustrated equal interval in the present study due to cloud cover and year wise unavailable image.
- To overcome the problem of bank line delineation, regular bank line has been considered.
- The study considered morphological changes of Teesta river during 42 years (1975-2017) through satellite image analysis. Besides, the present study collected the recent morphological change impact and adaptation data from the respondents. Because the respondents have forgotten the past economic and other losses owing to river morphology change. Therefore, there is variation in data of long term satellite image and short term impact and adaptation in the study unions.
- Most of the cases data of relief facilities are not recorded in Upazila and Zila commissioner’s office. So the researcher has to work hard to get the data and information.
- Regional office of NGO’s (Non-Government Organization) could not provide data and information about their initiatives for adaptation of victim in the Teesta river basin.
- The study unions are remote so there is no easy access of transportation. In the monsoon heavy rainfall and flood create disturbances to move one study union to another and conduct questionnaire survey standing in inundation. In the dry season, accessibility in the remote chars is hampered due to zigzag channel pattern.
- Few respondents create noise and quarreling to give his/her data first, Some respondents gave false economic loss data and some household head tried to give his son’s family information (who already migrated with his family in town) because they thought they will get relief facilities quickly, though they were informed that it is only a research related survey. In few cases village leaders tried to show fear to the respondents not to give actual data of relief facilities. The above mentioned situations have hampered data collection and consume much time.

1.9 Outline of the Thesis

The present research work has been carried out through a systematic method. To find out the morphological changes, its impact and adaptation strategies the study comprises of nine chapters. The outline of the thesis is as follows:

Chapter One

The first chapter provides the general background, relevant issues and problems, objectives, justification and scope of the study. The introductory chapter also contains the conceptual framework, and limitations of the study.

Chapter Two

The second chapter describes the operational definitions and theoretical background of river and its morphology. Similarly a comprehensive literature review containing flood, water discharge, erosion, sedimentation, channel shifting etc. occupies the second chapter.

Chapter Three

The third chapter discusses the Research Methodology including study area selection, data sources, sampling design, data collection techniques, data processing, analysis and interpretation techniques

Chapter Four

The fourth chapter deals with the Physiography and the hydro-morphological characteristics of the study area. Besides, this chapter contains the geographical location, geological settings, soil characteristics, Teesta river and its fluvial geomorphology, barrages and projects on Teesta.

Chapter Five

The fifth chapter includes the geomorphological features produced by Teesta river and morphological changes occurred in the river basin. The chapter delivers Morphological changes in Teesta river basin from Satellite Images which includes Teesta river morphology change from historical evidences, erosion and deposition of Teesta, union wise erosion and deposition, bank line shifting and channel migration of last 42 years.

Chapter Six

The sixth chapter conveys respondents profile and their perception about morphological change. The chapter includes Respondents age, sex, education, occupation and asset information. The chapter also includes the respondent’s perception about morphological change.

Chapter Seven

Chapter seven includes the impact of morphological changes of Teesta river on the respondents. Impact on economy, agriculture, food, education, health and environment are described based on field survey results in this chapter.

Chapter Eight

Adaptation strategies of the Teesta riparian community regarding river morphology change has been illustrated in chapter eight. Similarly the chapter includes institutional initiatives to mitigate and prevent the morphological hazard.

Chapter Nine

Chapter nine is the concluding section of the thesis. The chapter contains the findings, recommendations and conclusion of the study. Findings regarding flood, river bank erosion, sedimentation and channel migration have been discussed elaborately in this chapter. Likewise recommendations were formulated for morphological change reduction, impact minimization and adaptation. The study concluded with the remarks of integrated planning, floodplain zoning, timely forecasting, monitoring and improved warning system.

Chapter Two
Theoretical Background and Literature Review

2.1 Operational Definitions

Geomorphology

The term Geomorphology was first introduced by Keith in 1894 and the science of landforms are known as Geomorphology (Thornbury, 1954). Geomorphology is a complex science which is defined as the study of the earth surface and the processes that shapes the landscapes. The focal themes of Geomorphology are the landforms, the processes involved in producing landforms and the development of landscapes over time. (Gudie and Viles, 2010).

River Morphology

The ‘study of form’, in the context of geomorphology- a principal aim of which is to study the shape, size and origin of the landforms (Small and Witherick, 1995). River morphology means channel forms and patterns which is determined by slope aspects, discharge capacity, transported materials, width, depth and velocity of a river (Matsuda, 2004). Fluvial process controls the river morphology.

Aggradation/ Accretion/ Sedimentation

Aggradation is a holistic term used as sedimentation process directed by river and wave action. Aggradation occurs due to scouring and valley fill deposits in the river bed and bank. Accumulation of sediments through wind and hydraulic activity causes accretion. Accreted sediments may be fine grained to coarse grained. When sediment supply of a river is greater than its transportation capacity then the river starts accretion of its sediments in river banks and beds. Weathered rocks movement through river flow causes accretion and originates various fluvial landform features. Share stress of running water is an influential factor for sedimentation (Sikder, 2008). Clay, silt and sand are the fine materials work as suspended sediment in river water. Suspended sediment load generates turbidity in stream water (Matsuda, 2004). The sediments such as gravel, pebble etc. are deposited in river bed through the process called traction.

Degradation/Erosion

Degradation is a process of denudation to address erosion. Erosion is a geologic process which removes rock debris through wind, glacier, gravity and hydraulic action. Erosion of a river system occurs in both the river bottom and the river valley. Therefore, both down cutting and lateral cutting/sideways cutting take place in a river basin. In old stages river bank erodes mostly. Erosion depends upon the velocity of stream and high velocity determines high erosive activities of stream banks (Pipkin *et al.*, 2005)

Alluvium/Alluvial Soil

Alluvium has been deposited through Alluvial river in the floodplains. Land receives alluvium through each successive flood and an alluvial soil stratum develops. Alluvial soil is called *poli*[11] in Bangladesh. Alluvium is loose material buried by river and contains sand, silt, clay along with other particles such as boulders and pebbles. The type of alluvium deposition depends upon the characteristics and location of a river system.

River

The dictionary definition of river is large stream of water whereas streams are running water flow whether large or small. In geomorphology, the term river denotes channels which contain water flow in the wet season as well as dried channel or river bed. (Moriswa, 1968). A river is a long water course and flows through gravity with its valley. River valley develops from sheet erosion, rill erosion and gully erosion. River originates from glaciers, lakes and also from another river.

The river channel which holds water during and immediately after the rainy season but becomes dry rest of the months of the year is called Ephemeral. The river receiving water from ground water table, bears stream flow few months are termed as intermittent/ periodical/episodical/seasonal. The intermittent river flows part of a year. Streams carrying water all around the year is designated as Perennial river (permanent flow).

Alluvial River

Alluvial rivers are those rivers which has activity of floodplain and delta formation process with its transported materials. Course shifting is the characteristic feature of alluvial river (Rahman *et al.*, 2011). The alluvial river deposits different minerals and forms various fluvial geomorphological features. The Ganges river alluvium gives alkaline reaction and it is calcareous but the Brahmaputra has acidic reaction with noncalcareous alluvium (Islam, 2003). The alluvial river deposit produces fertile soil for crop production. The source region of a river contains the coarser sediments as gravel, cobble, pebble, boulder etc. On the other hand, the downstream river valley contains finer alluvium like silt, sand and clay. The river of Bangladesh contains high concentration of mica minerals. The Teesta is an alluvial river with yellowish, brownish and grayish coarse to very coarse grained sand, silt, clay alluvium deposits.

Channel Pattern

Channel patterns are the types of channel. River channels are three types: meandering, braided and straight. Morphological changes of a river causes three types of channel patterns broadly which are classified into straight, meandering and braided (Leopold and Wolman, 1957). River channels may also classified by small to large, width-depth ratio, low to high flow strength, suspended to bed load materials (Schumm, 1985). The floodplain channels are sandy, the channels in delta are muddy but the alluvial fan and mountainous channels are composed of gravels. River patterns encompass drainage network (Schumm, 1985). The channel pattern and characteristics of mountain and alluvial plain channels adopted from Matsuda (2004) has been shown in (Table 2.1)

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[11] *poli* is a local term used for that kinds of sediments which has good moisture holding capacity, well organized organic matter, clayey texture and balanced PH (Potential of Hydrogen) for agricultural production.

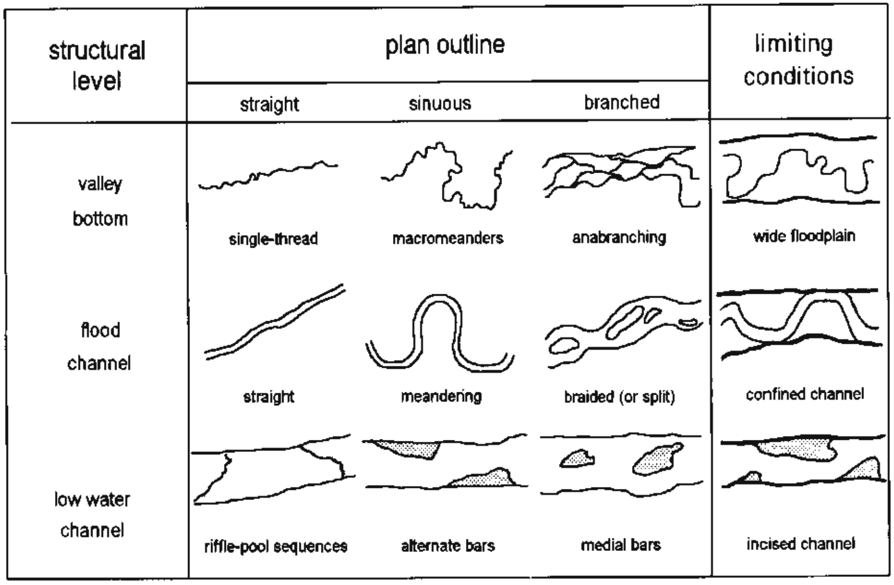
Table 2.1 Channel pattern and characteristics

Channel classification	**Channels of mountainous area**	**Channels of alluvial plains**		
		In alluvial fan	In flood plain	In delta
Materials of river bed	Rocky, gravely	Gravelly	Sandy	Muddy
Pattern of channel	Strait, braided	Braided	Meandering, strait	Bifurcated, strait, meandering
Conveyance by running water	Debris flow	Traction	Traction, suspension	Suspension
Channel depth	Different	Shallow	Shallow to deep	Deep
Slope of river bed	Steeper than 1/100	1/50 to 1/500	1/100 to 1/2000	Gentler than 1/1000

Source: Adopted from Matsuda, 2004

Alvarez (2005) analyzed the factors influencing channel pattern are slope, discharge, sediment load, bed materials, bed material size, bank composition and width. Factors affecting channel pattern are two types such as water flow strength and sediment load characteristics (Farguson, 1987). Farguson (1987) also divided channel patterns according to bed load which has been described as follows:

1. Sandy bed load rivers (straight, meandering, anabranching).
2. Slightly sinuous with altering bars.
3. Gravely bed load rivers.
4. Increasing stream power (straight).


structural level
plan outline
straight
sinuous
branched
limiting conditions
valley bottom
single-thread
macromeanders
anabranching
wide floodplain
flood channel
straight
meandering
braided (or split)
confined channel
low water channel
riffle-pool sequences
alternate bars
medial bars
incised channel

Source: Alabyan & Chalov, 1998

Figure 2.1 Channel pattern of an alluvial river

Meandering and Braided River

River channel pattern is characterized by sinuosity (Gupta, 2012). Meandering river is also known as sinuous channel. When rejuvenation[12] occurs in a river channel it under cut its valleys to run a river in the meandering valley which is called an incised river. A river should be considered as a meandering river if the sinuosity is ≥ 1.5 (Leopold and Wolman, 1957). According to Schumm (1963) sinuosity value ranges from 1.1 up to 2.3. Rapid valley cutting causes symmetrical side wall of a river valley and the mender is called entrenched mender. Gradual movement of meandering channel with steep slope and asymmetrical valley is known as ingrown meander. (Matsuda, 2004). River changes its planform pattern through meander migration.

Braided river is also designated as multithreaded / anastomosing/ separating and rejoining channel with numerous bars. A channel network containing divergent and convergent stream, detached with sand, mud, gravel or other sediments are termed as braided stream (Singh and Jamwal, 2010). The braided river channel forms for its erosional and depositional activities in the downstream location. Therefore, the braided river channels are very unstable. Braiding of a river is related with the intensification of channel growth (Morsawa, 1968).

River Basin

River basin is a land which captures water of a particular river, its tributaries and distributaries. It is also termed as catchment basin or drainage basin. Schumm (1981) identified a drainage basin as the source region of water and sediment. It is also designated as catchment area by the hydrologists. The drainage basin which has outlet to the sea is called Exorheic. On the other hand, drainage basin without any linkage to the sea is called Endorheic. The area which supplies water in a channel is called a drainage basin (Matsuda, 2004). River or drainage basin has both hydrological and morphological characteristics. Sen (1993) described four properties of drainage basin such as i) areal (shape and size of drainage basin ii) relief (elevation, slope) iii) linear (density, texture, pattern) iv) hydrological properties (discharge, velocity, load).

Stream Channel

A Stream channel develops through fluvial processes. Running water is responsible for stream channel development in a fluvial system. Stream channel encompasses both channel bed and channel banks. Each stream channel has its own slope, discharge capacity, width, depth and channel pattern.

Channel Migration

Alluvial river of floodplain migrate its channels through lateral erosion in stream banks. Sediment deposition in river bed causes bifurcate stream channel and thus channel migration also occurs.

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[12] Rejuvenation means readjustment of river through erosion. In a rejuvenated river down cutting occurs and a variety of landform such as river terrace, incised meander etc. develops in the river valley.

River Morphology Change

River morphology change means the change in river valley and river bank. Hydraulic action and anthropogenic impacts on river determines the extent of river morphology change. Frequent river morphology change occurs in alluvial rivers and in the downstream locations.

Impact

The synonyms of impact are consequence, effect or influence. Impact means the influence of anything that effect on environment and mankind. Impact may have positive and negative sides.

Adaptation

Adaptation means the ability to battle against an unfavorable condition. Adaptation depends upon the resilience capacity of an individual or community people. Peoples adjustment to his living environment has been termed as adaptation or coping. Adaptation is a process which integrates survival regarding socio-economic and environmental settings.

2.2 Theoretical Background

2.2.1 Variables of river morphology

Rivers are the architect of human civilization. Stream channel development, erosion, transportation and deposition of a river system are the combined effect of climate, weathering, topography, hydrology and geology. The development of a river valley is a central unit of fluvial geomorphology. Water velocity and discharge determines a stream channel flow. The erosional and depositional activity of a river shapes the stream channel. The deposition of fluvial sediment produces a variety of landforms. According to Alam *et al*., 2007 the variables of channel morphology are four types including:

- Hydrological variables (velocity of fluid, water discharge, share stress).
- Sedimentological variables (sediment size, sediment texture).
- Characteristics of channel (slope aspects, type and shape of channel, width, depth.)
- Bed and bank material characteristics (type and composition).

2.2.2 River Morphology with Flow Characteristics

The morphology of a river largely depends upon the hydraulic flow characteristics. The velocity of a river depends upon flow direction and flow accumulation (Venkatramanan *et al*., 2013). River hydraulics changes in flooding conditions. Basically there are two types of stream flow: Laminar flow and turbulent flow. Parallel water layer, low velocity and straight channel indicate laminar flow which is found in the river bed and bank. When channel condition is irregular then laminar flow turns into turbulent flow. Other elements of turbulent flow are density of water, velocity, depth and viscosity etc. (Morisawa, 1968). Reynolds number differentiates whether a flow is turbulent or laminar:

$Re=\frac{\rho uL}{\mu}$ Where, ρ is Density

μ is Viscosity
u is Velocity
Re is Reynolds number

If the Reynolds number value is small it specifies the laminar flow. When Reynolds number value is big then it postulates the flow as turbulent. The Reynolds number differs from 300-600. Turbulence is also subdivided into two types: Streaming flow (turbulence originates in most of the streams) and Shooting flow (initiates in higher velocity streams). Froude number is used to designate streaming or shooting flow:

$$Fr=\frac{V}{\sqrt{gD}}$$

Here, V is mean velocity
D is depth of water
g is force of gravity

Less than 1 value of Froude number indicates streaming turbulence flow and when the value of Fr is greater than 1 then it will show shooting turbulence flow. When streaming flow turn into shooting flow, the velocity increases. On the other, hand decreasing trend of velocity indicates shooting flow to streaming flow of water which causes back water effect and stationary wave (Morisawa, 1968). Vortices are also formed for turbulent flow. Any barrier in river bed causes development of eddies. According to Leighley (1934) there is a relationship among channel shape, velocity and turbulence. The zone of maximum velocity varies with change in channel shape. Maximum velocity of water has been found in the focal point and below the surface in symmetrical river channel.

Variation in channel shape, movement of current, topography are the influencing factors for eddy development, velocity change and turbulence in stream channel which contributes on morphological change in river. Energy of a river is transmitted through the hydraulics of stream that works as an agent of erosion, transportation and deposition. The fluvial process and landform development has been understood through hydrodynamic theory of turbulent flow (Morisawa, 1968). The action of running water denotes river bank erosion and sedimentation in a river regime. Thus changes have been taken place in a particular river reach.

2.2.3 River Morphology Change with Sediment Deposition and Erosion

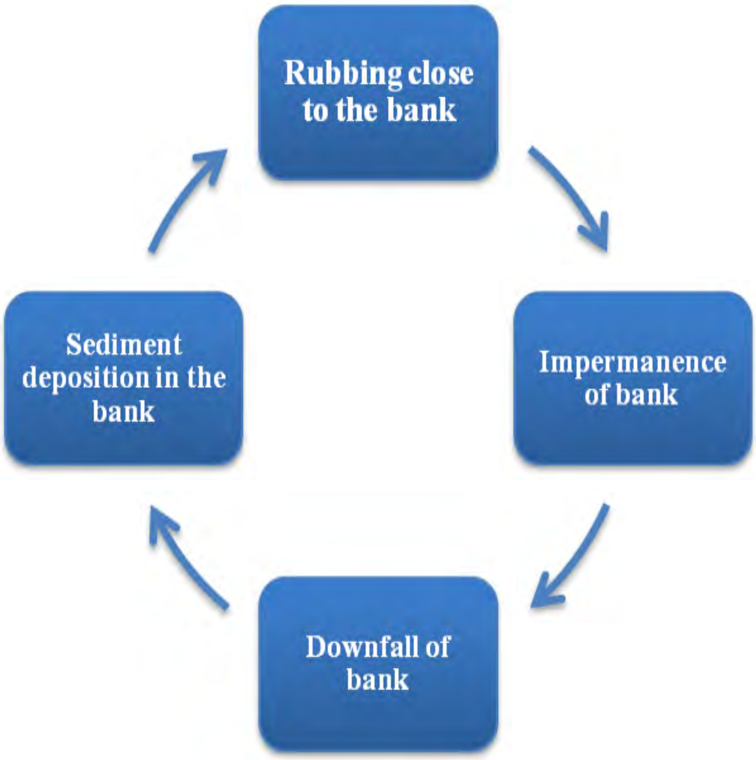
Sediment deposition and erosion are the key determinants of river morphology change. The process of erosion involved in sediment accumulation. Erosion occurs in the outer meander bend (concave bank) and sediment deposition takes place in the inner meander bend (convex bank) of an alluvial meandering river. Accretion or sediment deposition in river bank and bed is determined by different natural and manmade causes. Flood, erosion, landslide in the upper catchment of Teesta causes sediment deposition in the downstream valleys. Highest amount of sediment yields (98.40 cum/ha/year) has been observed in the Teesta basin among the other Himalayan rivers (Agarewal and Narain, 1991). The sediment source regions and erosion processes of Teesta are shown in (Table 2.2).

Table 2.2 Source regions of sediment and erosion processes

Sediment source region	**Terrain and major features**	**Erosion processes**
Sikkim Himalaya	High elevation, steep slope, glaciation.	Hill slope erosion, Debris flow, rock fall
Himalayan foothills	Moderate relief, gentle slope, fan deposits, Dense forest and cultivation.	Landslide, sheet, rill gully and channel erosion.
Teesta plains	Low relief, very gentle slope, alluvial deposits, grazing, cultivation	Sheet, rill, gully erosion, river bank erosion.

Source: Modified from Wasson, 2003

Movement of water in river bank, type of bank material, and slope aspects intensifies the bank failure of alluvial rivers like the Teesta. River bank erodes after the subsequent retreat of water in a bank full stage of flood. The process of erosion involves with sediment deposition in river basin. Erosion is the process by which water is the main transporting agent of weathered rocks in a river basin. (Ward,1975). River bank erosion and accretion is a complex process in which hydro-climatic and geomorphological processes are involved to regulate the river morphodynamics. Figure 2.1 illustrates the process of erosion and deposition of a river (adopted from Hung, 2006).



Source: Adopted from Hung, 2006

Figure 2.2 River bank erosion and deposition process

The erosion of the Teesta river follows two distinct phases: erosion during flood period and erosion after flood water recession. The process of river bank erosion and bank failure has been illustrated in Figure 2.3. During the flood the stream current hits the bank and collapses the bank materials. Bank erosion occurs suddenly in the monsoon but bank collapse and soil erosion occurs slowly in post flood situation. The water contamination in the river bank loses the compactness of soil bonding and bank failure takes place. Seepage of ground water into the river is responsible for post flood erosion (Mohiuddin *et al*., 2007). Rainfall, flood, mass movement, soil composition, deforestation, topography, tectonic movement and human interference on river are the controlling factors of river bank erosion and thus river changes its morphology. River bank erosion is a dynamic fluvial process. Bank erosion mechanism is influenced by scouring in the lower slope and sliding in the upper slope after flood water recession (Klaassen *et al*., 2005). River bank erosion occurs during June-November (Monsoon-post monsoon season). The intensity of erosion varies with the change in the variables of channel morphology.

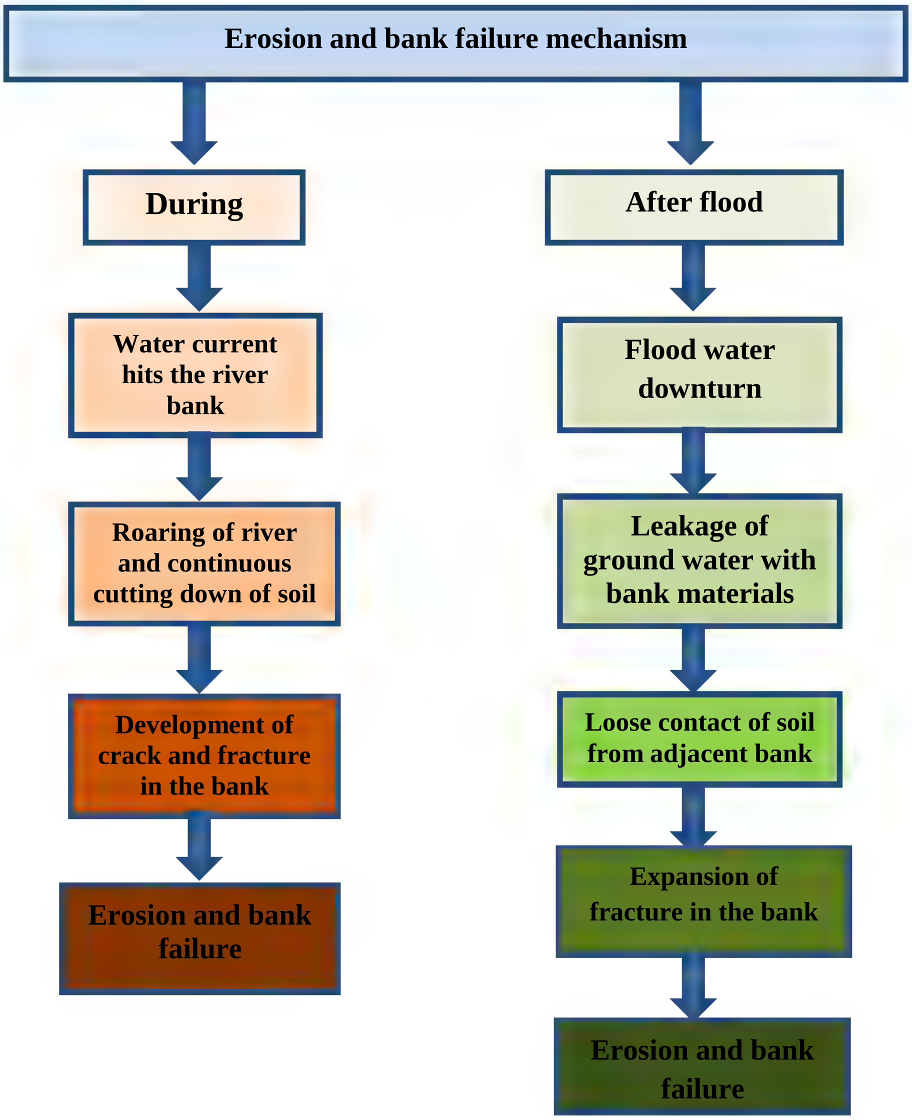

Erosion and bank failure mechanism
During
After flood
Water current hits the river bank
Flood water downturn
Roaring of river and continuous cutting down of soil
Leakage of ground water with bank materials
Development of crack and fracture in the bank
Loose contact of soil from adjacent bank
Erosion and bank failure
Expansion of fracture in the bank
Erosion and bank failure

Figure 2.3 Erosion and bank failure mechanism of an alluvial river (Developed by the researcher based on questionnaire survey, FGD and KII).

2.2.4 Flood and River Morphology

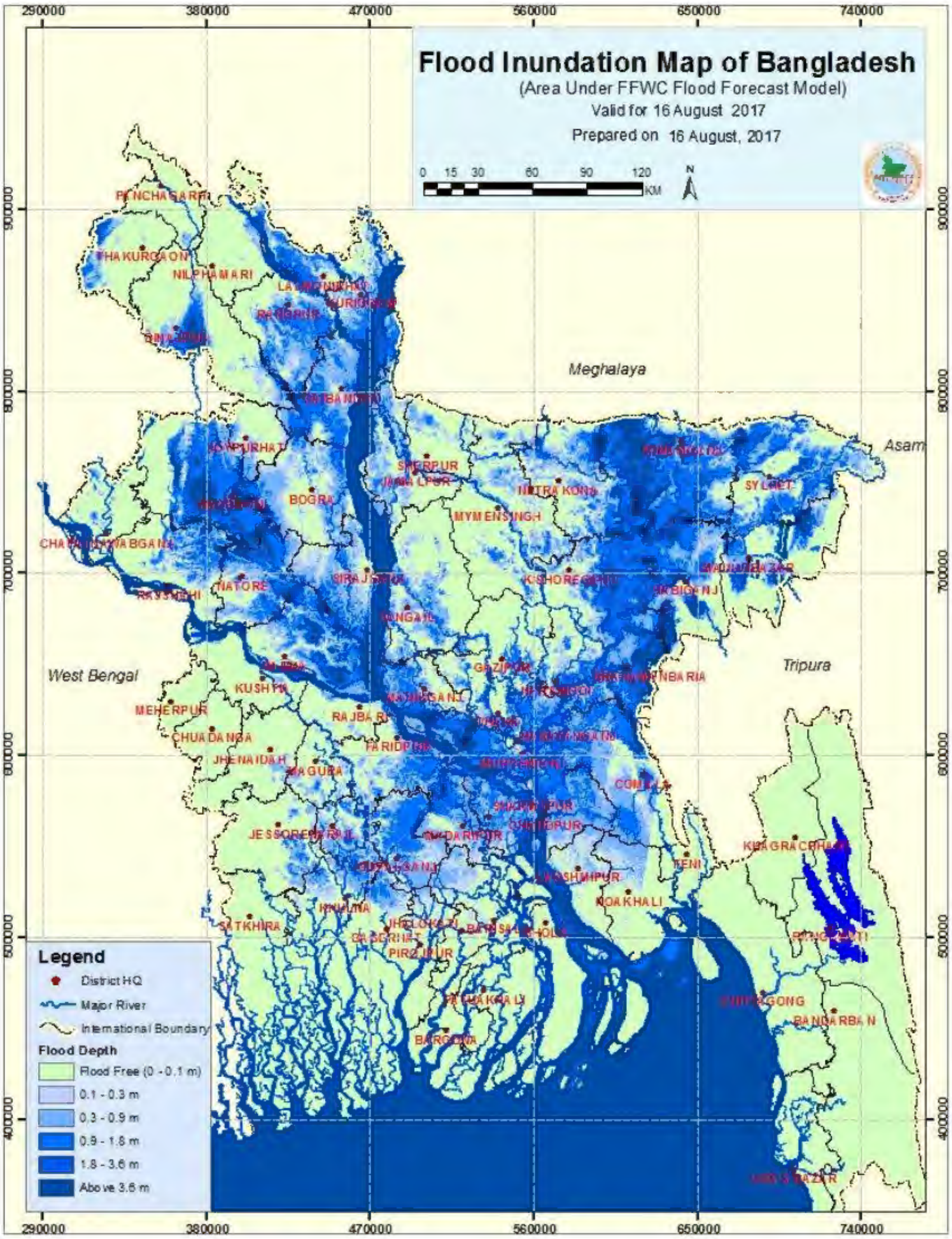
Flood occurs due to excessive rainfall, high tide and melting of snow in the mountainous region. Flood refers to the overflow of water from the river banks and inundation into the floodplains (Rasheed, 2011). Flood water brings huge sediments which have been deposited in the river bed, banks and floodplains. Thus, flood changes river morphology through its aggradation process. The major river systems of Bangladesh transports suspended sediments about 13 million tons/day throughout flooding conditions (Sikder, 2008). Moderate flood transports more sediment than catastrophic flood (Leopold *et al.*, 1964). Initial stage of flood accumulates high suspended sediment (Gupta, 2010). The recession of flood water causes bank erosion and river channel shifting in the floodplains. Therefore, flood has a great influence on river morphology change. Flood depends upon meteorological and physiographical features such as temperature, rainfall, slope, land and soil type, drainage pattern and topography. The casualty of flood water depends upon the flooding depth, inundation area coverage and the duration of flood. Long duration inundation serves much suffering to the society than height of flood (Islam *et al*., 2014).

2.2.5 Floods in Bangladesh

Bangladesh is a low-lying country with perennial flood. Flood mainly occurs in Bangladesh in monsoon. The overflow of river water exceeding its bank origins inundation in the land surface and causes flood. About 80% of land of Bangladesh is considered as flood prone. Among the flooded areas 20-22% of land is affected by flood each year in monsoon. Flood water inundation over 33% of land of the country is designated as catastrophic flood, in addition, inundation of 25-33% of land is considered as severe flood. (Rasheed, 2008). Flood inundation of Bangladesh in 2017 has been shown in Map 2.1. During flood the submergence of land by river water causes much damage to life and property. Physiographiclly Bangladesh is a low lying country with its almost flat topography. About 30% land of Bangladesh is affected by normal flood, 55% and above area is affected by severe floods. (Islam, 2003). More than, 60% landmass of Bangladesh has been affected by flood in 1988 and about 68 % area of the country was inundated with 65 day longevity in 1998 (Bhattacharjee, 2000).

First attempt of Bengal flood report of 1870-1922 has been made by professor PC Mahalanobish. The report describes the catastrophe of flood in north Bengal. A moderate flood occurs in every two year of duration, severe flood take place after 6-7 year of interval and calamitous floods take place on an average 33-50 years of period (Mahalanobish,1927). The floodplains of Bangladesh are affected by flood perennially. Both catastrophic and moderate frequency flood occurs in the country with alluvium deposition. The country faces various kinds of flood termed as flash flood, rain induced flood, monsoon flood etc.

Rapid rise and fall of river water is called flash flood. The flash flood water increases and downturn in 24 to 30 hours (Ahmed and Mirza, 1998). The Teesta, Dharla, Dudhkumar, Surma, Kushiyara, Manu, Sangu, Gumti, Halda are flashy rivers of Bangladesh. During March to May the Northern, Northeastern and Southeastern parts of Bangladesh experiences rapid rise and recession of flood water which is called flash flood (Rasheed, 2008). Usually flash flood occurs in the foothills of upstream rivers where topography is flat. Teesta river basin lies beneath the Chotanagpur and Meghalaya plateau which is the inherent cause of flash floods in the region. Rainfall intensity more than 300 millimeter in maximum 10 days is designated as flash flood within a given area (BANCID, 1995).


Flood Inundation Map of Bangladesh
(Area Under FFWC Flood Forecast Model)
Valid for 16 August 2017
Prepared on 16 August, 2017
0 15 30 60 90 120 KM
N
Meghalaya
Asam
Tripura
West Bengal
Legend
District HQ
Major River
International Boundary
Flood Depth
Flood Free (0 - 0.1 m)
0.1 - 0.3 m
0.3 - 0.9 m
0.9 - 1.8 m
1.8 - 3.6 m
Above 3.6 m
290000
380000
470000
560000
650000
740000
900000
800000
700000
600000
500000
400000
PANCHAGARH
THAKURGAON
NILPHAMARI
LALMONIRHAT
KURIGRAM
RANGPUR
DINAJPUR
GAIBANDHA
JOYPURHAT
BOGRA
NAOGAON
CHAPAI NAWABGANJ
RAJSHAHI
NATORE
SIRAJGANJ
SHERPUR
JAMALPUR
MYMENSINGH
NETRAKONA
SUNAMGANJ
SYLHET
MAULVIBAZAR
HABIGANJ
KISHOREGANJ
TANGAIL
GAZIPUR
NARSINGDI
BRAHMANBARIA
MANIKGANJ
DHAKA
NARAYANGANJ
MUNSHIGANJ
COMILLA
CHANDPUR
SHARIATPUR
MADARIPUR
GOPALGANJ
LAKSHMIPUR
FENI
NOAKHALI
PABNA
KUSHTIA
MEHERPUR
CHUADANGA
RAJBARI
FARIDPUR
JHENAIDAH
MAGURA
JESSORE
NARAIL
KHULNA
SATKHIRA
BAGERHAT
JHALOKATI
BARISAL
BHOLA
PIROJPUR
PATUAKHALI
BARGUNA
KHAGRACHHARI
RANGAMATI
CHITTAGONG
BANDARBAN
COX'S BAZAR

Source: FFWC, 2017

Map 2.1 Flood inundation map of Bangladesh, 2017

Rain induced floods are also known as meteorological flood. High intensity of rain causes the river banks over spill and flood occurs in Bangladesh. Intensive rainfall driven meteorological flood takes place between 10-30 degree latitude (Gupta, 2010). Rain induced flood depends upon the intensity and duration of rainfall. This type of flood takes place in the pre-monsoon (April-May) period.

River or monsoon flood is seasonal type of flood. In the monsoon heavy rainfall in the source region of the river causes slow increase of water level and continuing flood in a vast area through overbank spilling in Bangladesh (Rasheed, 2008). The monsoon flood water also declines slowly. The rivers, their tributaries and distributaries causes over spilling during monsoon which is demarcated as river-induced flood in Bangladesh. Non-meteorological floods are infrequent in nature. A flood which is non-meteorological occurs through dam collapse, ice melting from glaciers and earthquake. Earthquake induced landslide may block a river and produce catastrophic flood. Glacial outburst floods are determined as Jokulhlaups. (Gupta,2010). Another type of non-meteorological floods are created through breaching in embankments, public cut in the embankments in floodplains and polders in the coastal regions. Cyclone induced storm surges are responsible for coastal flooding. Cyclones of 1970, 1991, 2007 and 2009 occurred in the Bay of Bengal causes severe storm surge and flood. Coastal flood occurs suddenly and inundates the coastal lands with saline water. The country experienced most devastating floods in 1954, 1955, 1970, 1971, 1974, 1987, 1988, 1995 1998, 2000, 2004, 2007, 2008, 2013, 2017 respectively. The chronological flood affected area and damage is given in Table 2.3

According to UNDP and FAO (1988) the Flood hazard types in Bangladesh are:

1. Ruinous flooding accompanied by river erosion and or deposition of fresh alluvium.
2. Catastrophic flooding owing to storm surges, with or without cyclones.
3. Devastating flooding due to rapid rise and fall of flood water.

Table 2.3 Chronological flood affected area and damage

Year	Flood affected area in sq.km	% of flood affected area
1954	36000	25
1955	50500	34
1970	42400	29
1974	52600	36
1987	57000	39
1988	89970	61
1995	32000	22
1998	100250	68
2004	55000	38
2007	62300	42
2008	33655	23
2014	3895	25
2015	47200	32
2016	48,675	33
2017	61,979	42

Source: FFWC, 2017

2.3 Literature Review

In order to conceptualize the problems and concepts regarding river morphology change, a number of books, articles, reports and thesis papers have been reviewed. Extensive literature review has been carried out to fulfill the research gap. Insights from the Pre-existing literatures about flood, river bank erosion, river channel shifting along with impact and adaptation to such changes have been taken from various scientific articles.

2.3.1 Water Discharge and Flood

Bhuiyan *et al*., (2007) analyzed the flash flood situation in northeastern Bangladesh by numerical hydrodynamic model. The paper demonstrated the activities of Flood Forecasting and warning Centre (FFWC) along with the flood peak travel time. According to the study, Bangladesh use numerical hydrodynamic model for flood forecasting which is appropriate for the monsoon river floods but it is less effective for the flash floods. The study concludes with the probability of establishment of new hydrological Doppler radar at Moulvibazar will improve the flash flood warning system in the north eastern region. Thus the study suggests the radar signals monitoring of the Indian catchment will provide the lead time forecast of the flash flood of the rivers of north eastern region of Bangladesh.

Brammer (1990) carried out his extensive research on geography, soil and floods in Bangladesh. The study elaborated the activities of Flood Action Plan (FAP) after the devastating floods of 1987 and 1988 in Bangladesh and its possible mitigation measures. He pointed out the components and associated activities of action plan of flood control in Bangladesh. Upstream storage, storage basin in the floodplains and draw down of ground water has been suggested to mitigate the flooding situations. Environmental aspects of flood also considered in the study. Brammer concluded with upstream deforestation, earthquake as well as tectonic movement in the Himalayan and sub- Himalayan region, human intervention on river is the environmental facets of flood and sedimentation which influences river morphology.

Pal *et al*., (2016) has integrated the causes, and consequences of floods and landslides in the Teesta catchment. The history of flood has been described in the paper and indicated recurrent flood occurrences along with flash floods. The paper identified sudden cloud burst and orographic rainfall, geomorphic characteristics, landslides and anthropogenic reasons are the key factors responsible for floods in Teesta. The study marked channel migration and braiding in river channel are the geomorphic consequences of flood.

Ramkumar (2009) has shown a probabilistic view of flood control in his article “ Flooding- a manageable geohazard”. He investigated the causes and effects of flooding and pointed out that both natural and human interference on river morphology causes flood and turn into a geohazard. The study suggested awareness, dune development, natural vegetation, flood prone area mapping, land use planning, restoration of wetlands, floodwater diversion through river linking, flood hazard zonation, flood forecasting for flood management. The paper concludes with the remarks of proper understanding of flood by means of affirmative thinking.

Rahman *et al*., (2011) have investigated the discharge data of Teesta river at Kaunia station to analyze flow design of flood. The study also analyzed the flood frequency to estimate the flood of Teesta river of three different return periods. The study applied MIKE 11 model, Rainfall-Runoff (RR), Nedbor Afstromnings Model (NAM) and HDM (Hydrodynamic Model) to examine the discharge, design flood and stage computation of Teesta river. Using the rating curve equation the study result shows 32.43, 32.66 and 32.86 m flood stages of 25, 50, and 100 year return periods which may give assistance in flood zonation, vulnerability and risk reduction techniques.

2.3.2 River Degradation and Erosion

Thakur *et al*., (2012) has carried out a research on bank erosion in the upper course of Ganga through Remote sensing technique. The study investigates soil stratification, construction of Farakka barrage, high sediment accumulation are the factors responsible for erosion in the study area. The study used Landsat imageries from 1955-2005 to examine the bank erosion, braiding and sinuosity index. Temporal shifting of the river channel has been detected through cross section method and highest shifting was found during 2003-2005. The paper also demonstrated the socio-economic impacts of erosion. The study result shows that the right bank of the river reach has been occupied by hard rock, therefore the left bank is eroding which enhances the sinuosity of the study stretch. The study concluded with the recommendation of water flow diversion from the left bank would be the only solution for bank erosion control.

Hooke (1979) has been evaluated bank erosion and focused on the analysis of the process of river bank erosion. He investigated the factors affecting erosion are turbulent flow during flood, corrosion process, increasing discharge capacity, amount of rainfall, bank material etc. The paper grades number 1 rank to the variable rate of rise of discharge for river bank erosion. Frequency of erosion and thresholds value estimation has been carried out in the research. The study identified two main processes of river bank erosion namely corrosion resulting from river flow and slumping for soil moisture. The paper demonstrated the relation of soil moisture and soil texture as a controlling agent of river bank erosion.

Mohiuddin *et al*., (2007) has aimed to focus on the Padma river bank erosion vulnerability, mitigation measures and forecasting technique through state- of- the-art mathematical model. The study assessed the history of river bank erosion pattern, the shifting of thalweg profile, infrastructures of the erodible bank etc. to explore the risk of probable bank erosion. The authors identified four erosion vulnerable locations of the study area, categorized the erosion vulnerable risk and then recommended the categories of probable bank protection measures. Therefore the study illustrates what to protect, where, when and how.

Hassan *et al*., (2016) detected the river bank erosion of Padma river through temporal Landsat imageries and identified its socio-economic impact. The study has also conducted a questionnaire survey to examine the socio-economic consequences of river bank erosion. The study gave emphasis on the left bank erosion of Padma of Rajshahi which identified about 1319 hectare bank erosion from 1975-2009. The main socio-economic consequences identified in the study are agricultural loss, homestead loss, migration, property loss, dropout and property price fall down due to river bank erosion. The study is important one because it combined both the remote sensing and field survey based data to illustrate the bank erosion and its impact on the society. The study concluded with the suggestions of low inclined embankment slope with layers, eco-friendly geo-bag concentration in the bank and vegetation for soil compactness to reduce the river bank erosion.

Mollah and Ferdaush (2015) have examined the riverbank erosion and migration as an adaptive tool in the Kazipur upazilla in Sirajgonj district of Bangladesh. The study explored that in situ migration is higher than ex situ migration and projected the rate of migration 9.35% in the year 2011. High, moderate and low vulnerable area of river bank erosion has been detected through mapping techniques. The paper estimated forced migration of 12.75% population would be held in Kazipur upazilla in future if erosion continues. The study recommended distribution of relief materials, practice community based techniques, property relocation strategy and floodplain zonation would be best exercise to survive with river bank erosion.

Aktar (2013) explored the trend of Jamuna river bank erosion. Effect of water level and discharge on bank erosion has been investigated in the research. It also aims to explore the effect of main stream channel on river bank erosion. The association between width and bank erosion has been evaluated through satellite images in the study. The study result indicates the right bank of Jamuna river is stable but the left bank is responsive to flood water discharge and water level and thus erodes much than the right bank.

2.3.3 River Aggradation, Sediment Load and Deposition

Jian *et al*., (2009) narrated the sedimentation and erosional status of the Jiangsu reach of Yangtze river from 1959-2003 and showed that average sedimentation process was on going during 1959-1985 and average erosion was held on during the period of 1985-2003. The research revealed the leading cause of sedimentation and erosion are shortage of solid load discharge from the upstream and both the activity of tide and river current respectively. The paper illustrated year-wise river channel change through Digital Elevation Model (DEM). The study investigates how and why the river converted its sedimentation status to erosional activities and concluded with the time-space variation of river channel change.

Constantine *et al*., (2014) evaluated how sediment supply triggers meander and floodplain expansion in Amazon river basin area. The study has been conducted through the Landsat imagery of 1955-2013 and calculated average annual meander migration rate. The result of the study unveiled that the river which carries lesser amount of sediments has the capacity of low river bank migration rate and when the carrying capacity of sediment load of a river increases it become furious to channel shifting through erosion. The study also indicates that the external sources of sediment supply endorse floodplain development and bar formation but the situation is hampered by large water storage reservoir construction.

A research carried out by Promny and Vollmer (2011) on sediment budget and river morphology under climate change scenario. They evaluated the impact of climate change on navigation. The article is based on multi-stage model chain with three climatic settings. It tries to investigate how temperature and rainfall causes change in water quality and navigation channel. The paper contains two analysis of river morphology; the first one represents mean bed level change (2007-2050) and the second one is change of water depth (2010-2050).

Floodplain sedimentation of the lower Rhine river of Netherlands has been investigated by Middelkoop (2005). The paper narrated the pattern, process and methods of sediment deposition in the floodplains. Heavy metal contaminant deposition in the fluvial system is also examined in the study. The study demonstrated floodplain sedimentation models including large scale 1d sedimentation modeling, two-dimensional mathematical modeling of overbank flow and sediment deposition and 3d Computational fluid dynamics (CFD) modeling of flow hydraulics and sediment transport. Influence of flood magnitude on sedimentation, annual average sediment deposition rate and effective discharge for sedimentation has been analyzed in the study. The research is prize worthy to understanding the sedimentation process of the floodplain.

Meetei *et al*., (2007) has carried out a research on quaternary deposits of Teesta with an understanding on climate and tectonic traces. The paper illustrated the morphological features of middle Teesta river valley. It addresses a systematic analysis of straightegraphic succession of quaternary deposition. The study investigated the elevation data through GPS and mapping has been conducted through PAN and LISS-PAN (Linear Imaging Self-Scanning Sensor-Panchromatic) merged data and topographic map. Various schematic cross-section and lithofacies analysis were presented to show the terrace and fan morphology in the study. Sediment budget of Ganga-Brahmaputra catchment has been investigated by Wasson (2003). The research inspected that the high Himalaya is the main source of sediment of the two major catchments of the world. It also explored other sediment sources and processes involved in erosion in the source regions. The paper quantified the sediment budget. The study suggests for further research on causes of aggradation and policy oriented research with sediment source tracers to identify human intervention on sedimentation in the Gang-Brahmaputra catchments.

Mugade and Sapkale (2015) carried out a research on the effect of the aggradation and degradation status to river. The paper is noteworthy for its pinpoint review of aggradation and degradation related pioneering research works. The study discovered that sediment supply, discharge capacity of a river and hydraulic velocity are the key factors of the process involved in aggradation and degradation. According to the study, soil erosion, debris flow, bank failure, landslide has been designated as important causes of aggradation. The paper investigated aggradation and degradation are the influential factor for river channel shifting. The paper concludes with the remarks that the type of sediments also effects on the aggradation and degradation processes.

Hassan *et al*., (2017) estimated the coastal erosion and accretion of GBM delta using a series of Landsat imageries from 1973-2016. The study method includes image digitization with bank line delineation, geo-referencing, mapping and estimation of eroded and deposited area. The study result unveils that the rate of net accretion in the GBM delta is 31.8 sq. km per year during the study period. According to the study the Meghna estuary is highly erosion, accretion prone (unstable) but the Ganges estuary and the Karnaphuli coast has stable condition. The erosion accretion of the important island such as Bhola, Hatiya, Kutubdia and Maheshkhali has also been measured. The paper suggests more investigation about the morphological change in the coastal region to develop agricultural activities in the newly accreted land.

Yang *et al.,* (2006) have depicted the actual situation of the Yangtze river sediment discharge process from the time period of 1950-2004. The research unveils the decreasing trends of sediment supply due to the operation of the three gorges dam in 2003. It is based on the secondary data sources from four key gauging stations which gave pen picture of annual water discharge and sediment loads. The paper also investigates the impact of dam on sediment trapping and deltic erosion for reduced sediment supply and river bed scouring. The outcome of the research highlights that Yangtze river sediment discharge decreased in three different phases after the construction of Daniangkou reservoir in 1968, dams and conservation activities in 1985 and the three gorges dam operation in 2003. Finally the study depicts that the reduced annual sediment loads are less than 200mt/yr at Datong station which causes morphological changes in the Yangtze river basin.

2.3.4 Morphology, Morphometry and Drainage

Hydro-geomorphic analysis of fluvial system has been investigated by Chakraborty and Dutta (2013). They took an attempt to assess the causes and effects of fluvial hazards in Duars region of India. The study identified river bed rise, channel widening, bank failure, river course shifting, loss of biodiversity, health hazard are the notable consequences of fluvial hazards. The paper also investigated the factors affecting fluvial hazards are rainfall pattern, landslide, deforestation, mining in catchment area, boulder quarrying, human encroachment etc. The study remarks includes that research on hydro-geomorphic hazard provides remedial measures towards natural and human vulnerability.

Venkatramanan *et al.,* (2013) examined the morphological physiognomies of Tirumalairajan river. The article gives an insight into the technique of thematic mapping with the help of Arc GIS (Geographic Information System). The morphological characteristics have been depicted from topographic maps. The study reveals the drainage network, river basin, flow direction and other river morphology related phenomenon.
Islam *et al.,* (2014) identified different geomorphic units of Rangpur with satellite image processing such as active channel deposits, abandoned channel deposits, natural levee, flood basin and floodplain deposits. They highlighted on land use mapping and identified five land elements. The paper recommended incorporating geological information for land use planning, subsoil mapping and conduct detailed survey for development of the study area.

Khan (2009) attempted to analysis the morphometry of Khewra river basin of Pakistan. The research aims to interpret the landforms of Khewra salt mine region. An attempt has been made to analyze the stream order, stream numbering, length ratio, bifurcation ratio, drainage density etc. It also investigates the drainage pattern, stream frequency, drainage intensity, slope and stream gradient of the Khewra river basin of salt mine region.

Morphological progression of sand braid-bar along the Jamuna river have been investigated by Ashworth *et al.*, (2000). They conducted bathymetric survey in two monsoon flood season and land survey in low discharge to analyze the evolution of a large sand braid mid channel bar. The paper narrated the hydrology and geomorphology of the Jamuna river. Bathymetric maps were prepared from 1993-1996 and changes of position of the study bar has been depicted. To examine the sediment balance, the spatio-temporal change of erosion and deposition has been quantified. According to the study vertical aggradation occurs due to high flood discharge to form mid channel sand braid-bar and low discharge accounts for lateral bar formation. The study established a model of mid channel bar development and pointed out that dunes are the important factor to the evolution of a mid-channel bar. The paper concludes with the remarks that lateral accretion due to dune migration initiates bar widening and gives a new concept of conversion of mid channel bar to an alternate bar which contradicts from previous literatures.

Rahman *et al*., (2018) analyzed the morphometry of major watersheds of drought prone Barind region of Bangladesh. It is a GIS and remote sensing (RS) based study which delineates the watershed area through SRTM DEM and also the toposheet of Geological Survey of Bangladesh. The paper has been aimed to focus on the morphometric investigation of two distinct watershed for sustainable water resource management. The researchers used stream length, stream order, stream length ratio, bifurcation ratio, drainage density, drainage texture, relief ratio, stream frequency etc. as morphometric analysis parameters. The article compiled different types of morphometric maps such as drainage density, aspect, physiographic, land use/land cover, slope and stream ordering map drawn with modern tools and techniques. The study result unveils the studied watersheds have streams of 6th order, drainage textures are very coarse to ultra-fine, drainage follows dendritic pattern with gentle undulating slope. The paper recommends ground water recharge and surface water increase through storage would be the best practice water resource management in the water scarce Barind tract.

Rashid *et al*., (2015) highlighted the characteristics of drainage basins of northern Bangladesh on their article entitled “Drainage characteristics and evolution of the Barind Tract, Bangladesh”. The study investigated the processes involved in the evolution of the Bengal Basin. It unveiled that drainage characteristics has been controlled by the structural condition of the area. The paper emphasized on the neotectonic activities of the Barind Tract gearshifts the flow directions of the rivers which is an ongoing process. The study explored low to moderate sinuosity of the drainages in the northern part and high sinuosity in the north eastern part of the Barind Tract. The focus of the study indicated that incised channels, entranced valleys, disconnected former valleys, presence of numerous depressions, raised terraces, channel shifting, river course change is the evidence of tectonic upliftment of Barind tract.

Pramanik (2016) analyzed the morphometric characteristics of Teesta river through GIS and Remote Sensing techniques. They study examined the morphometry for sustainable water resource management in the river basin. DEM, satellite image, GIS and topographical sheets have been used in the study to illustrate the maps and data. The morphometric parameters measured in the study are stream ordering, stream number, stream length, bifurcation ratio, stream length ratio, drainage frequency, drainage density, elongation ratio etc. The study prepared aspect map and slope map of the watershed and made hydrological implication through morphometry.

2.3.5 Channel Change and Bank line Shifting

Ahmed and Fujita (2007) have investigated the recent morphological changes of Jamuna river after the construction of Bangabandhu bridge. The paper revealed the historical trends of morphological changes, channel configuration, change in bed topography and variation of width from cross section data. The study results showed the rate of bed load transportation and the channel bathymetry using the numeric simulation model.

Jacobson and Oberg (1997) has examined the geomorphic changes occurred in the Mississippi river due to flood 1993. The study is based on the levee break effects on geomorphology. It illustrated the erosional and depositional landforms produced by the river after flood 1993. The research investigated the historical channel positions of 1944, 1880, 1820, 1765 and Holocene channel position stages of the river in the Miller city. The study also examined the characteristics of geomorphic units, cross section of the scores, and frequency of geomorphic changes.

Li *et al*., (2007) explored the channel change from 1951-1997 in the middle Yangtze river. It illustrates channel planform change maps from navigation charts of 1981 and 1997. Topographic changes were shown through cross sections and longitudinal profiles were also drawn through DEM. The study estimated the amount of erosion and deposition from DEM. The study concluded with impacts of bank failure, influence of bank revetment, impact of levee construction and effect of hydrological regime change on geomorphic changes.

Chakraborty and Datta (2013) have analyzed the spatio-temporal changes of river channel, its causes and consequences through GIS-Remote Sensing techniques. The study has been conducted in the Jaldhaka-Diana river system of North Indian Plain. About 80 years (1930-2011) time period has been considered for temporal change of confluence point and landscape development in the study reach. The research investigated the hydro-geomorphic mechanisms of river channel changes and mentioned that the area is highly vulnerable to flood for ice melting as well as intense rainfall in the upper catchments. The article also pointed out the mechanism of river capture by lateral movement, avulsion, cut off and also aggradations of the river. The study result unveils the net upstream shifting of the confluence point during the study period is about 6 km and the shifting has not followed any trend.

Hossain *et al*., (2013) have been explored the morphological changes of Ganges river in Bangladesh using satellite imageries of 1973-2009. The study result points out that the left bank is accretion prone and the right bank is erosion prone. The study investigated the correlation between the annual water discharge with erosion and accretion. Average channel width has been detected 4.94-5.27 within the study period. The paper also inspected changes in sinuosity and river island of the study reach of the Ganges river. The study concluded with the remarks that the increasing trend of sinuosity, width and vegetated islands has strong relationship with net erosion of the active alluvial Ganges river.

Alam *et al*., (2007) have been contributed on the analysis of morphological change of old Brahmaputra river. They pointed out that sediment is the key source of morphological change and the north eastern part of Mymansing district has been changed abruptly due to river morphology change. Variables of channel morphology, channel type, type of meander changes have been narrated in the study. Landsat TM data of 1997 and 2004 have been analyzed to detect the change of river morphology. The paper identified the change of land and water area of the two selected years. The impact of erosion and sedimentation on physical, Social and ecological environment have been evaluated in the study. Finally the study suggested to use geotextile bag and synthetic material for protecting river bank.

A research entitled 'morphological changes in the coast of Chittagong' has been carried out by Rizvi (2008). The paper aims to investigate the shoreline change of coastal Bangladesh from Feni estuary to Bagkhali khal and represent the development of coastal landform. The study displays the beach materials of northern Chittagong are coarse sediments with sand dune, mud shoal and mud beach depositional landforms along with the erosional features of the coast are tidal creek, score in vertical bank, headland with less obstructive soil condition etc. Recent shoreline change in northern Chittagong indicates the Feni river shifted westward direction. The paper also identifies the landform features of southern Chittagong, their forms, processes and composition.

Dewan *et al*., (2017) has been explored the channel changes of the Ganga-Padma river system of Bangladesh from 1973-2011. The study assessed the channel changes through multi-temporal satellite imageries and hydrological data. The paper investigated flood frequency, flood duration etc. from river discharge data and measured the braiding index, sinuosity index and river width with GIS application. The study illustrated five spots of river bank line change and calculated the mean annual erosion and accretion rate of the Ganges and the Padma. The article is notable one to understand the river channel shifting and planform pattern.

Morphological change and bank line shifting has been demonstrated by Mallick (2016). The paper incorporates with erosion, accretion and bank line shifting of the moribund delta of West Bengal from 1968-2010. She used survey of India toposheet and satellite image for channel change comparison and GPS for ground truthing. The study result shows significant change of oxbow lake and the river channel. The study gave massage about increasing trend of river erosion and channel shifting occurs due to human activities.

Morphodynamics of Jamuna river have been explored by Islam *et al*., (2017). The study was carried out through multispectral satellite imagery and lithological data from Auger drilling. Ten geomorphic units have been observed in the study area, the Sariakandi upazilla of Bogra district. They estimated the area of old bar, new bar, river reach, and rate of erosion in studied decades. River channel shifting also has been illustrated in the study. The study result shows that 124.77 sq.km lands have been eroded in the western bank during 1956-2015. The study suggests taking proper bank protection measures with the considerations of river morphology to control river bank erosion.

Singh (2014) investigated the morphological change of ganga river of India. The study reveals the sinuosity of the river at two consecutive bends which has been analyzed through GIS techniques. It calculated the sinuosity and sand deposition change from 2002-2013. Meander shifting and channel change are the key theme of the present study. The study result indicates channel sinuosity has been reduced from 1.66-1.26 in the study time period.

Uddin *et al*., (2011) took an attempt to assess the morphological changes of Jamuna river and its vulnerability of bank erosion with remote sensing techniques. The paper investigated the morphological change through channel migration from 1973-2010. The study gave Emphasis on interpretation of channel movement but vulnerability got least importance and only threatened settlements were depicted on maps for vulnerability assessment.

Shaikh *et al*., (2015) has been illustrated the course shifting pattern of the Ganges river from 1780- 2013. The paper identified the actions affecting the environment and environmental impact of course shifting. The study has been carried out through overlapping the map of James Rennell (1780), survey of India map (1880), and satellite map of (1980 and 2013). The study reveals the pre-Farakka and the post-Farakka course shifting pattern of the Ganges with cross section wise erosion-accretion condition. The result of the study explored that the left bank of the Ganges is eroding and the right bank is depositing sediments through its transportation processes.

2.3.6 Channel Process and Planform Pattern

Matsuda (2004) has demonstrated the channel processes of a drainage basin. The paper narrated different channel pattern, drainage pattern, shape of drainage basin and stream ordering to designate the river morphology. The study reveals the terminologies of river morphology. Channel characteristics of alluvial plains and their classification long with mountain channels are also identified in the article. The article is very effective to understand the river morphology, its forms and processes.

The Teesta megafan building process of the sub-Himalayan region has been analyzed by Chakraborty and Ghosh (2010). The study revealed the geomorphology and sedimentology of the Teesta mega fan. The research investigated the paleo channels of Teesta and identified the multi-lobate physiognomies of the megafan. It also discussed the changing drainage of Teesta megafan and identified that the radial drainage pattern of the paleochannels is responsible for aggradation in the megafan. The study narrated the dynamics of deposition and lithofacies of the Tista megafan deposits.

Mohammadi *et al.*, (2008) has carried out a study entitled “Study and determination of morphological changes of Dough river in north of Iran using GIS”. The paper investigates different morphological parameters such as meander length, radius of curvature, meander width, central angle for changing river morphology. It focuses on the changes of meandering before and after 2001 flood event. The study also shows the longitudinal and cross section maps of the study reach. The study result shows that owing to the flood event the radius of meander bend has been greater than before.

Yuzhi and Chunde (2009) investigated the morphological characteristics of Huangshui river basin of China. It gives an analysis on terrain factors with different technological supports such as GIS, RS and GPS. The analysis of morphological characteristics such as slope, hypsography, altitude, relation of basin area and basin grade were depicted on this article. The study also shows the above mentioned morphological characteristics in the base of raster DEM.

Ghosh (2014) Examined the channel pattern and channel configuration of Teesta river in the west Bengal. The paper quantified the planform pattern through GIS techniques to compare the past and present scenario of Teesta after the construction of Gazoldoba barrage. It analyzed the mean annual discharge of the river from 1993 t0 2010. The study used PFI to quantify the braiding intensity. Bar development and channel sinuosity has been investigated in the study and the study result indicates the river as a sandy braided river.

Gupta (2012) has pointed out the planform dynamics of Ganga-Padma river system in four study reach of India and Bangladesh. Decadal changes of geomorphology of the river have been investigated through Landsat archives. The study identified the channel pattern and chute cut off in the studied meander bend. It also analyzed the influence of tectonics and meandering on avulsion process. Moreover the study highlighted the future research direction on geo-statistical modeling and detailed morphological explanation of river dynamics.

2.3.7 Human Interference on River Morphology

Topolska and Klucovska (1995) have identified morphological change of Danube river bed downstream of Bratislava occurred due to different development aspects. The paper took an attempt to analyze the river morphology and its bed load sediment transportation with MIKE 11 model simulation results from 1974 to 1990. The research finds out enormous change of the river bed for low flow of water level from one year to another year. The model examined the river morphology without and with dredging conditions and showed that the studied river reach has been degraded due to dredging, river training and gravel mining.

Khan and Islam (2015) have examined human interference on river morphology. The study gives an overview of manmade effect on rivers over the world. The article clearly identified various human induced morphological changes in the Teesta river and those are bank stabilization, agriculture and grazing, artificial levee and barrage construction etc. It identified that the river morphology is mostly affected and changed through barrage construction on stream bed. The paper also identified the drastic fluctuation of water discharge in monsoon as well as in the dry season. The findings of the study illustrated the decreasing trend of water flow and drying up conditions of the Teesta river with recommendations of proper planning, Bangladesh-India water sharing and ideal use of water.

Torab and Azab(2007) have analyzed the impact of Aswan high dam for shoreline change of Nile delta. The study investigated the morphological change of Nile delta coast through satellite image, sediment sample collection and field investigation. The main geomorphic units of the delta have been discussed in the study. The study investigated the major source of accretion in the Nile coast are promontories of Rosetta and Damietta but the construction of high Aswan dam causes morphological change of the delta. The annual rate of erosion before (1900-1964) and after (1964-2006) the Aswan dam construction has been examined. Sector wise erosion and accretion (1925-2001) has been analyzed to detect the morphological change. The study findings of grain size analysis of erosional and accretion beaches suggest that finer grains accumulate in the erosional beaches.

Mogborukor (2014) narrated the impact of urbanization on river morphology. The paper demonstrates the urban land use and construction activity causes river channel expansion. Three strategic steps were applied to know the morphological adjustments of Orogodo river basin. The study divided the basin surface land use in two parts like impervious surface and pervious surface and showed the relation of stream channel size variation with urban land use. The study also depicted the process of stream channel widening. The study result shows urbanization causes intensification of flood magnitude, surface run off and erosion.

Mei *et al.*, (2015) focuses on dam impacts on the hydrology of downstream valleys of Yangtze river. The study is based on the pre dam and post dam condition of water discharge and water level data from 2000-2013. The study shows the dam effects on sediment transport, water discharge, flow regulation and water level of the river regime. The study also highlights the decreasing trend of maximum and minimum water level after dam operation.

Raslan (2009) aims to investigate how human constructed phenomena changed the Nile river morphology. One-dimension mathematical model has been used in the research to show the flow behavior of the river. Analysis of bathymetric data also depicted the morphological changes of the study area. The study elaborately discussed the hydrological situations of Sannour island, flow conditions of eastern and western channels of the island and also shows the thalweg line of the island in two different years. The concluding remarks of the study indicate human impact on channel morphology decreased the flow rate of the eastern channel and the western channel flow shows high rate.

Yang *et al.*, (2007) has conducted their research on impact of Three Gorges Dam (TGD) on sediment supply in Yangtze river. The study is based on the hydrological data, erosion and accretion data of secondary data base. The study finds out that the TGD along with other anthropogenic factors decreases sediment load which hampers delta formation. The research also depicts the role of TGD on river erosion in the downstream valleys of the Yangtze river.

Wiejaczka *et al.*, (2014) has demonstrated human role on hydro-morphology of Teesta river. The aim of the study is to evaluate the impact of human activities on river flow, channel fragmentation and ecology. The study has been conducted through river habitat survey method and examined the Habitat Quality Assessment (HQA). Habitat Modification Score (HMS) index shows anthropogenic impact on the hydro morphology of the river reach in the article.

2.3.8 Impacts of River Morphology Change

A pioneer research work about river bank erosion impact has been carried out by Elahi and Rogge in 1990 entitled Riverbank erosion, flood and population displacement in Bangladesh. The paper discussed the causes and consequences of population displacement. It also emphasized the impacts of bank erosion on the displaced community.

Parvin *et al*., (2016) have demonstrated the impact of flood and coping pattern of rural poor of Bangladesh. The study examines the influence of climate change on floods and illustrates a “flood impact tree”. It explores the severity of flood of the river Padma at Goalanda upazilla of Rajbari district. It also emphasizes on change in income and shifting of occupation due to flood. The study depicts the financial coping strategies of the flood victims.

Baishya (2013) provides an overview of pattern and process of bank erosion and bank line migration of Baralia river of Assam, India. The study examined the socio-economic status of the study area, magnitude of bank erosion and erosion affected areas. It took an attempt to identify the causes, effects and impact of bank erosion. The study also described the mechanics of bank erosion and the remedial measures of river bank protection.

Armah *et al*., (2010) explored the impact of flood on livelihood of Northern Ghana. The study describes the causal loop of flood impacts. It explored the ecological, humanitarian and economic effects of floods of two communities. The paper pictured the impact of flood on farmers for access of seed and also depicts the influence of flood on food production. It gives a ranking of factors of vulnerability and livelihood impacts. Finally the study describes the flood induced out migration and coping strategies of the communities.

Banik (2016) took an attempt to examine the socio-economic impact of Gazaldoba barrage. The paper illustrated the development of irrigation potential of the multipurpose river valley project in different stages. The study unveils the irrigation, hydroelectric power generation, flood protection, tree plantation, transportation and communication, tourism, recreational facilities are the multipurpose development initiatives served through the Gazaldoba barrage. According to the study, though the Teesta barrage project is an ambitious task, it will positively transform the socio-economic status of the entire region.

Bhuiyan *et al*., (2017) have explored the impact of river bank erosion of Padma river. The study identified the erosion trend from 1973-2011 which shows 189.4 sq.km area has been eroded from the left bank and 166.5 sq.km area has been eroded from the right bank of the Padma river. They discussed the impact of erosion on economy, infrastructure, agricultural land, cropping pattern, livelihood, population displacement and soil fertility. The paper also demonstrated the comparison of vulnerability among the study unions. The study finds out that the local community depends upon the natural capital to sustain their livelihood.

Das *et al*., (2017) examined the impact of Ganges river bank erosion in the lower reaches in Maldha district in India. The study gave emphasis on the economy, living condition education and health as socio-economic indicator to analyze the impact. They studied the impacts of river bank erosion through occupational pattern and poverty indices. The study result indicates that the displaced households are suffering for better life condition. The research shows the short term impact is economic loss and long term impact of river bank erosion is poverty.

Rahman and Khan (2011) analyzed the socio-economic damages of flood and identified the causes of flood in Swat valley of the Hindu Kush region, Pakistan. The study designates the record of flood events from 1992-2010 and describes the type of damages. The analysis of the study reveals the damaged sectors are houses, agricultural lands, social infrastructures, livestock's, and human lives. It estimated the monetary cost of the damaged sectors. The study recommended land use control policy formulation, making house with flood resistant materials and community participation for decision making will minimize the damages of flood.

Latif and Rahman (2017) have compiled the impact and survival strategies of bank erosion of Jamuna river of Kazipur upazilla, Bangladesh. The study depicted the social impacts such as family structure change, relocating households, problem of sanitation and drinking water supply. The economic impact includes change in occupation, income, savings and peasant type before and after the bank erosion. The study identified the coping techniques adopted by the victims are damage minimization techniques, bank prevention through indigenous practices, use of movable housing materials, lives and property shifting and clustered settlement pattern development. Concluding remarks of the study suggests long term policy formulation, identification of erosion prone area, polder or cross dam construction, tree plantation and provide low interest financial assistance.

Impact of Bhagirathi-Hoogly river bank erosion has been examined by Chatterjee and Mistri (2013). They investigated the socio-economic damage of the victim villagers of Nadia district of west Bengal. The study result shows that each year 10 meter land has been lost due to river bank erosion. The paper inspected monetary loss, household property loss and land loss are the impacts of bank erosion. Mass displacement is a very common issue for survival and about 66.82% respondents were displaced 4 times within 20 years in the study. The concluded with the suggestions of dredging, erosion resistant crop variety cultivation, use coconut and wood fiber as well as synthetic mat to protect river bank from erosion.

Rahman (2010) has depicted the impact of river bank erosion in one of the major floodplains of Bangladesh, the Jamuna river floodplains. Erosion rate of different rivers and river width change rates of the years 1984-93 were portrayed in this article. The paper gives prominence on the socio-economic impacts of river bank erosion hazard. The study result shows how flood and climatic variables effects on erosion.

Uddin and Basak (2012) investigated the impacts of erosion on livelihood of the inhabitants of Gaibandha and Sirajganj district alongside the Jamuna river. The intensity and causes of erosion has been discussed in the study. The study shows the loss of agricultural land and loss of production causes livelihood destruction. According to the study the ultimate cause of livelihood damage is force displacement or migration. The study unveils that the livelihood vulnerability of the affected people has been reduced through low expenditure in food, education and health care.

2.3.9 Adaptation Strategies to River Morphology Change

Haque (1988) evaluated human adjustment towards river bank erosion in Bangladesh. The study has been carried out in the Jamuna river floodplains. The mode of coping such as acceptance, reduction and change has been described in the paper. The study finds out that the perceived adjustment measures and actual adjustment strategies are correlated and the actual adjustment strategy is highly diversified.

Haque and Zaman (1989) assessed the adjustment strategies of bank erosion victims. The study explores the channel shifting of Brahmaputra-Jamuna floodplain. The study recommended enhancing people's ability on the way to adjust with river bank erosion.

Hutton and Haque (2003) examined the adaptation strategies of river bank erosion displace in Bangladesh. The research aimed to investigate the socio-cultural coping and gave emphasis on psychological distress of the river bank erosion victims. The study finds out the cause of impoverishment of erosion induced displaces. The paper also highlights on hazard analysis, disaster preparedness and mitigation.

Paul and Routray (2010) investigated the coping strategies of rural Bangladeshi communities towards flood. The study examined a comparison of flood proneness of the two study villages. The research paper elaborately discussed the determinants of coping with flood. The study finds out coping techniques regarding human lives; shelter; protect crop, poultry, livestock; food, fuel and water. The study result indicates that indigenous coping strategies reduce flood vulnerabilities.

Rumi (2002) explored the facts behind the flood damage and defense of 1998 floods. The study evaluated the national level flood damage along with the family level flood damage and effective flood protection techniques. It also illustrated the possible causes of 1998 flood and indigenous practices of adaptation with floods. The study concludes with the emphasis of nonstructural measures would be more influential for flood defense.

Islam *et al*., (2013) narrated coping techniques of flood and river bank erosion affected char population of Bangladesh. The paper gives a comparison of impact and adaptation strategies of two selected villages of Tangail district. The study identifies move in safer place, use water hyacinth barrier, homestead raising are important adaptation techniques during flood and the river bank erosion coping techniques adopted by the villagers are housing material saving, standing crop and tree cutting, livestock sell etc. The article also occupies the relationship between respondent's income and food availability, education level and flood forecasting information collection, food availability and occupation. Thus the study finds out the facts that the respondents who have better education, income and job opportunities are less vulnerable to river bank erosion and flooding conditions.

A study conducted by Nasreen and Kundu (2008) identifies the facts behind the role of women coping with monga in the Northern Bangladesh. The study is qualitative in nature which elaborates the untold sufferings of the women during economic hardship. The article illustrates the wage discrimination, intra-household crisis, food insecurity of the vulnerable women who are the lonely soldiers of her family without her husband's presence in the economic hardship period and sometimes lifelong absence of male members. The identified coping strategies are vegetable collection, fuel wood collection, borrow money, advanced labor sell, double payment of harvested aman paddy, arrange alternative food items etc. The study pinpoints economic hardship as a social disaster and recommended a national policy for economic hardship.

Islam *et al*., (2014) focused on the *char* population's adaptive capacity towards flood and river bank erosion through their indigenous survival mechanism. It is evident from the study that to adapt with the adverse situation, people migrate in different areas of the country. The study has been conducted in the *char's* of Jamuna river and the findings of the paper identified that without any outer facilities the char people adapted themselves with indigenous coping techniques in the adverse environmental conditions.

Rahman *et al*., (2008) assessed the vulnerability and adaptation of climate change in the coastal area of Bangladesh. The study analyzed the demographic, socio economic, physical as well as cyclone and storm surge vulnerability of the study area. It also illustrated a vulnerability map of the study area. The study finding also exposes coping strategies of the community people of different hazards and adaptation options occupied by the Government of Bangladesh. The study suggestion includes cyclone shelter facility upgrading, early warning system development, afforestation and earthen mount construction.

Sheheli and Khan (2015) elaborated the survival strategies of woman in Bangladesh with special reference to flood. The study characterized women's coping strategies with flood into three classes such as prevention, management and recovery. The study analyzed FCSPI (Flood Coping Strategies Practice Index) through 30 flood survival techniques followed by woman and ranked the techniques. It also assessed the score of flood coping ability of woman. Finally the study suggests improvement of health, education, shelter and credit would recover the damage of livelihoods of the poor woman.

Hossain (2015) has analyzed the survival techniques of displaced population due to Padma river bank erosion. The study focused on the adversities faced by the study area population and their coping techniques with cruel bank erosion. The case studies conducted in the study clearly describes the adaptation techniques of the victim people. Finally the study has drawn a policy model to combat with river bank erosion.

Minhaz (2013) examined the coping strategies and vulnerability of disaster in Bangladesh. The study assessed the socio-economic characteristics of the disaster affected people. It gave emphasis on flood disaster and flood vulnerability of the affected people. The study also highlighted a number of flood coping strategies of the respondents for survival. Finally the study demonstrates the factors prompting the community people acceptance of such coping strategies for flood.

2.3.10 Flood and Erosion protection, warning, mitigation and management

Kabir *et al*., (2007) analyzed erosion protection measures for different floods of the Jamuna, Ganges, Padma, and Mahananda river. The research was based on the two dimensional morphological model MIKE21C. The study finds out the erosion vulnerable areas and made guidelines for appropriate protection measures for those affected areas. The study suggested that the Jamuna right bank erosion protection measure should be revetment, the Ganges and Mahananda left bank erosion protection measure would be the combination of revetment with hard points and short spur series, the Padma river right bank erosion protective measure would be revetment type structure. The paper is an important work in river bank erosion study for its erosion vulnerable area selection, recommendation of suitable erosion defense measures and its planning as well as design. Rahman *et al*., (2011) have conducted a study on river bank protection through bamboo bandalling. The study describes the river bank stabilization mechanism with bamboo bandalling structure. The paper highlights the comparison among the costly structural river bank erosion protection measures with low cost bamboo bandalling structure. The practical evidence of bamboo bandalling structure in the Jamuna river indicates that it protects river bank erosion and traps sediment in river bank. The paper concludes with the remarks that dredging and sand mining should be restricted to stabilization of river bank with bamboo bandalling.

A study entitled “River bank erosion and mitigation strategies in Vietnam” has been conducted by Klaassen *et al*., (2005). The study focused on two erosion prone rivers of the country, the Mekong and the red river. It described the characteristics and planform pattern of both the rivers. Deforestation, increasing flood magnitude and frequency, sand mining, increasing population and economic activity etc. are identified the causes for acceleration of river bank erosion. The study gives an overview of bank protection measures of Vietnam and discusses long term bank protection works. Possible bank protection techniques suggested by the study are initiating a master plan for river, capacity building for erosion forecast, monitor, prevention and management along with sustainable financing.

Hung, (2006) elaborated the concept of forecast river bank erosion on his M.sc thesis about river bank erosion forecast and mitigation methods in the lower Mekong river. He narrated the processes of river bank erosion, its causes and effects. Description of both empirical and numeric modeling unveils the fact that mathematical modeling is very effective for river bank erosion prediction. The research is based on mathematical modeling and Geographical Information System. Preventive measures for bank erosion suggested in the thesis are revetment, cutting of meandering bend and construction of permeable groin in suitable location. The thesis is noteworthy to understand river bank erosion, forecast and its possible mitigation measures.

Chowdhury and Ward (2007) explored the variability of seasonal flooding of Bangladesh in their article entitled ‘Seasonal flood potential- Bangladesh- a scheme for an advance warning and response plan for hazard mitigation’. The findings of the paper revealed that both upstream and downstream rainfall is correlated with the seasonal flow of the major rivers. Moreover the paper also inspected the El Nino Southern Oscillation (ENSO), Sea Surface Temperature (SST) and General Circulation Model (GCM) for seasonal flooding. The study recommended Flood Forecasting and Warning Response System (FFWRS) as a significant tool for seasonal flood forecast and hazard mitigation.

Shoeb and Assheuer (2008) has highlighted the experiences of the NGOs for flood management. The study finds out the facts about the genesis of NGOs in Bangladesh, the inflow of external aids and different activities of the NGOs through Participatory Rural Appraisal (PRA) method to the community people of the study villages. The study finds out the Income generating Activities (IGA) through microcredit plays a significant role in flood management.

Hassan *et al*., (2007) explored mathematical model as a best option for flood management. Their study findings explored nine options for flood management of Gumti river but they recommended only one option which termed as release of excess flow from Gumti in Ghungur and re excavation of Ghungur river through different impact assessment. The study also explored the possible causes of embankment breaching.

Hossain *et al*., (2008) investigated the flood mitigation practices in Bangladesh. The study discussed the flooding condition, flood types, damages due to flood and river bank erosion for flood occurrences. It narrated the structural and nonstructural measures for flood management in Bangladesh. Though high cost bank protection measures are initiated in the country in large scale, the study noticed low cost measures such as bamboo bandals, floating screens, bamboo porcupines are implemented in minor scale. The study also mentioned a new concept of bottom vanes which is low cost and initiated in Elanjani river to flood control through sediment deposition in the eroded banks.

Schielen and Roovers (2008) have integrated adaptation techniques as a method of flood management. The study initiated a new approach for flood management that people should take flood as normal situation and the flood affected community has to know how to minimize flood damage. The concept is described as adaptation in the article. The study discussed the current flood defense system of Netherland and the adaptation process investigated in the study is adaptation within the society rather than adaptation with individuals. The concept explained five elements of safety chain such as prevention, preparation, repression and recovery as well s illustrated a bow-tie model for safety chain. Finally the research discussed six elements of flood defense for adaptation.

Fleta *et al*., (2008) explored the planning of fluvial environment through flow discharge, river side zonation and management. The riverine ecosystems have been taken into consideration for fluvial environment planning. The study includes the morphodynamics, physical, biological and cultural environment to develop a fluvial environment planning. The research also examined fluvial area, hydric system and flooding zone aimed at fluvial zonation for land use.

Karamouz *et al*., (2008) carried out a research on “Developing a flood warning system: A case study”. The study examined a flood warning system of Kajoo watershed of Iran. Hydrological and weather data has been analyzed in the study to develop a flood warning system. The study investigated rainfall-run off simulation model and hydraulic simulation model for flood routing. Flood warning algorithm has been used in the study to predict the return period of flood.

Ringo *et al*., (2016) have explained the role of indigenous knowledge in flood management in Tanzania. The study examined implementation of local knowledge and indigenous practice helps the local community to manage the flooding condition. The paper also evaluated the contribution of indigenous knowledge to control flood. The study concludes with the remarks of rich heritage of indigenous knowledge assist the community people to control flood.

Ahmed (2007) has examined the role of different organizations for river basin and water resource management. The author focused on the regional and sub-regional multilateral cooperation and take lessons from global experience of Multi-purpose River Basin development (MRD) initiatives. The study recommended establish River Basin organization (RBO) in the co-riparian country, develop MRD, initiate public participation in decision making, take initiatives for trans boundary water issues including the Teesta.

2.4 Research gap

River morphology is an interesting term and Bangladesh is widely known as a country of rives. The Brahmaputra-Jamuna and the Ganges-Padma river has attracted the geomorphologists, geographers, geologists, hydrologists and river engineers from national to international scale. The Teesta received very tiny devotion in terms of other rivers of the country for research. Most of the river related studies showed the consequences and adaptation of flood and riverbank erosion Such as Banik (2012), Chatterjee and Mistri (2013), Baishya (2013), Bhuiyan *et al*., (2017), Ran (2008), Hutton and Haque (2003), Haque and Zaman (1989), Paul and Routray (2010), Islam *et al*., (2012), Sheheli and Khan (2008), Hossin (2015). Notable research works on flood has been carried out within the country by Haque (1988, 1993), Brammer (1996,1999), Haque and Zaman (1993, 1994,). Now a days satellite image processing and GIS based research on river channel shifting has been fascinated by the researchers such as Chakraborty and Dutta (2013), Ashworth *et al*., (2000), Ahmed and Fujita (2007), Alam *et al*., (2007), Jacobson and Oberg (1997), Li *et al*., (2007), Uddin *et al*., (2011), Matsuda (2004), Chakraborty and Ghosh (2010), Yuzhi and Chunde (2009), Ghosh (2014), Gupta (2012), Venkatramanan *et al.*, (2013), Islam *et al*., (2014). The reviewed articles regarding GIS and RS show the spatial and temporal changes of river morphology but most of the cases the causes and consequences have not been flourished.

Aggradation or sedimentation has been considered as an important topic of research. Jian *et al*., (2009), Constantine *et al*., (2014), Promny and Vollmer (2011), Middlekoop (2005), Meetai *et al*., (2007), Wasson (2003) , Hassan *et al*., (2007), Yang *et al*., (2006) carried out their research on aggradation of river system that impacts on river morphology. The pioneer research on river bank erosion in Bangladesh has been done by Elahi and Rogg(1990), Elahi (1991). Moreover a number of literature reviews on river bank erosion has been done such as Hooke (1979), Mohiuddin *et al*., (2007), Thakur *et al*., (2012), Hassan *et al*., (2016), Akter (2013), Mollah and Ferdaush (2015) etc. The present study also reviewed the researches about human interference on river morphology such as Topolska and Klucovoska (2008), Khan and Islam (2015), Torab and Azab (2007), Mogborukor (2014), Mei *et al*., (2015), Raslan (2009), Yang *et al*., (2007), Wiejaczka *et al*., (2014).

A number of studies of different river basin have been carried out inside and outside the country. But the downstream course of the Teesta river basin and its topography, hydro-climatic condition, geology, physiography is quite different from those river basins. Flood, river bank erosion, bank failure, siltation, mid-channel bar formation, all these morphodynamic events are very common in the study reach. The community of the basin area faces a variety of disastrous and worse situation for changing river morphology which made the vulnerable people take different adaptive measures. So the study is totally different in that context. The study also differs from other studies because it tries to explore the impacts of river morphology change, causes behind that change and also the adaptation for this kind of change. All the studies of river morphology change analyzed the issue through GIS and RS techniques. But the present study will explore the morphological change of Teesta river by GIS, RS techniques and also people's perception about river morphology change, impact of morphological change and adaptation strategies through questionnaire survey. Some studies showed the impact and adaptation strategies by questionnaire survey method such as Nasreen and Kundu (2008), Minhaz (2013), Islam *et al*., (2014), Rahman *et al*., (2012) etc. There is not available any study about both morphological change (through GIS, RS) and its impact, adaptation (through questionnaire survey). So it is very much crucial to conduct a comprehensive study about morphological change detection, its impacts on the environment and local community and thus explore the facts behind the river channel change, course shifting, erosion, and sedimentation. So the present research will enhance our knowledge about the particular issue and also give new essence in the study of river morphology change, its impact and adaptation.

Chapter Three
Research Design and Methods

3.1 Nature of the study

The study is both exploratory and explanatory in nature. Data and information about respondent's perception on morphological change, its impact and adaptation strategies have been investigated from questionnaire survey. Moreover, the data of water discharge, water level, flood and erosion has been collected from different secondary sources for explanation and exploration of the research problem. Besides different GOB (Government of Bangladesh) and NGO activities regarding river morphology change related issues and adaptive measures to ensure livelihood options has been investigated through structured questionnaire. Respondent's opinion and suggestions for better management of river morphology has been explored in the study as well. Data analysis has been done with SPSS software (Statistical Package for Social Science) and represented by different statistical techniques. Morphological change of the study area has been depicted by analysis of satellite images of last four decades and spatio-temporal change of river morphology has been illustrated through GIS and Remote Sensing techniques.

3.2 Research Design

Research design is an integrated task of literature review and scientific investigation technique. A comprehensive literature review has been carried out to establish a research design. It embraces the problem statement, research gap identification, research objectives identification, field observation, questionnaire survey, satellite image processing, data analysis and interpretation. To organize such a huge effort, research coordination schema has been prepared. Both qualitative and quantitative data has been collected from the field survey and the secondary sources to analyze the data regarding the issues. To fulfill the objectives of the current study both satellite image processing and questionnaire survey have been conducted. To identify the erosion, deposition and river bank line shifting a multi-date Landsat imageries ranging from 1975-2017 have been used. Arc GIS 10.2.2 version has been used to detect the river morphology change. Diagrammatic representation of the research design is displayed in Figure 3.1

3.3 Research Methods

3.3.1 Selection of study area

The study area has been selected purposively. The study area has been selected carefully to investigate the Teesta river morphology change, impacts of the change and peoples adaptation strategies for such changes.

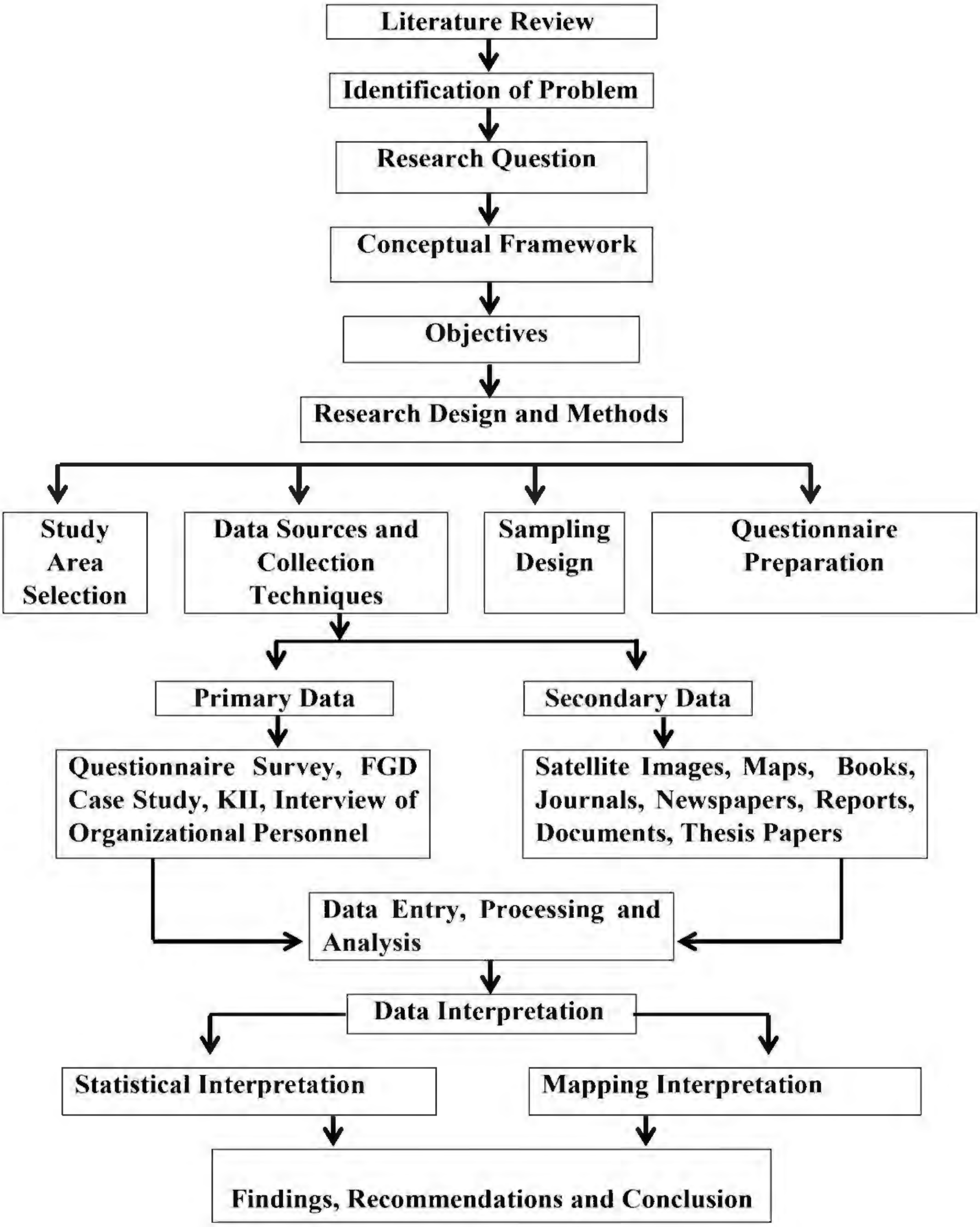

Literature Review
Identification of Problem
Research Question
Conceptual Framework
Objectives
Research Design and Methods
Study Area Selection
Data Sources and Collection Techniques
Sampling Design
Questionnaire Preparation
Primary Data
Secondary Data
Questionnaire Survey, FGD Case Study, KII, Interview of Organizational Personnel
Satellite Images, Maps, Books, Journals, Newspapers, Reports, Documents, Thesis Papers
Data Entry, Processing and Analysis
Data Interpretation
Statistical Interpretation
Mapping Interpretation
Findings, Recommendations and Conclusion

Figure 3.1 Flow chart of research design

3.3.1.1 Selection criteria of study area

The man-environment relationship is influenced by the Teesta river in the study area. The Teesta river flows through the districts of Nilphamari, Lalmonirhat, Rangpur, Kurigram and Gaibandha. The inhabitants of the mentioned five districts are directly and indirectly affected by the morphological changes of the Teesta river. The study area selection criteria are as follows:

- The study unions are bordering to the Teesta river.
- River morphology change related hazards take place in the study area regularly.
- The hazardous events convey distresses to the river basin community.
- The agriculture and livelihood of the study area mostly depends upon the Teesta river water and river morphology.
- The study area is identified as morphologically changed hotspots from satellite images.
- The study area is highly flood, erosion and accretion prone which is also marked in national newspapers.
- Moreover, the study area possesses a long geomorphological history of river course shifting, floods, erosion, sediment deposition and flood plain formation.

Hence, considering the above mentioned criteria, the study area has been selected for the present research to carry out the facts behind the morphological changes in the Teesta river basin. From the field observation it has been identified that the study area is always changing its morphological landscape which performs as a driving force for the basin area community people’s life, resource, livelihood and death.

3.3.1.2 Study Area Selection Procedure

The communities of the river basin are influenced by the riparian environment. The inhabitants of the Teesta river basin are closely related with the river for their everyday life. The present study purposively selected five districts of Northern Bangladesh as study area which lies in the Teesta river basin. Seven *upazilla*[13] from five study districts and then one *union*[14] from each *upazilla* have been selected purposively (Map 3.1 and Map 3.2). Satellite image analysis also reveals that the Teesta river channel shifting occurs enormously in the study *upazillas* and *unions*. Number and name of selected districts, *upazilas* and unions are shown in (Table 3.1)

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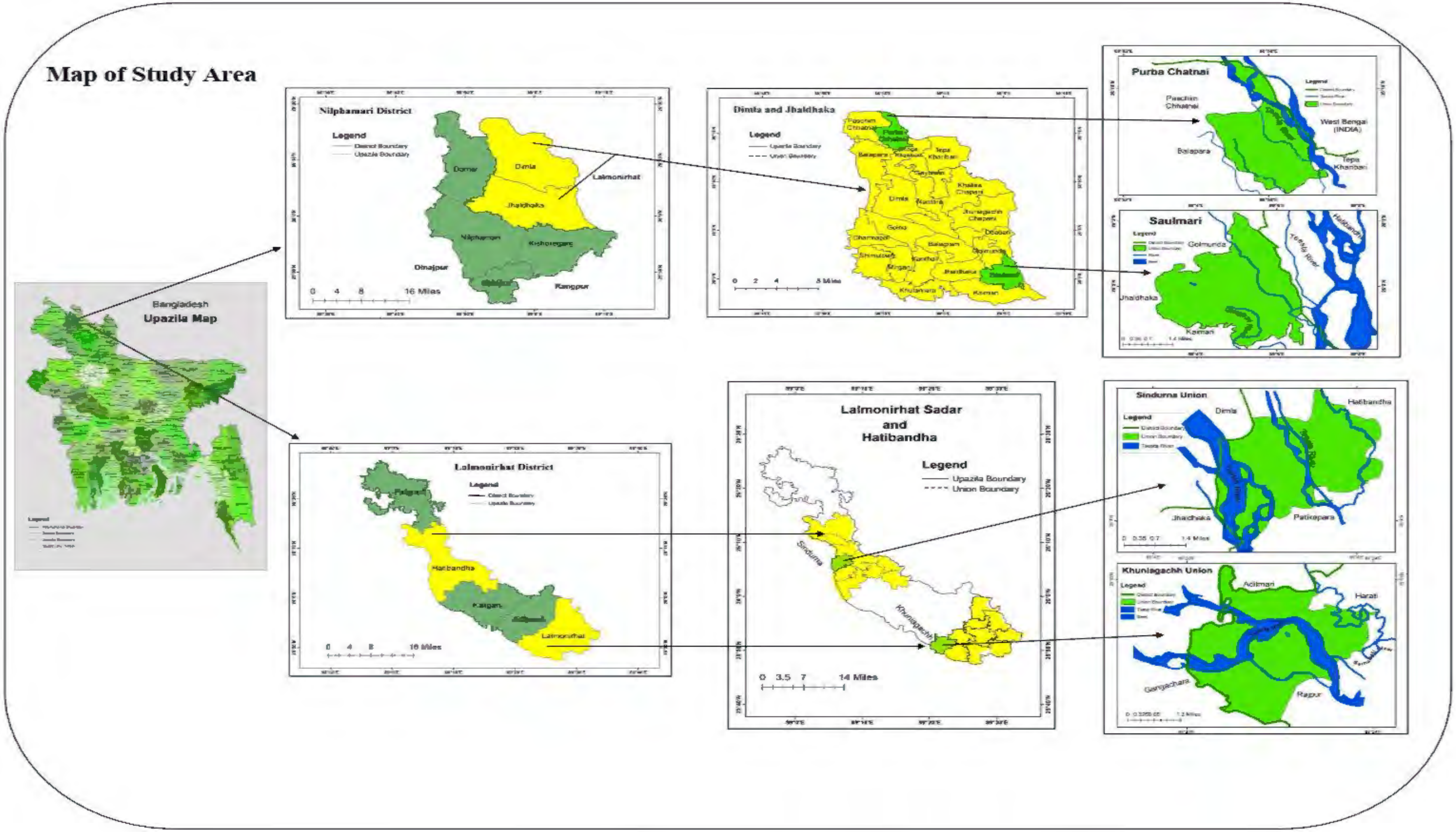
[13] *Upazilla* refers to the subunit of district which comprises of several unions.

[14] *Union* is the lower most administrative unit consisting of several villages.

Table 3.1 Number and name of selected districts, *upazilas* and *unions*

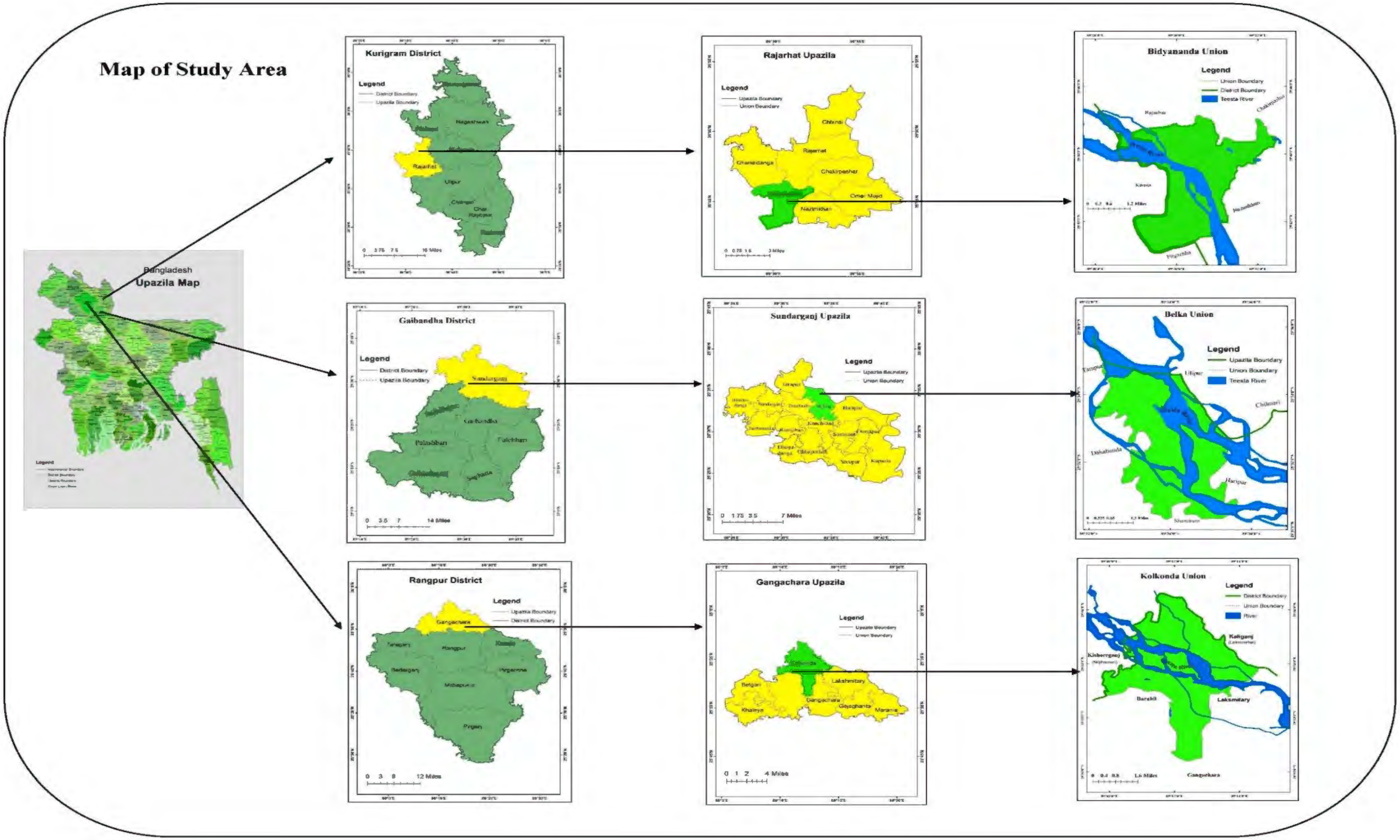
Name of districts	Total no. of upazillas	No. of upazilias under Teesta Flow	Name of upazillas under Teesta Flow	Selected upazillas	Total number of unions	No. of unions under Teesta Flow	Total number of selected union	Name of Selected unions
Nilphamari	6	3	Dimla, Jaldhaka, Kishoregonj	**Dimla**	10	6	1	Purba chatnai
				Jaldhaka	10	3	1	Saulmari
Lalmonirhat	5	5	Patgram, Hatibandha, Aditmari, Sadar, Kaliganj	**Lalmonirhat sadar,**	9	3	1	Khuniagachh
				Hatibandha	10	6	1	Sindurna
Kurigram	9	3	Rajarhat, Ulipur, Chilmari	**Rajarhat,**	7	3	1	Bidyananda
Rangpur	8	3	Gangachara, Kaunia, Pirgacha	**Gangachara**	10	5	1	Kolkonda
Gaibandha	7	1	Sundarganj	**Sundarganj**	15	6	1	Belka
Total	35	15			71	31	7	

Source: BBS, 2011


Map of Study Area

Bangladesh
Upazila Map
Nilphamari District
Legend
District Boundary
Upazila Boundary
Domar
Dimla
Jhaldhaka
Nilphamari
Kishoreganj
Saidpur
Dinajpur
Rangpur
Lalmonirhat
0 4 8 16 Miles
Dimla and Jhaldhaka
Upazila Boundary
Union Boundary
Paschim Chhatnai
Purba Chhatnai
Balapara
Tepa Kharibari
Khalisa Chapani
Jhunagachh Chapani
Golna
Dharmapal
Shimulbari
Golmunda
Saulmari
Kaimari
0 2 4 8 Miles
Purba Chatnai
West Bengal (INDIA)
Saulmari
Jhaldhaka
Teesta River
Lalmonirhat District
Patgram
Hatibandha
Kaliganj
Aditmari
0 4 8 16 Miles
Lalmonirhat Sadar and Hatibandha
Sindurna
Khuniagachh
0 3.5 7 14 Miles
Sindurna Union
Patikapara
Khuniagachh Union
Harati
Rajpur
Gangachara

Map 3.1 Map of study area (Nilphamari, Lalmonirhat)


Map of Study Area
Bangladesh
Upazila Map
Legend
Kurigram District
Legend
District Boundary
Upazila Boundary
Nageshwari
Rajarhat
Ulipur
Chilmari
Char Rajibpur
0 3.75 7.5 15 Miles
Rajarhat Upazila
Legend
Upazila Boundary
Union Boundary
Chhinai
Rajarhat
Ghariadanga
Chakirpashar
Omor Majid
Nazimkhan
Bidyananda
0 0.75 1.5 3 Miles
Bidyananda Union
Legend
Union Boundary
District Boundary
Teesta River
Gaibandha District
Legend
District Boundary
Upazila Boundary
Sundarganj
Gaibandha
Palashbari
Fulchhari
Gobindaganj
Saghata
0 3.5 7 14 Miles
Sundarganj Upazila
Legend
Upazila Boundary
Union Boundary
Belka
Haripur
Kanchibari
Sarbananda
Chhaparhati
Kapasia
Sreepur
0 1.75 3.5 7 Miles
Belka Union
Legend
Upazila Boundary
Union Boundary
Teesta River
Ulipur
Chilmari
Haripur
Rangpur District
Legend
Upazila Boundary
District Boundary
Gangachara
Taraganj
Rangpur
Kaunia
Badarganj
Pirgachha
Mithapukur
Pirganj
0 3 6 12 Miles
Gangachara Upazila
Legend
Upazila Boundary
Union Boundary
Kolkonda
Betgari
Lakshmitary
Khaleya
Gangachara
Gajaghanta
Morneya
0 1 2 4 Miles
Kolkonda Union
Legend
District Boundary
Union Boundary
River
Kaliganj
Kishoreganj
Barabil
Lakshmitary
Gangachara

Map 3.2 Map of study area (Kurigram, Rangpur, Gaibandha)

3.3.2 Sampling Design

3.3.2.1 Sample size determination

To determine the sample size from finite population the formula of Kothari (2004) has been used.

$$n = \frac{z^2 . pq . N}{e^2(N-1) + z^2 . p . q}$$

Here,

n= Sample size

N= Total number of households

z= Confidence level (at 95% probability=1.96)

p= Estimated population proportion (0.5 which maximizes the sample size)

q= 1-p

e= Error limit of 5% (0.05)

3.3.2.2 Sampling techniques

Two sampling techniques are used such as purposive sampling and simple random sampling to collect data through field survey (Table 3.2). At first five districts and seven upzillas are also selected purposively. Among the upazillas of the district’s one upazilla of Rangpur, Kurigram and Gaibandha district and two upzillas of both Nilphamari and Lalmonirhat districts are selected purposively. Then one union of each upazilla is selected purposively. Two upaziilas of Nilphamari and Lalmonirhat districts are selected because three upazillas of Nilphamari and five upzillas of Lalmonirhat district show linear pattern distribution adjacent to Teesta river basin and the selected upazillas and unions face high frequency of river morphology change as well as human casualty.

Table 3.2 Sampling methods of study area and respondents

Sampling Methods	Sampling population
Purposive sampling	Districts: Nilphamari, Lalmonirhat, Kurigram, Rangpur, Gaibandha.
Purposive sampling	Seven Upazillas from five districts.
Purposive Sampling	One union from each upazilla (total 7 unions).
Simple Random Sampling	Selected 381 households.

Simple random sampling technique has been used to select household to collect information from respondents. Out of 40542 households, the sample size has been determined 381. Table 3.3 depicts the sample size of the present study.

Table 3.3 Household statistics and sample size determination

Name of Selected unions	Total Household	No. of calculated respondents	Reserve sample (5%)
Purba chatnai	3446	34	2
Saulmari	6208	64	3
Khuniagachh,	7029	72	4
Sindurna	3026	30	2
Bidyananda,	4530	41	2
Kolkonda	6448	64	3
Belka	7608	76	4
Total	40542	381	20

Source: BBS, 2011

3.3.3 Data sources

Both primary and secondary data has been used in the present study. Data has been collected from different sources to fulfill the aims and objectives of the research.

3.3.3.1 Sources of Primary data

Primary data has been collected from the respondents of the selected study area of Teesta river basin through questionnaire survey. To collect data and information from the field, different types of survey such as questionnaire survey, case study, FGD, Key Informants Interview (KII) etc. has been conducted.

3.3.3.2 Sources of secondary data

All necessary secondary data has been collected from various sources. The statistical information has been gathered from Bangladesh Bureau of Statistics (BBS), zila[15] community series, upazilla office, union office etc. Data of water discharge, water level and flood has been collected from BWDB. Different journal articles, books, newspapers, reports, conference paper, and unpublished thesis, has been used as secondary data sources. Toposheet of the year 1975, and 1991 has been used for morphological feature study. Satellite images have been gathered from United States Geological Survey (USGS). To detect the morphological change of Teesta river Landsat thematic mapper series such as TM, with 30 meter, MSS (Multi Spectral Scanner) with 60 meter and OLI-TIRS (Operational Land Imager Thermal Infra-Red Scanner) with 30 meter resolution has been used. The satellite images have been processed through Arc GIS software. So, the study is a combination of field survey, GIS and RS techniques. The secondary data sources are:

- Books, journals and newspapers
- Bangladesh Bureau of Statistics(BBS)
- Bangladesh Water Development Board(BWDB)
- Soil Resource Development Institute(SRDI)
- Records of upazillla statistical office
- United States Geological survey satellite image
- Different Websites

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[15] *Zila* is a local term which is synonymous to district.

3.3.4 Questionnaire preparation and respondent selection

Different types of questionnaire have been prepared to collect data and information from field survey. Respondents are selected carefully.

3.3.4.1 Questionnaire preparation

According to the aim of the present study a well-structured questionnaire is prepared for bringing together information from the respondents. The language of the questionnaire is easy to response and it is prepared sensibly so that it would not irritate and annoy the respondents. The questionnaire is designed carefully so that it can identify the causes and impacts and adaptive measures of the local community for morphological change of the study area. Moreover, questionnaire for key informants, questionnaire for FGD and questionnaire for different organizational personal has been prepared carefully to collect necessary data and information.

3.3.4.2 Type of respondents

Primary data has been collected from different types of respondents. Household questionnaire survey data has been collected from the household head. The respondent types are:

I. Household head of Riparian community.
II. Experts of the issue.
III. Organizational personnel.

3.3.4.3 Selection of respondents

To collect primary data it is necessary to select respondents to get correct information. In every sector questions has been asked to the head of the household. If the head of the household is not present then data has been collected from the reserve sample. The respondents are assured that their information would be secured. A Well-structured both open and close ended questionnaire has been designed to assemble information. Experts of different fields were selected as KII and GO/NGO officials are also selected as organizational personnel to collect data from the field. Table 3.4, 3.5 and 3.6 represents the list of experts, list of organizational personnel and total number and type of respondents respectively.

Table 3.4 List of experts from different sectors

Category	**Number**
Geomorphologist	2
River/ water researcher	2
Hydrologist	2
Total	6

Table 3.5 List of organizational personnel

Category	**Number**
NGO personnel (One personnel from each NGO)	5×1=5
GO personnel (One personnel from each Government organization)	5×1=5
Total	10

Table 3.6 Total number and type of respondents

Type of respondents	Number
River basin area sample population	381
Experts of the issue	6
Organizational personnel	10

3.3.5 Primary data collection techniques

Different techniques have been adopted to collect data from primary and secondary sources.

3.3.5.1 Reconnaissance survey

A reconnaissance survey has been conducted during first field visit. Reconnaissance survey helps to conceptualize the practical situation of river morphology and obtaining background information of the study area before questionnaire survey. In order to identify the present status of Teesta river morphology, impact of river morphology change and adaptation strategies of the riverine communities of the study area the reconnaissance survey smoothed the path of study area selection, factor determination and questionnaire finalization.

3.3.5.2 Field observation

Observation is an oldest technique for scientific data collection. Basic facts about the study area have been accumulated through field observation. The observed evidences have been noted. The observation technique has been conducted to framing out the present scenario of river morphology as well as its impact on the local community and their adaptation practices for such changes.

3.3.5.3 Questionnaire survey

Questionnaire survey is a popular method to collect information from households. Questionnaire survey has been conducted to collect information about respondent’s perception, causes of morphological change, its impact and adaption strategies. The questionnaire survey session has been facilitated through the respondent’s face to face interview with a structured questionnaire during day time ranging from 7 to 9 hours.

3.3.5.4 Focus group discussion (FGD)

FGD is a cost effective method to obtain insight from target population. Respondent’s perception, local wisdom regarding river morphology change, causes and consequences of such changes on local community has been gathered through FGD. It is a popular and easier method to collect various data and information within a limited timeframe. The present research conducted one FGD from each union. For each FGD 10 people both male, female with various age group and occupation such as farmer, fisherman, day labor, housewife, house maid, business man, teacher etc. has been selected.

3.3.5.5 Case study

Case study method has been adopted to collect in-depth impact and adaptation techniques of the respondents. The study conducted four case studies to acquire knowledge about river morphology change impact and adaptation. Among the case studies two were directed to know how the river morphology change process ruined each person's life and livelihood. The another two case studies also portraits the survival techniques of the vulnerable Teesta river basin communities. The respondents of case study have been chosen purposively.

3.3.5.6 Key informants interview

River/ water researcher, Geomorphologist and Hydrologist who are the experts in the field, has been considered very essential source of information. The interview has been conducted through questionnaire to provide unknown facts about the issues and expert's suggestions about river morphology management.

3.3.5.7 Interviews of GO and NGO officials

Interviews of different officials of Government and non-government sector has been conducted with structured questionnaires to know their views, ideas and experiences working with river morphology change related issues. Officials of NGOs such as RDRS (Rangpur Dinajpur Rural Services), GUK (Gono Unnayan Kendro), POPY (Peoples Oriented Program Implementation) etc. and Government Officials of BWDB, Local government, Social welfare, Land office, District Commissioners office, *Upazilla* office were taken into considerations for collection of data and information.

3.3.5.8 Photographs

To illustrate the actual scenario of the study area, photographs are considered as an important tool. Photographs on the basis of different conditions such as fluvial geomorphology, hydrology, impacts and adaptation of changing river morphology has been collected which easily demonstrates the actual situation. The collected photographs of different situations are:

- Morphological change related photographs.
- Photograph of landform features.
- Photograph of flood, erosion and sedimentation.
- Photograph of impact on man and environment.
- Photograph of preventive measures.
- Photograph of adaptation strategies.

3.3.6 Collection of Satellite Images and Maps

To illustrate the erosion and sedimentation, and geomorphological features of the study area, satellite images have been collected. Maps of geological condition, flood, river bank erosion etc. have been collected from different websites and the seminar library of the department of Geography and environmental studies, University of Rajshahi. To detect the morphological change of Teesta river Landsat MSS, TM and OLI-TIRS of each decades ranging from 1975-2017 have been collected from USGS Earth Explorer. Green, blue, red, infrared and near infrared bands of Landsat imageries has been used for False Color Composite (FCC). The projection method was Universal Transverse Mercator (UTM) 46N. Software used in this study is ERDAS Imagine 2014 to process remotely sensed data and spatial analysis. ArcGIS 10.2.2 used to process data in GIS operation. Table 3.7 shows the list of Imageries Used in the study for morphological change identification.

Table 3.7 List of Imageries Used in the study and their Attributes

No	Images	Path/ Row	Sensor ID	Resolution	Date of Acquisition	Source
1.	Landsat 1975	148/42 149/42	MSS	60 meter	17th and 18th November 1975	USGS Earth Explorer
2.	Landsat 1987	138/42	TM	30 meter	24th November 1987	USGS Earth Explorer
3.	Landsat 1997	138/42	TM	30 meter	1st November 1997	USGS Earth Explorer
4.	Landsat 2006	138/42	TM	30 meter	1st January 2006	USGS Earth Explorer
5.	Landsat 2017	138/42	OLI_TIRS	30 meter	8th November 2017	USGS Earth Explorer

3.3.7 Data processing, analysis and interpretation

Data processing is the key factor for conducting a research. Both the primary and secondary data were carefully processed, analyzed and interpreted. The processing procedure consists of three parts: editing, coding and computerization. The data have been edited carefully and necessary corrections were made for coding the data.

3.3.7.1 Field data processing, analysis and interpretation

The collected data have been checked and necessary corrections have been made for data standardization. After verification data coding and entry have been completed. SPSS software has been used for data processing, analysis and interpretation. Data processing, analysis and interpretation procedure has been shown in Figure 3.2.

The analyzed data has been interpreted through tabular form. The descriptive statistics has been represented through frequency distribution and percentage distribution. Cross tabulation, correlation, regression, has been conducted for analytical analysis Qualitative data were analyzed in a coherent way to advance in a process of logical arguments for recommendation and conclusions.

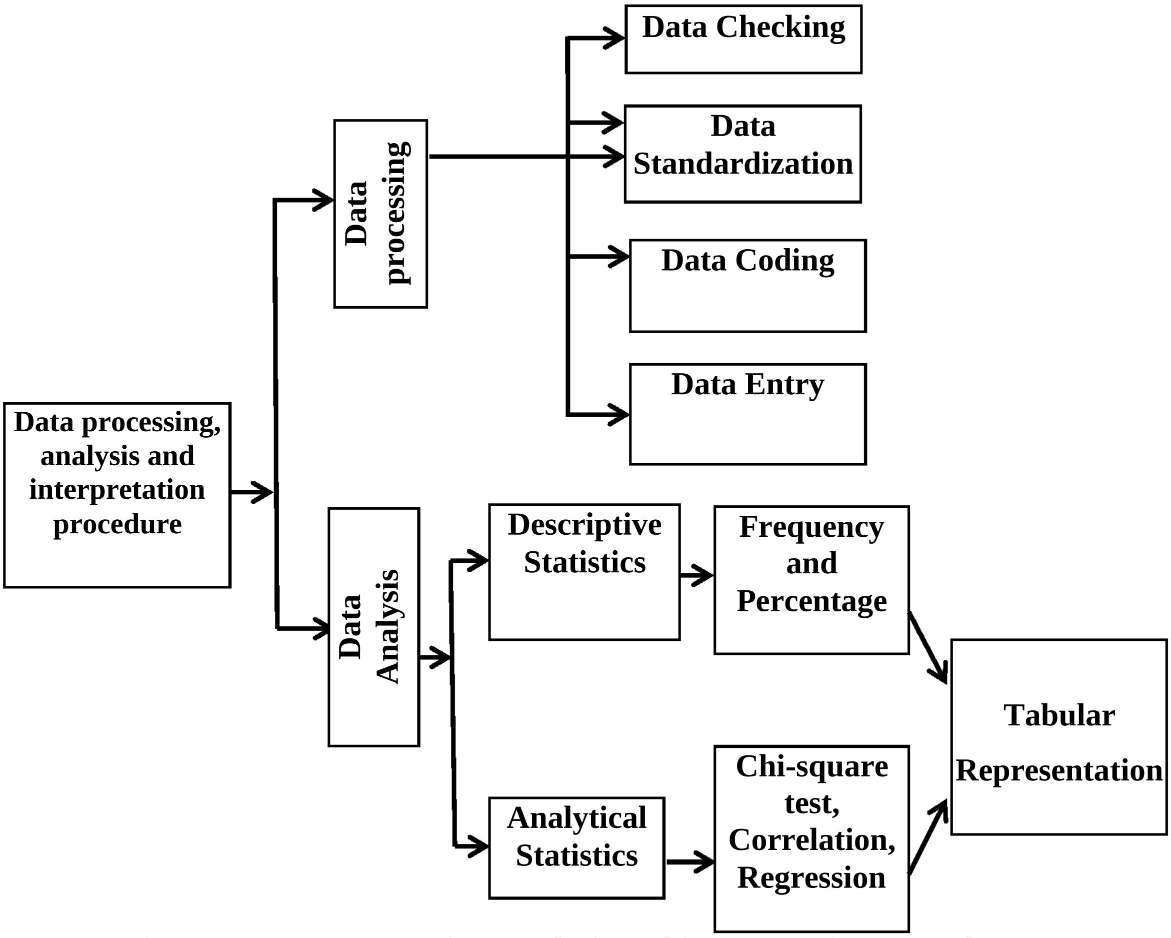

Data Checking
Data Standardization
Data Coding
Data Entry
Data processing
Data processing, analysis and interpretation procedure
Data Analysis
Descriptive Statistics
Frequency and Percentage
Tabular Representation
Chi-square test, Correlation, Regression
Analytical Statistics

Figure 3.2 Data processing, analysis and interpretation procedure

3.3.7.1 (a) Quantitative analysis

Frequency distribution and percentage distribution were applied to illustrate the descriptive statistics. Cross tabulation, correlation, regression and Chi-square test were used for statistical analysis in the study.

3.3.7.1 (b) Qualitative analysis

Field observations, Focus group discussion, case study, Key Informants Interview were conducted to attain qualitative information for authentication of quantitative data. Different data were analyzed in a coherent way to advance in a process of logical arguments for recommendation and conclusions.

3.3.7.2 Image processing, analysis and interpretation

Satellite images of five different years with approximate 10 years interval were processed, analyzed and interpreted to detect river morphology change. The present study unveils the historical changes of Teesta river from 1975-2017. The satellite image processing and analysis includes the process of image collection, geometric and radio metric correction, digitization, classification and change detection. Figure 3.3 represent the flow diagram of satellite image processing, analysis and interpretation.

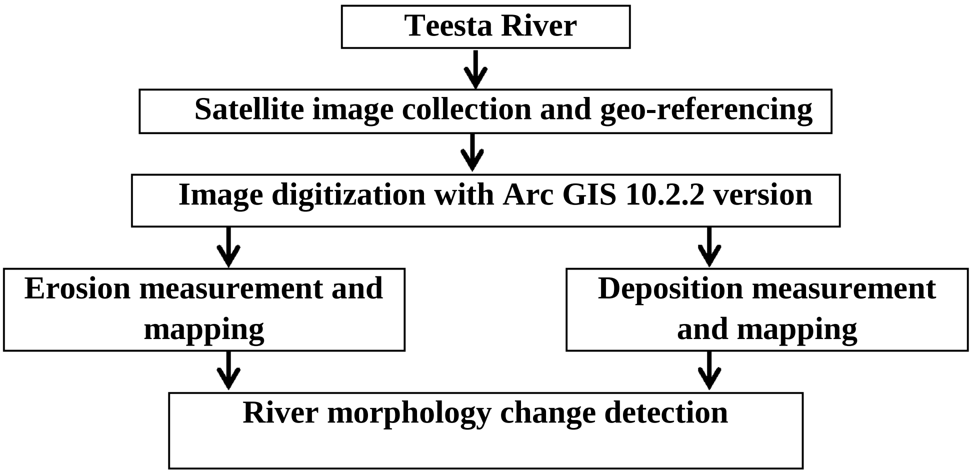

Teesta River
Satellite image collection and geo-referencing
Image digitization with Arc GIS 10.2.2 version
Erosion measurement and mapping
Deposition measurement and mapping
River morphology change detection

Figure 3.3 Satellite image processing, analysis and interpretation techniques

3.3.7.2 (a) Geometric Correction

Geometric correction reduces the geometric misrepresentations occurring on the original satellite images. It also fits the image on a real map projection. All images have been geo-referenced with the base image of Landsat 8 as we know Landsat 8 image is orthorectified.

3.3.7.2 (b) Radiometric correction

Radiometric correction is a process which finds out the changes of pixel values to their actual reflectance values. The changes rise from device failures and also from the effects of our atmospheric alteration. The application of the procedures changes the pixel values. Radiometric correction is conceded in the ground stations and the users get improved quality of image. The misrepresentations of the detection method are condensed by alteration in system. Its significant character is the deduction of striping or missing lines of data, and also the elimination of strength alterations between the bands. The mistakes in the lines can be modified by recapping lines above or below or standardizing the defective data lines conferring to the rest of the data. Electromagnetic radiation such as absorption, scattering and reflection can be minimized through atmospheric correction.

3.3.7.2 (c) Image Classification

Digital image classification has been done using supervised classification in four land cover classes using software ERDAS Imagine 2014. Supervised classification means determination of the samples based on the spectral characteristic of the classes. Supervised classification was carried out with Maximum Likelihood Algorithm. Selection of training areas was based on the ground truth points obtained from the field.

3.3.7.2 (d) River bank extraction and change detection

Spatial analysis has been done to analyze the change in river morphology. First the land cover map from different years 1975, 1987, 1997, 2006 and 2017 were produced and attribute of all image class were recorded for to be same. Figure 3.4 illustrates the change detection process.

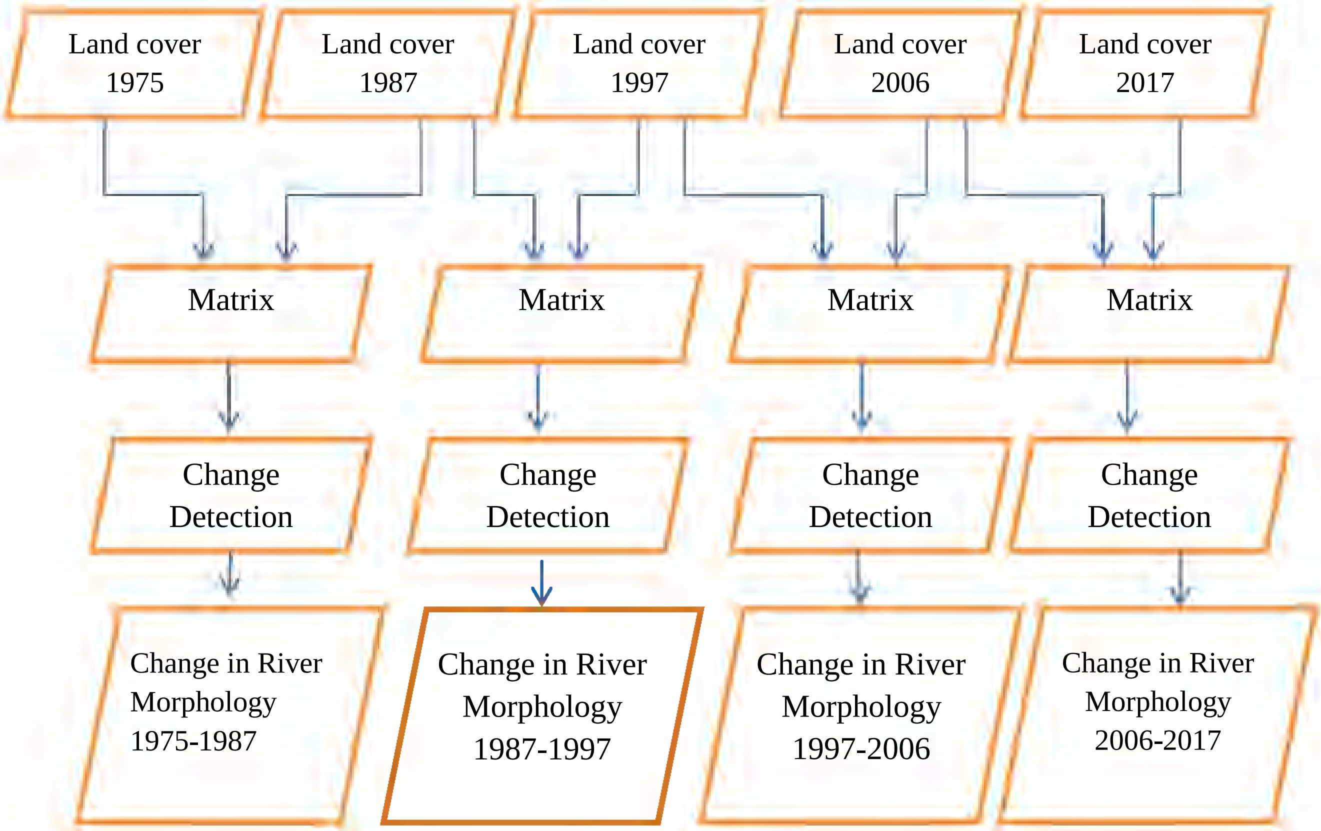

Land cover 1975
Land cover 1987
Land cover 1997
Land cover 2006
Land cover 2017
Matrix
Matrix
Matrix
Matrix
Change Detection
Change Detection
Change Detection
Change Detection
Change in River Morphology 1975-1987
Change in River Morphology 1987-1997
Change in River Morphology 1997-2006
Change in River Morphology 2006-2017

Figure 3.4 Flow chart of change detection process.

Using FCC bank line of the river has been extracted. Digitization has been completed from the five selected years of the Teesta. Classified images were transferred into GIS layer to mapping interpretation and area measurement. Then bank line of the river as well as classified images were overlapped and area of erosion-deposition was measured. The river boundary of 1975 has been deducted from the river boundary of 1987 and the classified image of the base year has been clipped. The clipped layer designates the eroded area of 1975 to 1987. The same process has been repeated in the other three couple of years to determine the eroded land. On the other hand, riverine area of 1987 has been removed from the riverine area of 1975 for deposition illustration and similar procedure has been followed.

3.3.8 Schematic representation of the research

The present research is a combination of different field survey methods along with GIS and remote sensing techniques. The morphological change analysis has been carried out through Landsat imagery analysis. The consequence analysis of river morphology change has been completed through questionnaire survey. The consequence of river morphology change has been investigated in two sections such as impact analysis and adaptation analysis. Finally the study depicted the findings of the study and drew recommendations for morphological change reduction, impact minimization, planning and adaptation. Schematic representation of the research has been shown in figure 3.5.

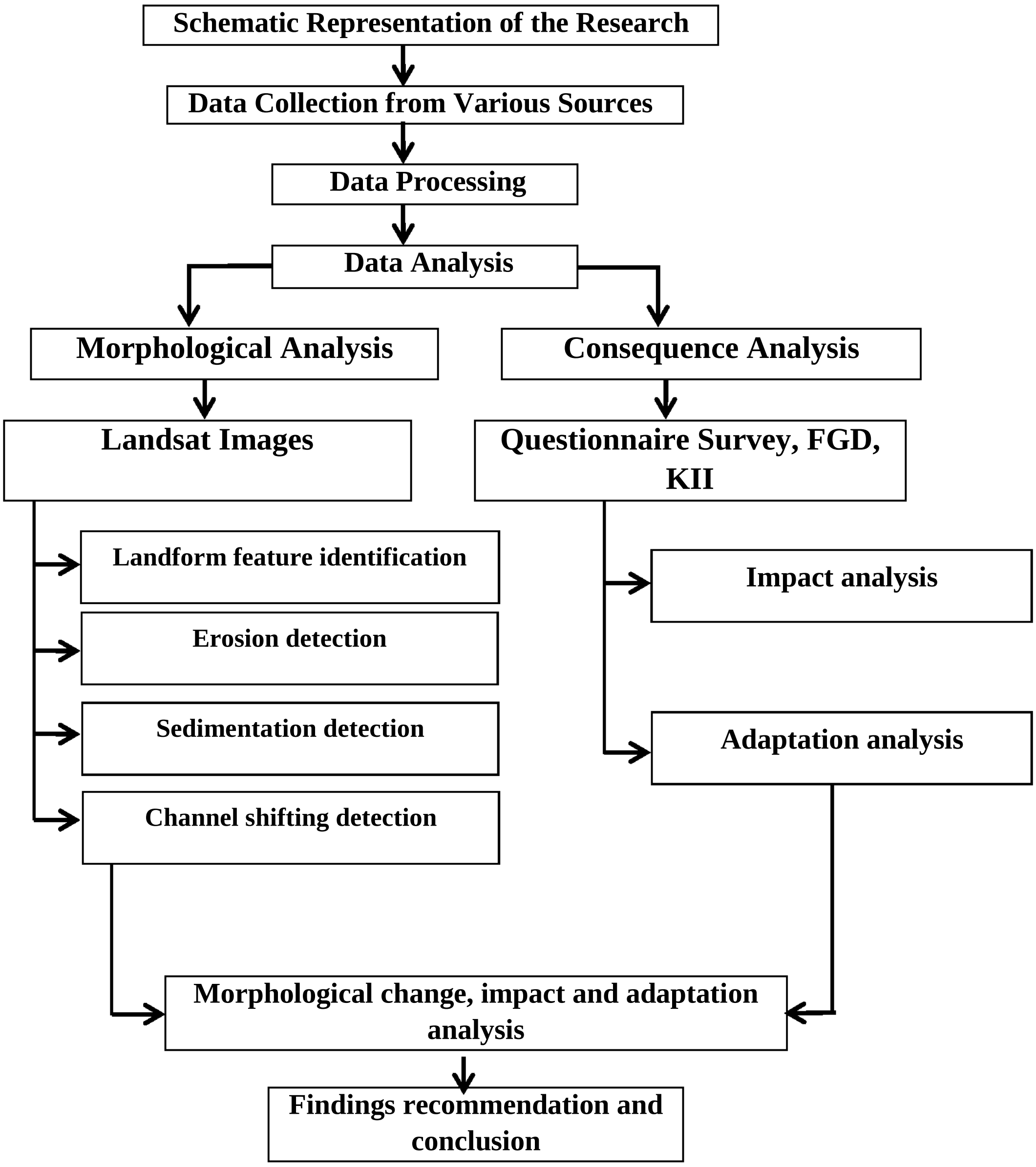

Schematic Representation of the Research
Data Collection from Various Sources
Data Processing
Data Analysis
Morphological Analysis
Consequence Analysis
Landsat Images
Questionnaire Survey, FGD, KII
Landform feature identification
Erosion detection
Sedimentation detection
Channel shifting detection
Impact analysis
Adaptation analysis
Morphological change, impact and adaptation analysis
Findings recommendation and conclusion

Fig 3.5 Schematic representation of the research

Chapter Four
Physiography and Hydro-Morphological Characteristics of the Study Area

4.1 Geographical Location of the Study Area

The study area occupies the north western part of Bengal basin. The study area is a transitional zone between the Ganges floodplain and the Brahmaputra-Jamuna floodplain. The total area of former greater Rangpur district is 3705 square miles and the riverine area of this district is 144 square miles (Khan, 1991). The region occupies north-western to south-eastern steep slope (Sheikh, 2016). Map 4.1 illustrates the geographical location of the study area.

Rangpur (Gangachara upazilla)

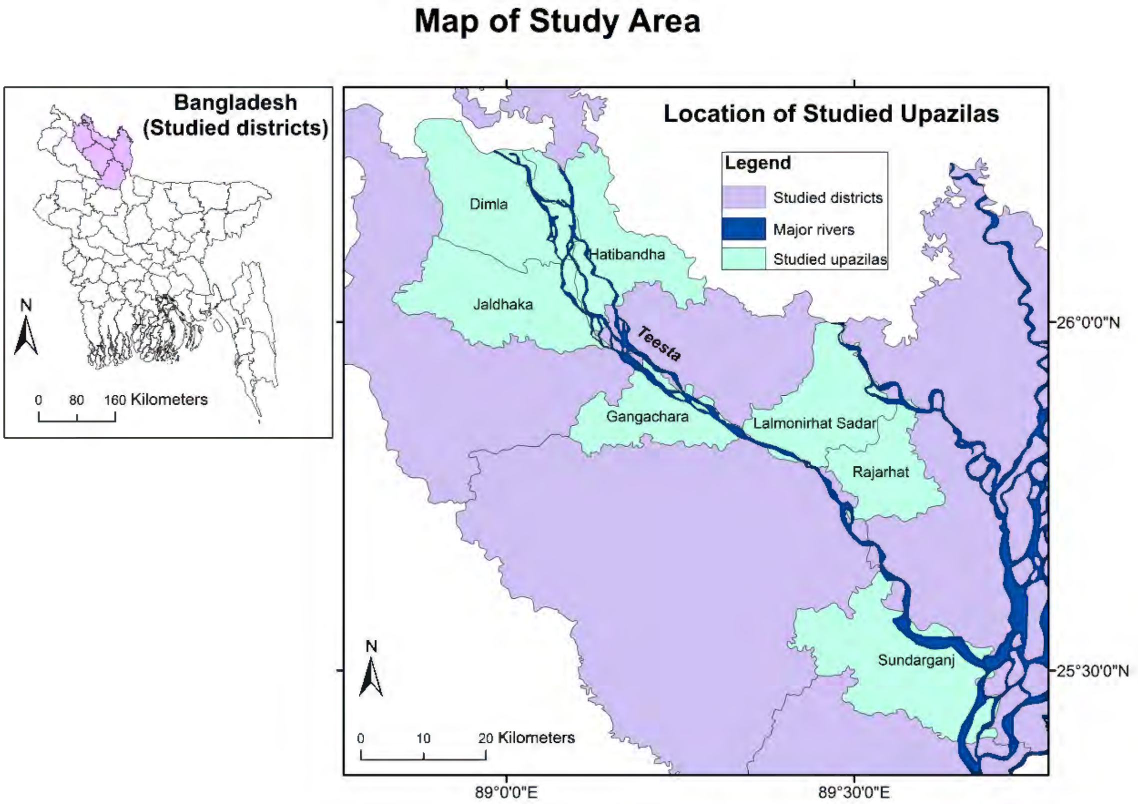
The district of Rangpur established in 1874. The total area of Rangpur district is about 2307.78 sq. km. of which 40.35 sq. km is riverine area (B.B.S, 2008). Spatial distribution of Rangpur extends from 25° 18′ and 25° 57′ north latitudes and 88° 56′-89°32′ east longitude. The Gangachra upazilla of Rangpur district is about 209.61 sq. km and bounded by the upazillas of Rangpur, Nilphamari and Lalmonirhat. The Teesta river formed the floodplain of Gangachara upazilla with alluvial soil and the soils are composed of clay and sandy loam (B.B.S, 2008).

Lalmonirhat (Hatibandha and Sadar upazilla)

In 1984 the district of Lalmonirhat has been established. Lalmonirhat district occupies 53.38 sq. km riverine area (B.B.S, 2008). Lalmonirhat extends from 25° 46′-26° 33′ north latitudes and between 89° 01′-89° 36′ east longitude. Hatibandha is the largest (288.42 sq.km) upazilla of Lalmonirhat district. The Hatibandha Upazilla is surrounded by Dimla and Jaldhaka upazillas of (Nilphamari) on the west, Kaliganj upazilla (Lalmonirhat) on the south, West Bengal on the east, West Bengal and Patgram upazilla of Lalmonirhat on the north. The Lalmonirhat sadar upazilla has an area of 259.54 sq.km with sandy soil occupied by the Teesta, Dharla and the Sati river. The sadar upazilla is bounded by Kurigram district in the south, Nilphamari district in the west and India in the north and east.

Kurigram (Rajarhat upazilla)

Kurigram has been declared as district in 1984. The location of Kurigram district is 25° 18′-25°14′ north latitude and 89° 28′- 89°54′ east longitude. Kurigram is bounded through India in the east and north, Lalmonirhat, Rangpur and Gaibandha in the west and Jamalpur in the south. The Rajarhat upazilla is 166 sq.km and surrounded by Fulbari upazilla (Kurigram) in the north, Kurigram sadar in the in the east, Ulipur upazilla (Kurigram) in the south and Lalmonirhat district in the west (B.B.S, 2008). The Brahmaputra, Teesta, Dharla and Dudkumar are the rivers flows through the Kurigram district.


Map of Study Area
Bangladesh (Studied districts)
N
0 80 160 Kilometers
Location of Studied Upazilas
Legend
Studied districts
Major rivers
Studied upazilas
Dimla
Hatibandha
Jaldhaka
Teesta
Gangachara
Lalmonirhat Sadar
Rajarhat
Sundarganj
N
0 10 20 Kilometers
26°0'0"N
25°30'0"N
89°0'0"E
89°30'0"E

Map 4.1 Location of studied *upazillas*

Nilphamari (Dimla and Jaldhaka upazilla)

The district of Nilphamari also has been established in 1984. The district is situated between 25° 44′-26° 19′ north latitudes and 88° 44′- 89° 12′ east longitudes. The district of Nilphamari is surrounded by Lalmonirhat district in the east, Dinajpur and Panchgarh in the west, India in the north and Rangpur in the south. The study upazillas Dimla and Jaldhaka are bounded with India in the north, Lalmonirhat in the east, Rangpur in the south and Domar upazilla (Nilphamari) in the west. The Dimla upazilla is 326 sq.km and Jaldhaka upazilla is 303.51 sq.km (B.B.S, 2008). Dimla upazilla occupies 12.90 sq.km riverine area and Jaldhaka occupies 7.71 sq.km riverine area. Teesta is the main river of Nilphamari which forms the silty floodplain of the district.

Gaibandha (Sundarganj upazilla)

The district of Gaibandha also initiated in 1984. The location of the district is 25°02′-25°39′ north latitude and 89° 11′- 89°46′ east longitude. The district has been surrounded by Kurigram in the north, Jamalpur upazilla in the east, Bogra in the south, Rangpur and Dinajpur in the west. The study upazilla Sundarganj is situated in the northern part of Gaibandha district. The Sundarganj upazilla is surrounded by Rangpur (west and north), Kurigram (east), Sadullapur upazilla (Gaibandha) and Gaibandha sadar in the south. The Sundarganj upazilla is 426.51sq.km with 49.26 sq.km of riverine area (B.B.S, 2008). The floodplain of Gaibandha district consists of soil of the Teesta, Ghaghat, Karatoya, Bangali and the little jamuna river.

Table 4.1 Total area and riverine area of the study area

Name of district and upazilla	Total area in sq. km	Riverine area in sq.km
Rangpur	2307.78	40.45
Gangachara	209.61	9.09
Lalmonirhat	1241.46	53.38
Lalmonirhat sadar	259.54	8.5
Hatibandha	288.42	16.37
Kurigram	2296	245.00
Rajarhat	166	-
Nilphamari	1581.03	28.31
Dimla	326.80	12.90
Jaldhaka	303.51	7.71
Gaibandha	2171.37	221.58
Sundarganj	426.51	49.26

Source: B.B.S, 2008

4.2 Geological Settings

In the Late Tertiary period, the Himalaya had been raised from the Tethys sea and river systems of Indian subcontinent has been established, which developed the Bengal Basin. Bangladesh is a part of Bengal Basin and world's largest delta, occupied with flood plain deposits of the major river systems. About 3000 m thick alluvial deposits of Quaternary period formed the Ganges-Brahmaputra-Meghna (GBM) delta which is geologically known as the Bengal Basin (Sikder, 2008). Among the three main geological units of Bangladesh the Tertiary sediments, the Madhupur clay and the recent alluvium, the study area lies beneath the recent alluvium of floodplains. Three-fourth portion of Bangladesh is filled with Holocene alluvial and Pleistocene fluvial deposits (Islam, 2003) . The recent alluvium of the study area has been deposited through the active and abandoned channels of the Teesta river. Debris flow and fan deposits are found in the Teesta which are the evidences of quaternary deposition (Meetai *et al.*, 2007). Chronological channel changes of the Teesta river occupies different stratigraphic succession in Teesta floodplain. The Teesta floodplain sediments are regarded as high concentration of silt and sand. The clay deposits of Teesta alluvium are chlorite, kaolinite and ellite. The percentage of sand deposit (biotite) is highly significant 45-75%.(Brammer,1996). The mineral assemblage of the Teesta, Brahmaputra and Ganges river sediments are given in Table 4.2.

Table 4.2 Mineral assemblage of Teesta, Brahmaputra and Ganges river sediments

Name of mineral	Percentage
Feldspar	15-30
Mica(Muscovite, Biotite)	5-30
Heavy minerals	2-9
Easily -weatherable minerals	25-40

Source: Brammer, 1996

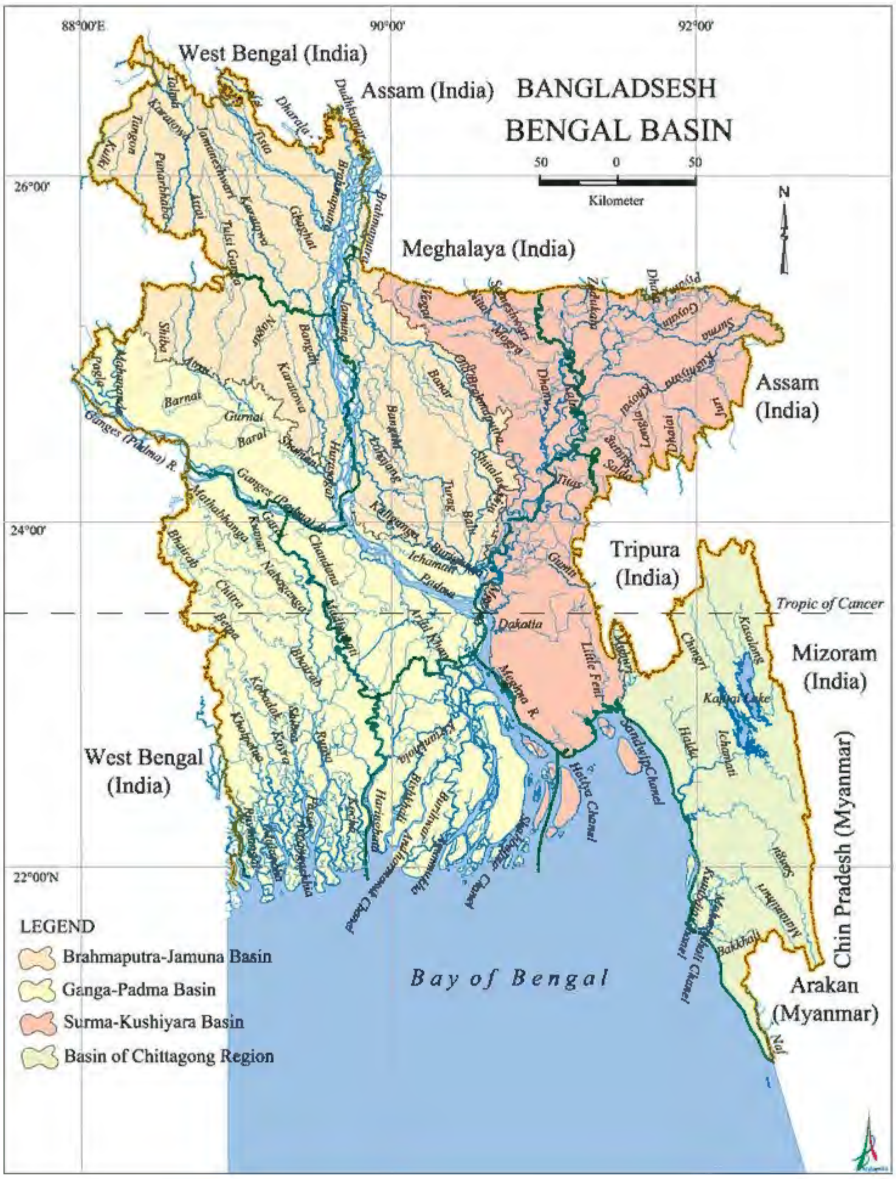
4.3 Tectonic Movements

Tectonically Bangladesh lies in the seismic active zone between the Eurasian and the Indian plate. The Bengal basin is an active tectonic zone with subduction fault in the north and a transform fault in the east. The Garo-Rajmahal gap is a narrow gap between the Meghalaya plateau and the Chhota Nagpur plateau which bear old base rocks of the surface in the Dinajpur, Rangpur and Naogaon region. (Rashid, 1991). This basin inhabits huge sediments from the Ganges, Brahmaputra and the Meghna river (Milliman and Made, 1983). About 2 million years ago the delta of Bangladesh developed in the Quaternary era. The Bengal basin is one of the important and thickest sedimentary sinks of the world (Khan and Chouhan, 1996). Due to the orogenic movement in the Indian sub-continent in the last 10 million years, the Meghalaya plateau formed a horst and the Dinajpur shield became a graben and the Brahmaputra with its fluvio-morphological process deposited the sediments in the depressions (Yesmin, 2009).

Bangladesh is shaped through the Indian platform and the Bengal basin (Map 4.2). Though, the Indian platform is stable but the Bengal basin has its active delta formation process (Bakhtine, 1999; Guha, 1978). The study area lies in the Dinajpur slope/saddle and Rangpur slope/saddle of Indian platform. In the north-east it is restricted through the Shillong Plateau. In the western side it is confined to the Rajmahal hills and the south is limited with the Bogra slope. (Rasheed, 2008). The Dinajpur slope is called as the northern slope of the Rangpur saddle which has 1-2 degree to 3-4 degree dip near the Himalayan foredeep. The Rangpur saddle has been established in the Gaaro-Rajmahal gaps containing 97.2 km width. The southern slope of the Rangpur saddle is termed as the Bogra slope which extends up to the hinge zone. The Bogra slope is 64-129 km wide with 1-3 degree inclination. (Zaher and Rahman, 1980).

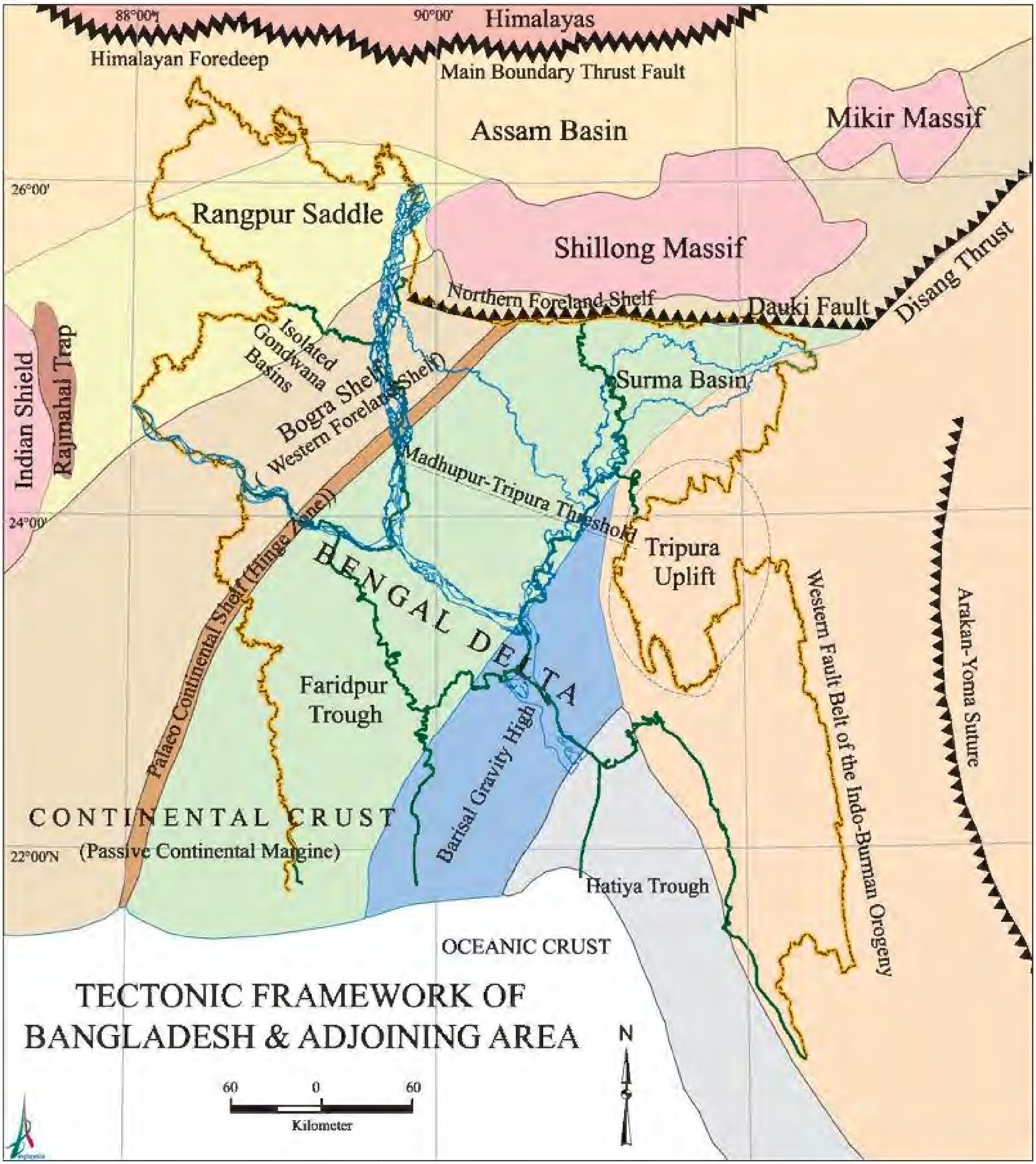
In the northwest a stable Cambrian platform is situated in the country and on the other hand, in the south-east there exists a geo-syncline basin. Between these two tectonic platforms there exists a narrow stripe in the middle of the country which called the hinge zone. The hinge zone is 25km wide. The study area lies in the stable Precambrian platform which is filled with sedimentary rocks. A basement of igneous and metamorphic rocks re found beneath the sedimentary deposits. The platform is divided into two parts: in the north, the Rangpur Saddle (130 to 1,000m) and in the south it is Bogra shelf (1 to 6 km) depth. (Islam, 2003). These tectonic zones have fragile geological condition. Sinking and uplifting is a continuous process in the Bengal basin in recent times along the faults. The evolution of Ganges- Brahmaputra delta developed for the tectonic movement of the Bengal basin in the Cretaceous period (63-135 Million years Ago). The Arakan Yoma orogenic movement actively sunken the Bengal basin and the gulf of Assam evolved. Ganges- Brahmaputra diverted in the Bengal basin with huge sediments and sank 6-8 km. The tectonic activity of the north eastern part of the Bengal basin uplifted the Madhupur tract and down wrapped the Jamuna. The Assam gulf is filled with the deposits of the Ganges Brahmaputra. (Islam, 2003).

The study area has been affected by the earthquake of 1897. Several sand fissure expulsion has been recorded in the earthquake in south eastern areas of Rangpur (Brammer, 1996). The earthquake made the Teesta and Ghagat river channel sluggish in many places. In Gaibandha the cultivable land turned into saucer shaped lands. Besides, low lands also raised. (Brammer, 1996). Bangladesh is divided into 3 seismic zones: the north eastern part is at high risk of seismicity (Zone-I) which is nearest to the epicenters of Assam, Shillong and Arakan-Yoma; Zone-II comprises of the central part of the country and the Zone-III includes the southern part of Bangladesh. The tectonic zones of Bangladesh have been illustrated in Map 4.3. The Teesta river valley lies in both the Zone-I (High risk) and Zone-II (Intermediate risk). The geological condition, faulting situation and seismic activity also effects on river morphology change. The Assam earthquake in 1950s has a great influence in the hydro morphology in the Brahmaputra basin which resulted in the rise in the river bed. The reduced river bed is an important cause for increased extreme flooding situations in Bangladesh. (Choudhury, 2009).


88°00'E
90°00'
92°00'
26°00'
24°00'
22°00'N
West Bengal (India)
Assam (India)
BANGLADSESH
BENGAL BASIN
50 0 50
Kilometer
N
Meghalaya (India)
Assam (India)
Tripura (India)
Tropic of Cancer
Mizoram (India)
West Bengal (India)
Chin Pradesh (Myanmar)
Arakan (Myanmar)
Bay of Bengal
Dakatia
Little Feni
Meghna R.
Hatiya Chanel
Sandwip Chanel
Kaptai Lake
Ganges (Padma) R.
Jamuna
Brahmaputra
Teesta
Padma
LEGEND
Brahmaputra-Jamuna Basin
Ganga-Padma Basin
Surma-Kushiyara Basin
Basin of Chittagong Region

Source: Banglapedia, 2003

Map 4.2 Bengal basin


88°00'
90°00'
Himalayas
Himalayan Foredeep
Main Boundary Thrust Fault
Assam Basin
Mikir Massif
26°00'
Rangpur Saddle
Shillong Massif
Northern Foreland Shelf
Dauki Fault
Disang Thrust
Indian Shield
Rajmahal Trap
Isolated Gondwana Basins
Bogra Shelf
(Western Foreland Shelf)
Surma Basin
Madhupur-Tripura Threshold
24°00'
Tripura Uplift
BENGAL DELTA
Western Fault Belt of the Indo-Burman Orogeny
Arakan-Yoma Suture
Faridpur Trough
Palaeo Continental Shelf (Hinge Zone)
Barisal Gravity High
CONTINENTAL CRUST
(Passive Continental Margine)
22°00'N
Hatiya Trough
OCEANIC CRUST
TECTONIC FRAMEWORK OF BANGLADESH & ADJOINING AREA
N
60 0 60
Kilometer

Source: Banglapedia, 2003

Map 4.3 Tectonic zone of Bangladesh

4.4 Physiography and Physiographic Units

Basically Bangladesh is divided into 3 physiographic regions termed as floodplain areas (80%), terrace areas (8%) and hill areas (12%). These 3 areas are occupied with 23 physiographic units. The study area is situated in the Teesta floodplain areas. The Teesta floodplain is bordered by the Old Himalayan Piedmont plain in the west and the Old Brahmaputra floodplain in the east. Sandy ridges with narrow strips, *beel*[16], natural levee, and smooth landscape are the physiognomies of Teesta floodplain. It is covered by Teesta valley fill deposits. The land height is almost flat except the ridges and natural levee deposition. Topographically the area is amended through different stream channels such as the Teesta, Karatoa, Atrai, Jamuneshori, Ghagat etc. with shallow flooding depth. Thus, the relief features of the study area displays two types of landscapes: i) ridges and ii) basins. Among the different floodplain areas, the Teesta floodplain is an important physiographic unit in Bangladesh. The Teesta floodplain is divided into two subunits: the Active Teesta floodplain and the Teesta meander floodplain. The physiographic map of the study area has been shown in map 4.4.

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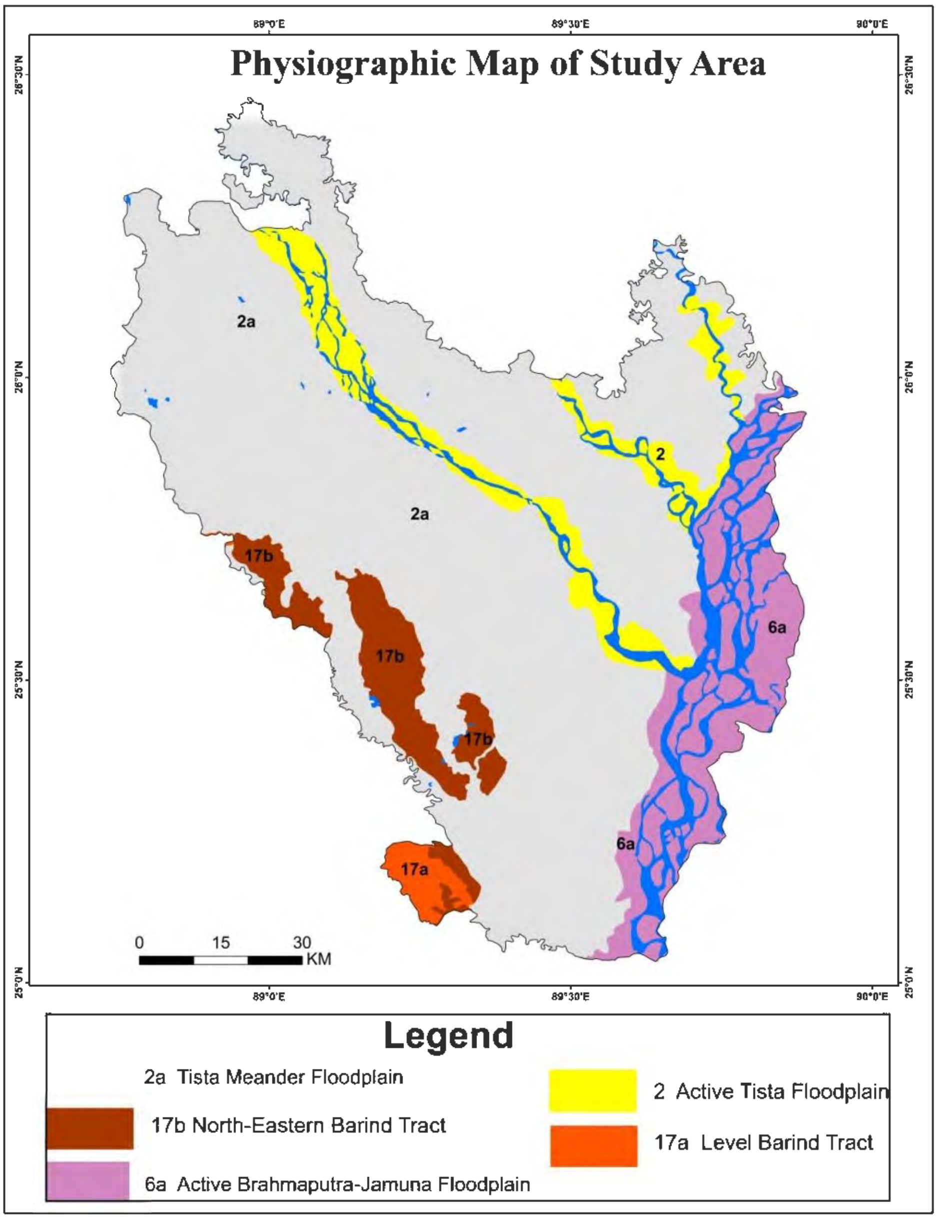
[16] *Beel* refers to the low lands occupied by water in the monsoon.


Physiographic Map of Study Area
89°0'E
89°30'E
90°0'E
26°30'N
26°0'N
25°30'N
25°0'N
2a
2
17b
6a
17a
0 15 30 KM
Legend
2a Tista Meander Floodplain
17b North-Eastern Barind Tract
6a Active Brahmaputra-Jamuna Floodplain
2 Active Tista Floodplain
17a Level Barind Tract

Source: Modified from BARC, 2016

Map 4.4 Physiographic map of the study area

4.4.1 Active Teesta Floodplain

The active Teesta floodplain is 830 sq. km including the active floodplains of the Teesta, Dharla and Dudhkumar river (Islam, 2003). Active floodplain is determined by its water discharge, flow category, sediment transport, sediment deposition and erosion status. Braided stream, char formation, river bank failure and frequent channel shifting are very common feature in the Active Teesta floodplain. One of the important characteristics of active Teesta floodplain is its continuous erosion and bank line shifting and thus changes its location, direction and slope. Flash flood is recurrent in the Active Teesta floodplain. Alluvium deposition, medium and smooth ridges, inter-ridge depressions, seasonal shallow flooding and cut off channels are the main characteristics of this physiographic unit.

4.4.2 Teesta Meander Floodplain

The Teesta meander floodplain is characterized by its meandering channel pattern in some areas, presence of oxbow lakes and floodplains. The Teesta meander floodplain is about 9468 sq. km. It covers the most important parts of the Teesta floodplain as well as the Atrai, little Jamuna, Dharla, Dudhkumar and the Karatoya river. The fertility of the Teesta meander floodplain is low-medium and the soil contains good moisture containing capacity. The floodplain ridges contain olive brown loamy soil which has rapid permeability. The lowland of this floodplain comprises of grey or dark grey heavy silt loam or silty clay loam soils with slow permeability. The high lands of the Teesta meander floodplain contain low organic matters but the low land holds moderate organic matters. (Islam, 2003).

4.5 Soil Characteristics and Soil Types

In Bangladesh generally the upper courses of rivers are sandy, the middle courses are formed with silt and the lower courses are composed of clay material accretion (Rashid, 1991). Teesta floodplain soils are composed of alluvial deposits. Silty, sandy and clayey deposits are available in the alluvium of Teesta river basin. The river banks and ridges are composed of sandy soil. Moreover the river basin is commonly filled up with clay materials though there are also silty sediments in the basin. (Brammer,1996). The soil fertility level and organic matter of Teesta floodplain soil is low to medium (Islam, 2003). Total area and soil characteristics of Teesta floodplain area are presented in Table 4.3

Table 4.3 Soil characteristics of Teesta floodplain

Teesta Floodplain	**Total Area sq. km.**	**Type***	**Soil Character**		
			Sand%	Alluvium%	Clay%
Active Teesta floodplain	836	2	41	59	0
Teesta meander floodplain	9468	3	6	88	6

*2 Non- calcareous alluvium * Non- calcareous grey

Source: UNDP, FAO, 1988

The soil types of Teesta floodplain are shown in map 4.5. The soil types of Teesta floodplain are as follows:

a) Noncalcareous Alluvium

Active floodplains of Teesta are formed with this type of soil. Non calcareous alluvium soil shows neutral to alkaline behavior without lime. Shallow to deep flood occurs in these soils with bank erosion. The soil type has low moisture holding capacity. Immature soils are most common but mature soils are found in 30-60 cm. deep.

b) Noncalcareous Grey Floodplain Soil

The soil type is found 25-125 cm. below the surface. Most of the Teesta floodplain has been recognized this type of soil. The Teesta floodplain occupies silt loam soils which has moderate to high moisture holding capacity and high productivity. It is also affected by seasonal flooding. The ridges are composed with sandy soils with low moisture holding capacity. The soil is grey to olive grey in dry phase but become dark in wet phase. The substratum of non-calcareous grey floodplain soil is stratified and sandy but it is clayey in the basins. It is neutral to slightly alkaline. The basin soil textures are both silty clay loams and silty clay.

c) Noncalcareous Dark Grey Floodplain Soil

Non calcareous Dark Grey Floodplain soil is second most wide-ranging soil of the country which is dark grey to black in colour. The texture of the top soil is light than the subsoil. The subsoil is 20-45 cm thick. Its moisture holding capacity is slow. In dry phase the soil is strongly acidic otherwise it shows neutral reaction.

d) Noncalcareous Brown Floodplain Soil

The soil type occurs in the northern part of Teesta floodplain. The soil is yellow brown to dark brown in colour. The soil is medium to strong acidic. The agricultural productivity of the soil is moderate to low. Silty loam soil occurs in low ridges in contrast high ridges occupied with sandy loam soils. Shallow flooding, presence of low organic matter, low moisture holding capacity is the main features of non-calcareous brown floodplain soil.

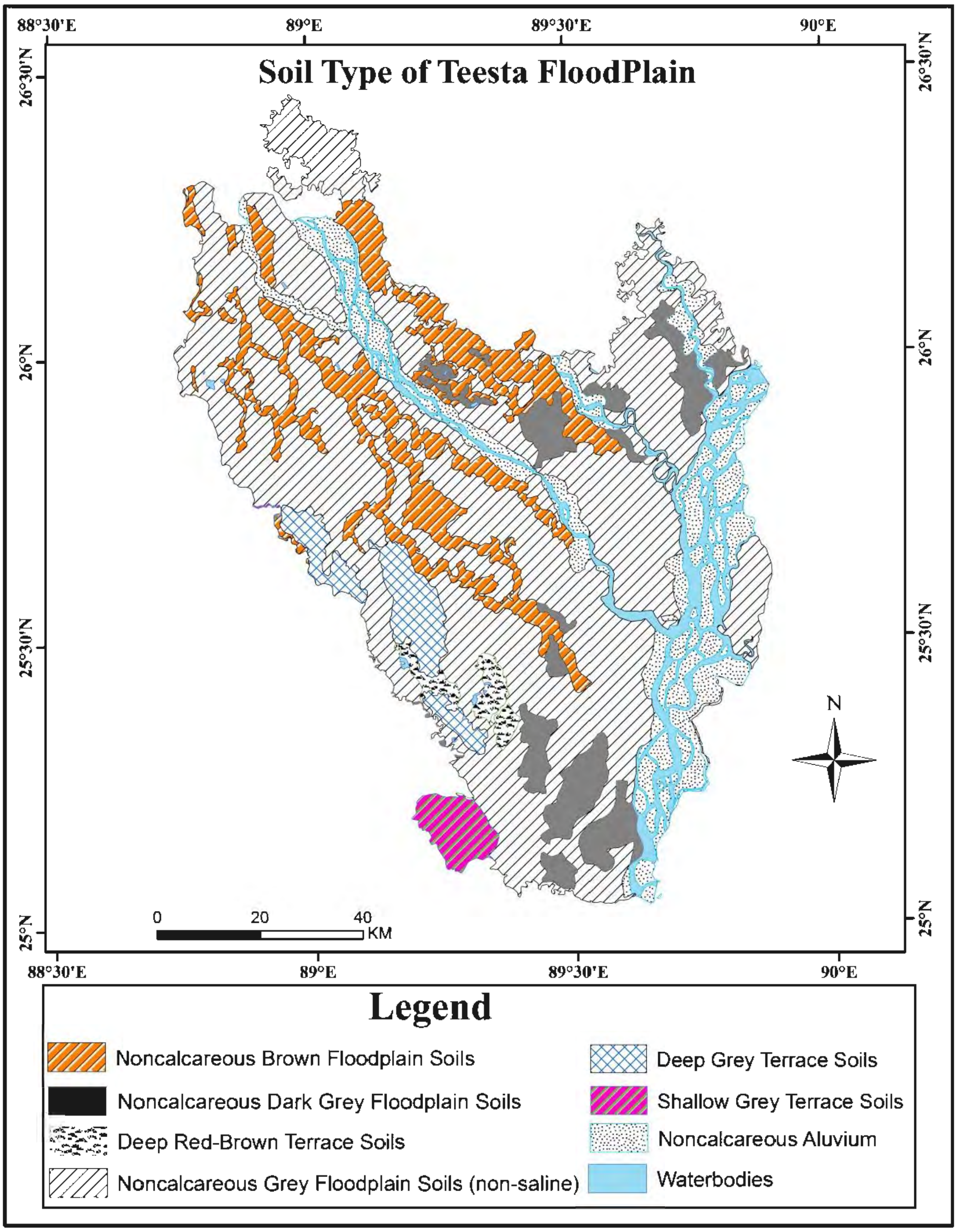
Table 4.4 soil series and general soil type of Teesta floodplain

Soil series	**Parent material**	**General soil type**
CHILMARI	Teesta alluvium	Non calcareous grey floodplain soil
DOMAR 2	Teesta alluvium	Non calcareous brown floodplain soil
GANGACHARA	Teesta alluvium	Non calcareous grey floodplain soil
JALDHAKA	Teesta alluvium	Non calcareous alluvium
KAKINA	Teesta alluvium	Non calcareous dark grey floodplain soil
KAUNIA	Teesta alluvium	Non calcareous grey floodplain soil
PALASHBARI MDLD	Teesta alluvium	MADELAND
PALASHBARI Nor	Teesta alluvium	Non calcareous brown floodplain soil
SANDY TEESTA ALL	Teesta alluvium	Non calcareous alluvium
SHAGHATTA	Teesta alluvium	Non calcareous alluvium
SILTY TEESTA ALL	Teesta alluvium	Non calcareous alluvium
ULIPUR	Teesta alluvium	Non calcareous grey floodplain soil

Source: UNDP, FAO, 1988

e) Made-land Soil

Usually the soil is loamy but sand, silt and clay deposits are also remarkable. Made-land soils are found in the Teesta floodplains like other floodplains of the country. The soil shaped on elevated earthen platforms which lies above local flood level. These soils are permeable and darker than the natural soils. Made-land soils contain diverse materials and this soil is suitable for horticulture. The soil series and general soil type of Teesta floodplain is shown in (Table 4.4)


Soil Type of Teesta FloodPlain
88°30'E
89°E
89°30'E
90°E
26°30'N
26°N
25°30'N
25°N
N
0
20
40
KM
Legend
Noncalcareous Brown Floodplain Soils
Noncalcareous Dark Grey Floodplain Soils
Deep Red-Brown Terrace Soils
Noncalcareous Grey Floodplain Soils (non-saline)
Deep Grey Terrace Soils
Shallow Grey Terrace Soils
Noncalcareous Aluvium
Waterbodies

Source: Modified from BARC, 2016

Map 4.5 Soil types of Teesta floodplain

Table 4.5 Soil type and area in hector

Soil type	Area (hector)
Non-calcareous alluvium	120671.50
Non-calcareous gray floodplain soil (non-saline)	524615.16
Non-calcareous brown floodplain soil	127164.31
Non-calcareous dark gray floodplain soil	70598.62
Deep red-brown terrace soil	13224.15
Shallow gray Terrace soil	16100.84
Deep gray Terrace soil	36668.25

Source: BARC, 2016

4.6 Hydro-Morphological Characteristics of Teesta River

The name Teesta is derived from Sanskrit word Trisrota which means three currents. In ancient times Teesta river flows through three stream channels named Atrai, Punaraba and Karatoa of northern districts of Bangladesh. The devastating flood of 1787 has changed the flow of Teesta into a new channel Jamuna. According to the Statistical Year Book of Bangladesh 2015 the length of Teesta river is 113 km in Bangladesh.

4.6.1 Source and Basin Morphology of Teesta

The Teesta river originates from the Pauhunri glacier of Sikkim Himalaya near Khangchung lake with 7,128 m altitude. Chitamu lake of the same destination with 7200m also acts as a source of Teesta. The recognized source region of the Teesta river are Pahunri glacier, Zemu glacier, lake Gurudongmar and lake Cholamu. After its rigorous journey in the mountainous region the Teesta meets to the plains of Darjeeling. The Teesta passes through a renowned gorge at Sevok, Darjeeling and then Alipur duars. In the Himalayan region the tributaries of Teesta are Rangpo, Lachung chhu, Rani khola, Dik chuu etc. The most important tributary of Teesta is Rangeet. Other tributaries of Teesta in sub-Himalayan region (North Bengal of India) are Leesh, Geesh, Chel, Neora, Karala etc. The width of Teesta varies from 3.2-10.8 km. in the plains of sub-Himalayan region (Banik, 2016). The catchment area of Teesta river has been shown in Table 4.6

Table 4.6 Catchment area of Teesta river in source region and in the plains

Areal extent of catchment	Area in sq. km	Total area in sq.km
Sikkim	6930	8051
West Bengal (Hills)	1121	
West Bengal (Plains)	2104	4108
Northern Bangladesh	2004	
India		10155
Bangladesh		2004
Total catchment		12159

Source: Khan and Islam, 2015

The Teesta river entered into Bangladesh through Paschim Chatnai union of Dimla upazilla of Nilphamari district. It covers the upazillas of Dimla, Jaldhaka, Kishoreganj, Patgram, Aditmari, Hatibandha, Kaliganj, Lalmonirhat sadar, Rajarht, Ulipur, Chilmari, Pirganj, Kaunia, Gangachara and Sundarganj. It falls into the Brahmaputra at Fulchari ghat of Chilmari upazilla of Kurigram district. The Teesta catchment area is 1719 sq.km; depth in dry season is 1m or 8 cubic foot per second (cusec.) and depth in wet season is 5.5m (4494 cusec.) (Sheikh, 2016). Mean monthly discharge of Teesta is 2430 cubic meter per second (cumec.) (Islam, 2003). The average discharge of water in the Teesta during monsoon is 994.73 cusec. and the discharge decreases at 71.20 cusec. in the summer season (Khan and Islam, 2015). The width of the river varies from 300-550m (Islam *et al*., 2004). The basic information of Teesta river is as follows (Table 4.7)

Table 4.7 Basic information about Teesta

Information about Teesta	Statistics
Mountain catchment(sq.km)	8,637.8
River length in mountains(km)	182.0
River gradient in mountains (%0)	46.4
River length in piedmont (km)	12.4
River gradient in piedmont (%0)	1.9
Length of river valley (km)	315-400
Length in Bangladesh (arguably)	113-172
Touched land about (sq. km)	9,667
Villages in number	5427
Estimated population in million (2011)	9.15
Serves people directly or indirectly dependent on river (Million)	21

Source: Prokop and Sarker,2012; Bari and Haque, 2016

4.6.2 Topography and Morphometry

Gentle slope and flat topography is the distinctive feature of Teesta basin in Bangladesh. In the Sikkim- Darjeeling belt (upstream) the Teesta river gradient is steep but in Bangladesh (downstream) it's gradient is low (Pramanik, 2016). The slope of the Teesta river is 0.47-0.55 m/km (Rahman *et al*., 2011). The topographic and morphometric characteristics of Teesta river basin are as follows:

Table 4.8 Topographic and morphometric characteristics in the upstream and downstream of Teesta river basin

Parameters	Descriptions	Remarks
Basin mouth height (m)	9 m	In Bangladesh where Teesta megafan formation is active.
Maximum basin height (m)	8484	North-western part of the basin in Sikkim
Total basin relief(m)	8475	-
Relief ratio	24.21	-
Basin area (km^2)	11252.69	The basin are is too large
Basin length (km)	350	Basin length is very high
Elongation ratio	0.21	Elongated.
Circularity ratio	0.12	Strongly elongated and heterogeneous geological structure.
Drainage frequency	0.15	Low stream frequency.
Drainage density	0.40 km	Drainage density is very low for rock resistance.
Drainage texture	0.06	Highly resistant permeable rock with low infiltration rate and high relief.

Source: Pramanik, 2016

4.6.3 Rainfall in Teesta Basin

High temperature, high humidity and adequate rainfall occur in the Teesta basin. Sometimes plenty rainfall occurs in the pre monsoon period. The monsoon in the study area extends from June to September. Humidity in the monsoon is high in the study are. Torrential rainfall takes place in the months of June-August. Local rainfall impacts on flooding condition, water discharge and water level of the study area. Year wise average monthly rainfall at Dalia point has been shown in (Table 4.9).

Table 4.9 Year wise average monthly rainfall at Dalia point (inches)

Year/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Au	Sep	Oct	Nov	Dec
1987	0.06	1.54	1.8	3.86	6.94	27.3	34.3	24.2	17.1	10.3	.28	0.0
1988	0.00	4.50	1.15	2.45	6.13	13.4	23.1	37.8	15.0	0.03	.58	0.0
1995	0.15	0.51	0.3	0.33	5.77	13.8	23.4	14.6	23.8	1.2	1.9	0.0
1998	0.00	0.08	0.84	6.7	2.65	16.4	30.7	16.8	7.39	2.9	0.0	1.13
2003	0.23	0.33	-	3.7	6.9	28.3	21.1	5.7	5.7	9.9	0.0	0.6
2007	0.00	1.53	-	-	7.8	11.9	18.6	9.4	23.6	4.1	0.0	0.0
2008	1.7	0.83	8.6	4.2	6.3	15.3	18.2	32.7	11.5	5.9	0.0	0.0
2013	0.00	0.53	3.1	4.9	4.8	14.5	16.7	12.0	5.9	6.9	0.23	0.0

Source: BWDB, 2018

Rainfall in the upper catchment of a river system determines the flooding conditions of the downstream river valleys. The floods of Teesta basin during 2017 has influenced by the rainfall in the upper catchments and also by the local rainfall. Table 4.10 illustrates the rainfall of upper catchments of Teesta in 2017

Table 4.10 Rainfall of upper catchments of Teesta in India (2017)

Station	Rainfall (8-8-2017 – 14.8.2017 mm)
Gajaldoba	410
Jalpaiguri	590
Domohoni	570
Cuchbihar	640
Alipurduar	1070
Dhubri	220
Goalpara	330

Source: BWDB, 2017

Table 4.11 Monthly rainfall of selected stations of Teesta basin in 2017 (mm)

Stations	May	June	July	August	September
Kurigram	407.5	261.5	438	356	227.5
Dalia	389	509	445	907	279
Rangpur	267	146	394	524	170
Gaibandha	222	218	426	382	233

Source: BWDB, 2017

4.6.4 Water Level and Flooding Situation of Teesta

Water level and flooding situation of the Teesta River Basin (TRB) depends upon the hydro-climatic condition of the upstream river. When the upper catchment of the Teesta experiences intensive rain fall it causes flash floods in the downstream. Characteristically the Teesta is a flashy river. The entire Teesta river basin is covered with flash floods every year which causes river bank erosion and loss of life and property. As Teesta is a trans boundary river it is quiet impossible for Bangladesh to forecast the flash flood. Because hydrologic data, river discharge and water level data of the upstream catchment of India executes constrain of flash flood forecast (Bhuiyan *et al.*, 2007). The water level of Teesta river at Kaunia station is given in the table 4.12.

Table 4.12 Water level of Teesta river at Kaunia

2010-2011		2011-2012		2012-2013	
Highest	Lowest	Highest	Lowest	Highest	Lowest
29.44	25.50	29.20	25.54	29.31	25.40

Note: Water year (April-March)

Source: BBS, 2015

When the water level of Teesta crossed its danger level then catastrophic flood occurs in the study area. In monsoon 2017, the water level (wl) of Teesta crosses danger level in 4 times. Power development board (PWD) has been observed highest peak (53.05 m) at Dalia point on 13th August 2017 and that was 65 cm above danger level (DL) (52.40 m). The danger level of Teesta river at Dalia and Kaunia station has been shown in Table 4.13.

Table 4.13 The danger level of Teesta river at Dalia and Kaunia station (in m PWD)

Station	Previously recorded maximum	Danger level (DL)	Peak of the year			Days above danger level		
			2017	1998	1988	2017	1998	1988
Dalia	52.97	52.40	53.05	52.20	52.89	6	-	8
Kaunia	30.52	30.00	30.00	29.91	30.43	NA	-	38

Source: BWDB, 2017

In 2017 two times flood occurred in the Brahmaputra basin, in 1st week of July and the 2nd week of August. The magnitude of the second flood was much higher than the first one which causes lots of human sufferings. At Dalia point the Teesta experienced 6 days of crossed danger level and in Gaibandha the Ghagot river crossed 15 days of danger level. The districts of Lalmonirhat, Kurigram, Nilphamari, Rangpur and Gaibandha experienced short to medium term inundation and the Dalia point exceeded the previous record of danger level. (BWDB, 2017).

High volume of water discharge from upstream along with huge sediment loads are the main causes of flood in the Teesta basin. Flash floods from the foot hills of the Himalayas are dominating flood type in the Teesta basin. Rather than the top of the ridges most of the floodplain is covered with shallow flood during monsoon (Brammer, 1996). The average water discharge of Teesta at Kaunia station has shown in Table 4.14 along with maximum and minimum water discharge.

Table 4.14 Water discharge of Teesta at Kaunia station in (M)3/S

Year	Max. discharge	Min. discharge	Ave. discharge
1987	3770	138	1254.58
1988	6810	131	1351.10
1995	5080	91.2	679.70
1998	5625.19	37.02	1296.14
2003	3405.53	16.49	1106.61
2007	208.1	20.71	96.52
2013	1628.92	9.5	358.87
2015	62.14	33.67	47.32

Source: BWDB, 2018

In the Teesta basin flood occurs from mid-May to October. Both the regular river flood and flash flood destroys the livelihoods of the Teesta river basin community 2-3 times in a single year. First flood hits in mid- May to mid- June, second flood attack in mid-June to mid- September and third flood takes place from mid-September to mid- October in the Teesta basin (Shafie and Rahman 2009). The Flood affected area, household and population of the study districts has been presented in Table 4.15

Table 4.15 Flood affected area, household and population of the study districts

Districts	Affected area in sq. km	Flood affected household	Affected population
Rangpur	134.37	665	2060
Lalmonirhat	204.29	12987	45279
Kurigram	1339.65	92128	301647
Nilphamari	8.0972	4100	15705
Gaibandha	485.00	37786	134630

Source: Department of Disaster Management, 2014

4.6.5 Planform Pattern of Teesta

The basic channel planform patterns are Brided, Meandering and Straight. The Teesta is a dynamic river and bank erosion is recurrent in the basin during the pre-monsoon, monsoon and post-monsoon season. The planform pattern of the Teesta basin changes due to river bank erosion. Channel planform depends upon the hydrology and morphology of a river system. The relationship of hydrological and geomorphological variables is marked for stream channel planform.(Ward,1975). The Teesta river channel planform displays braided pattern in the wide valleys. Simultaneously in the narrow bends it illustrates meandering planform pattern. Variation in stream discharge, channel size, debris load, violent movement of water, geology and location are the factors affecting meandering channel development. (Yang, 1971). Among the above mentioned conditions the Teesta river has meander bends in the upazilas of Dimla, Gangachara, Rajarhat and Sundarganj.

The Teesta river has well developed braiding pattern. The non-cohesive sands transported through the Teesta river is responsible for the mid channel bar and pointed bar formation in the river bed. Non-cohesive mobile bed material controls bar formation process at high discharge in a braided stream channel (Ward,1975). Valley widening through river bank erosion and bank failure is another mechanism to transport the fine grained sediment deposition in the Teesta river bed and thus numerous bar formation process is exaggerated.

As Bangladesh possesses the downstream valley of Teesta river, the river has no gorge and canyon like the upstream. Waterfall is also invisible in the study area. The river valley floor is covered with silt and sand. It is occupied by numerous sand bars and multithreaded channels. Some channels are narrow and some are wide in shape. During flood period abrupt changes in river valley creates new channels.

4.7 The Teesta River System

The Eastern Zone

The Brahmaputra is the biggest river in the eastern zone of the Teesta river. The Teesta is the most important tributary of the Brahmaputra. High discharge is recognized in the monsoon but in the dry season Teesta and its adjoining rivers are poorly drained. Beels are the most influencing drainage topographies in the eastern zone. Sonkosh is a river with 9-10 km length. It flows through the Kurigram district. The Sonkosh is a tributary of Gangadhar river.

The Western Zone

The western zone covers the Ghagat, Jamuneshori, Buri Teesta river channels. The Ghagat is the main distributary of the Teesta river. It is a perennial river and affected by normal flood. The river Jamuneshari flows through the upazillas Domar, Jaldhaka, Kishoreganj of Nilphamari district and Taraganj, Badargnj and Mithapukur upazillas of Rangpur district. Buri Teesta is a distributary of Teesta. It is feed by few small stream channels like the Dhum, Chikli, Saru, Giria,Naotara etc. Chikli is an small, active and perennial river channel of western zone. Dhum and Naotara are the tributary of Buri or mora Teesta.

The Northern Zone

The western zone of Teesta river covers the Gangadhar, Trimohoni, Soti and the Swarnamati river

The Southern Zone

Once the Teesta flowed through the Karatoa channel. Now the Karatoa is a seasonal river. Sarai is a distributary of Teesta. It originates from the Teesta at Sundrganj upazilla of Gaibandha.

4.8 The Teesta Barrages

The hydrology and morphology of Teesta river depends upon the anthropogenic activities such as barrage, Bridge, hydroelectric projects on the river. Teesta barrage is situated at Doani point of Dalia which is 16 km downstream of Bangladesh-India border. The Teesta barrage has been aimed to supply irrigation water in Kharif-II season as well as flood control and enhance the drainage facilities of the districts of northern Bangladesh. The Teesta barrage has been initiated in 1979 and completed in the 1990s. The barrage diverts the Teesta river water in the agricultural field through its main, secondary and tertiary diversion cannels. The project area occupies 33 upazillas of Rangpur, Dinajpur and Bogra districts. It is the largest irrigation project of Bangladesh. The Teesta Barrage project has been initiated for poverty alleviation of those districts through crop diversification (Farooque, 2004). The barrage is about 615 m in length with 44 sluice gates and 12,750 cumec. discharge capacity (Islam, 2003). The structures of Teesta Barrage Project are as follows:

Table 4.16 Structures in the Teesta Barrage project

Structures of Teesta barrage	**Length**
Flood embankment	80 km
Flood bypass	610 m
Main canal	34 km
Major secondary canal	120 km
Secondary canal	360 km
Tertiary canal	590 km
Drainage channel	960 km

Source: Islam, 2003

However, the ambitious Teesta Barrage Project (Bangladesh) and The Gazoldoba Barrage project (India) is responsible for thousands of people as well as its environmental impact is a major concern. Recurrent flood, river bank erosion and channel shifting situation become worsen after the barrage construction. The operation of Gazoldoba barrage significantly interrupts the functional activity of Teesta barrage by water withdrawal in summer and release in the monsoon (Islam and Khan, 2015).

The Gazoldoba barrage in the Teesta river of Jalpaiguri district, India has been initiated in 1993 for agricultural development and conveys the rivers of west Bengal into a solo system (Banik, 2016). The The northern districts of West Bengal (Jalpaiguri, North Dinajpur, South Dinajpur, Cooch Behar, Darjeeling and Malda) are the beneficiary for the multipurpose Gazoldoba barrage. The barrage is situated 99 km upstream of the Teesta river of Bangladesh.

4.9 Existing projects on Teesta

The Teesta “V” dam has been completed in 2007 in India which has a capacity of 510 mw hydroelectricity power generation. The Rangit (iii) dam (India) has been completed in 2000 (60 mw hydroelectricity power generation capacity). Moreover, India has begun a lot of hydroelectric projects on Teesta. The projects are: Tista I (North) Himalayan green energy Pvt. Ltd. (280 mw), Tista II (North) Him Urja infrastructure Pvt. Ltd. (330 mw), Tista III (North) Teesta Urja Limited (1200 mw), Tista IV (North) NHPH Limited (495 mw), Tista V NHPH Limited (510 mw), Tista VI (South) Lanco energy pvt. Ltd. (500 mw), Panan North Himagiri hydro energy pvt. Ltd. (300 mw), Lachen North NHPH Ltd. (210 mw), Rongnichu (East) Madhya Bharat power corporation Ltd. (96 mw), Rangyong (North) BSCPL-SCL joint venture (117), Chujachen (East) Gati infrastructures Ltd. (99 mw), Sada Mangder (South) Gati infrastructures Ltd. (71 mw), Rolep (East) amalgamated transpower (1) Ltd (36 mw), Bhasmey (East) Gati infrastructures Ltd. (32 mw), Chakhungchu (North) amalgamated transpower (1) Ltd. (50 mw), Rangit II (west) Sikkim venture Pvt. Ltd. (60 mw), Ralong (South) amalgamated transpower (1) Ltd. (40 mw), Rangit IV (west) Jal power corporation Ltd. (120 mw), Jorethang loop (South) DANS energy Pvt. Ltd. (96 mw), Dikchu (North) Sneha kinetic power projects Ltd. (96 mw), Thangchi (North) Lachung power private Ltd. (40), Lingza (North) SSNR super power private Ltd. (120 mw), Bimkyong (North) Teesta power pvt. Ltd. (99mw), Ting Ting (West)SMEC (India) Pvt. Ltd. (70 mw), Bop (North) Chungthang power Pvt. Ltd. (90 mw), Tashiding (West) Shiga energy Pvt. Ltd. (60 mw), Rateychu Bakchachu (North) coastal projectsPvt. Ltd.(40mw). These entire projects are ongoing in Teesta which will change the hydrological and morphological characteristics of the entire river basin.

4.10 Role of Teesta in the Northern Bangladesh

21 million populations of Bangladesh live in the Teesta river basin and 70% population of Northern Bangladesh directly depends upon Teesta river. The livelihood of 9.15 million people of Rangpur division is dependent on the Teesta river. (Haque, 2016). The bars (*char*) developed in Teesta river bed is blessings for the river erosion victims. Settlements are common manmade features in the point bars and mid channel bars. Plenty of grasses locally named *shon* ghas[17] and *kasia ghas*[18] (catkin grass) are grown in bars. Therefore, these bars are ideal for cattle grazing. Moreover these grasses are used as thatching, basket making and household cleaning material. The local people try to grow corn, *Kaun*[19], pulses in these bars to improve the soil quality. The bar which is mostly silty is suitable for cultivation.

The river plays vital role in agriculture, fishery, transport and communication in the entire region. The Teesta barrage project supplies irrigation water in the northern districts of the country. The river is the transformer of landscapes, source of surface and sub-surface water and occupies drainage discharge in the northern Bangladesh. The river also plays dominant role in the cultural heritage of the Teesta riparian communities. Though, the Teesta river is the lifeline of the northern Bangladesh, the morphology, biodiversity, ecology and the agriculture of the study area are now in fragile condition due to its trans-boundary water issues.

4.11 Trans boundary water issues

Trans boundary water issues are prominent in Bangladesh for its downstream location. The country has 57 trans boundary rivers including the Teesta. About 54 river shares its water within India-Bangladesh and 3 rivers are bordered within Myanmar and Bangladesh. The trans boundary characteristics of the rivers impose strict barrier for the country to maintain its morphology and hydrology. The agrarian society of the northern Bangladesh is very much vulnerable for their livelihood due to unilateral water withdrawal of the neighboring country. Availability of irrigation water supply is restricted through one sided water extraction of India (Islam *et al*., 2004). Shared river basin is a common problem of Bangladesh with the giant neighbors like India and China. Ahmed (2007) described the challenges of sustainable water resource management in the river basins are:

---

[17] *Shon* ghas is a variety of grass found in the bank of river and bars in Bangladesh.

[18] *Kasia ghas* refers to the local variety of grass which grows plenty in the river islands and blooms in the Autumn season.

[19] *Kaun* is a native variety of food grain cultivated in Teesta basin.

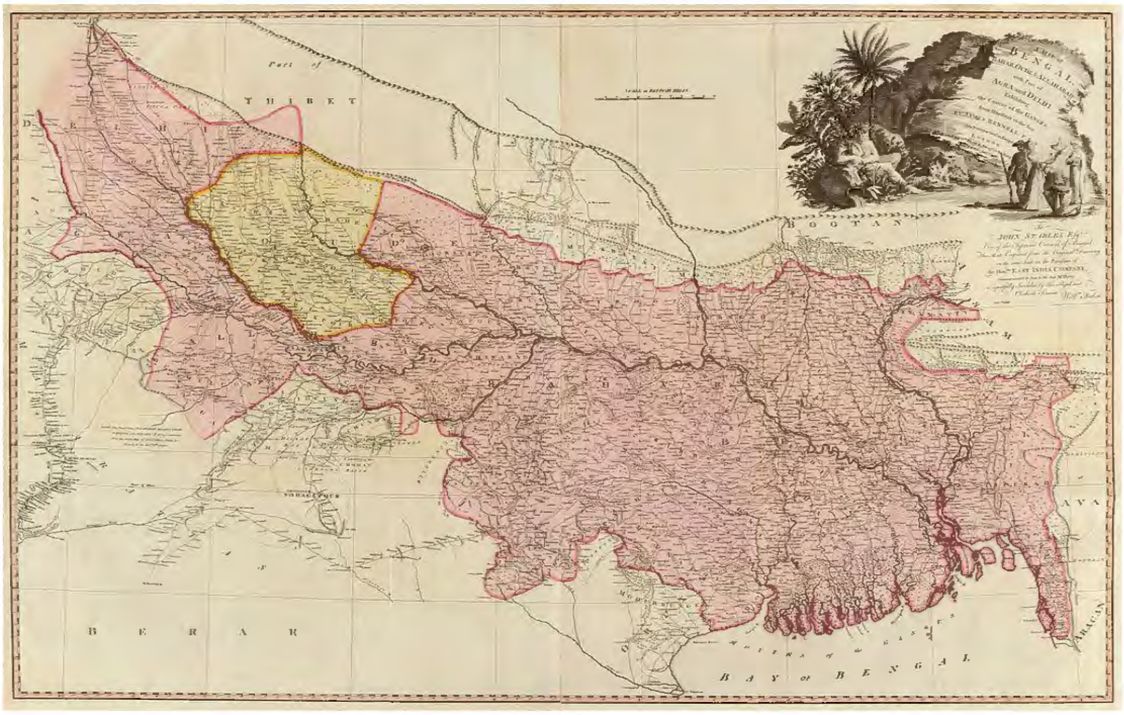
- Deficiency of regional financial significances and political spirit
- Dearth of effective water management and controlling authority.
- Scarcity of actual appliance for regional water allocation.
- Non- consent of water distribution according to the international resolutions
- Scarcity of jurisdictive and organizational structure to resolve water related issues.
- Paucity of regional organizing authority.
- Investment shortage for hydropower expansion.
- Deficiency of storage reservoir maintenance in the upper valley of river.
- Inter-river water allocation scheme of India.

Now a days, Bangladesh have to face a great problem due to river linking projects of India. This water diversion project will create negative impacts on morphology, hydrology, ecology, agriculture and livelihood of Bangladesh. The mega project of India will connect 37 rivers with 30 links. From the 30 links 14 are in the Himalayan rivers and 16 are in peninsular rivers. The amount of transferred river water would be 173 cubic meter from one river to the other. India has not yet gets any concerns from the trans boundary basin sharing countries to implement the project which is a complete violation of international rules. (Ahmed, 2007).

Chapter Five
Morphological Changes and Geomorphological Features

5.1 Morphological Change of Teesta from Historical Evidences

The Teesta river changed its morphology in historical past. In the map of James Rennell (1786) (map 5.1) the early flow of Teesta was recognized as three channels the Punarbhaba, Attrai, Karatoya and meets the Ganges. It is evident from the map of James Rennell that there was no existence of the river Jamuna before1787. A devastating flood occurred in the Teesta river in 1787 which diverted its course eastward towards the Brahmaputra and extended a new stream channel Jamuna. Before 1787 the Teesta flowed through three different channels but after the extreme flood of 1787 the river changed its course into a new channel Jamuna (Islam, 2003). Intensive rainfall of August 1787 caused the devastating flood which clogged the Atrai river with sand resulting the Teesta overspill into the entire region. The extreme high flood water of Teesta flowed through an old small departed channel Jenai-Konai that is now known as the Brahmaputra-Jamuna river system. The Mymansing earthquake in 1782 also has supported the river morphology change (Brammer, 1996). Epirogenic movement influences the eastward diversion of Teesta. The uplifting mechanism of the Madhupur tract may have a strong influence in the alteration of the river course (Fergusson, 1863).



Source: Faden, 1811

Map 5.1 Map of James Rennell shows the earlier flow of Teesta river in1786

Morgan and McIntyre (1959) argued about the subsidence zone between the Barind tract and the Madhupur tract. According to Morgan and McIntyre (1959) the influencing factors of the diversion of river courses are the steep gradient along the Jamuna, submergence of Garo- Rajmahal gaps in the Cenozoic era, the existence of faults in the north east of Barind tract and western side of the Madhupur tract. Faulting in the recent alluvium causes diversion in the Ganges and Teesta river (Islam, 2003). The Barind and Madhupur tract worked as a horst and between these two Pleistocene Terrace the land became a rift valley to form the Brahmaputra-Jamuna river system (Islam, 2003). The formation process of Brahmaputra- Jamuna river system had been carried out about 30 years after 1787 floods. The old course is known as old Brahmaputra. As Bangladesh possesses the downstream channel of Teesta river, it always changes its course by its aggradation and degradation activities. At present Teesta is known as an important tributary of Brahmaputra river. It shifts its channels through flood, river bank erosion and sediment deposition. The Teesta river is shifting from west to east (Chakraborty and Datta, 2013).

5.2 Erosion and deposition of Teesta

Teesta is a dynamic river for its erosional and depositional fluvial characteristics. The spatio-temporal change of hydrology and sedimentology along with the topographic condition are responsible for change in erosion and deposition in Teesta river. The present study tries to investigate the decadal variation of river bank erosion and accretion from 1975-2017. Supervised image classification have been done through ERDAS IMAGINE software and classified the land into four categories such as sand bar, vegetated bar, main land and water body. Eroded and deposited areas have been identified with sequential bank line shifting of the river.

5.2.1 Right and Left Bank Erosion of Teesta

Satellite image analysis displays that the left bank of the Teesta river in Bangladesh is more erosion prone than the right bank during 1975-2017 (Table 5.1). Highest right bank erosion has been detected in the decade of 1975-1987 and it was 31.53 sq.km. On the other hand, lowest right bank erosion (7.51 sq.km) was observed in 1997-2006. The status of left bank showed almost same erosion values while the right bank exhibited discrete erosion status. During the last 42 years the right bank of Teesta eroded about 39.97 sq. km while the left bank erodes 70.43 sq.km. The spatial pattern of erosion and deposition of Teesta (1975-1987), (1987-1997) have been shown in Map 5.2 and Map 5.3

Table 5.1 Right and left bank erosion of Teesta

Year	Right bank erosion (in sq.km)	Left bank erosion (in sq.km)
1975-1987	31.53	36.01
1987-1997	24.13	36.27
1997-2006	7.51	34.16
2006-2017	10.54	26.24
1975-2017	39.97	70.43

Source: Calculated from Satellite Image

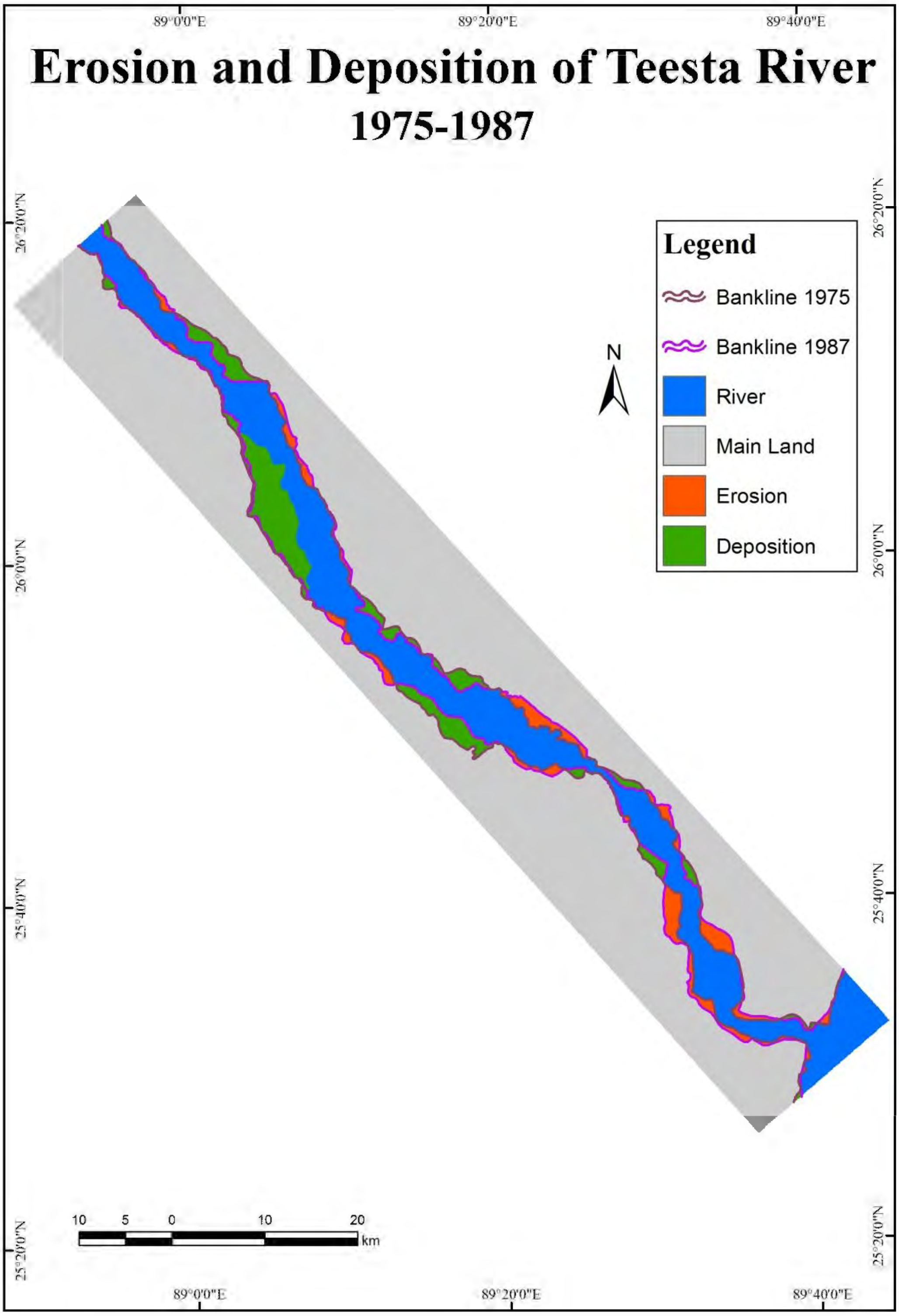
5.2.2 Right and Left Bank Deposition of Teesta

The right bank of Teesta showed highest deposition (61.88 sq.km) in 2006-2017 and the second highest right bank erosion was 51.10 sq.km and it has been noticed in the decades of 1997-2006. Table 5.2 illustrates the right and left bank deposition of Teesta. While the left bank of Teesta designate highest left bank deposition (37.48 sq.km) in 1987-1997 and lowest left bank deposition (8.09 sq.km) in 2006-2017. The spatial pattern of erosion and deposition of Teesta (1997-2006), (2006-2017) have been shown in Map 5.4 and Map 5.5. The analysis of the study unveils that during 1975 to 2017 the right bank deposited more sediments (132.03 sq. km) than the left bank (33.48 sq.km). Therefore, it has been observed from the study that the left bank of Teesta is more erosion prone and the right bank is more accretion prone.

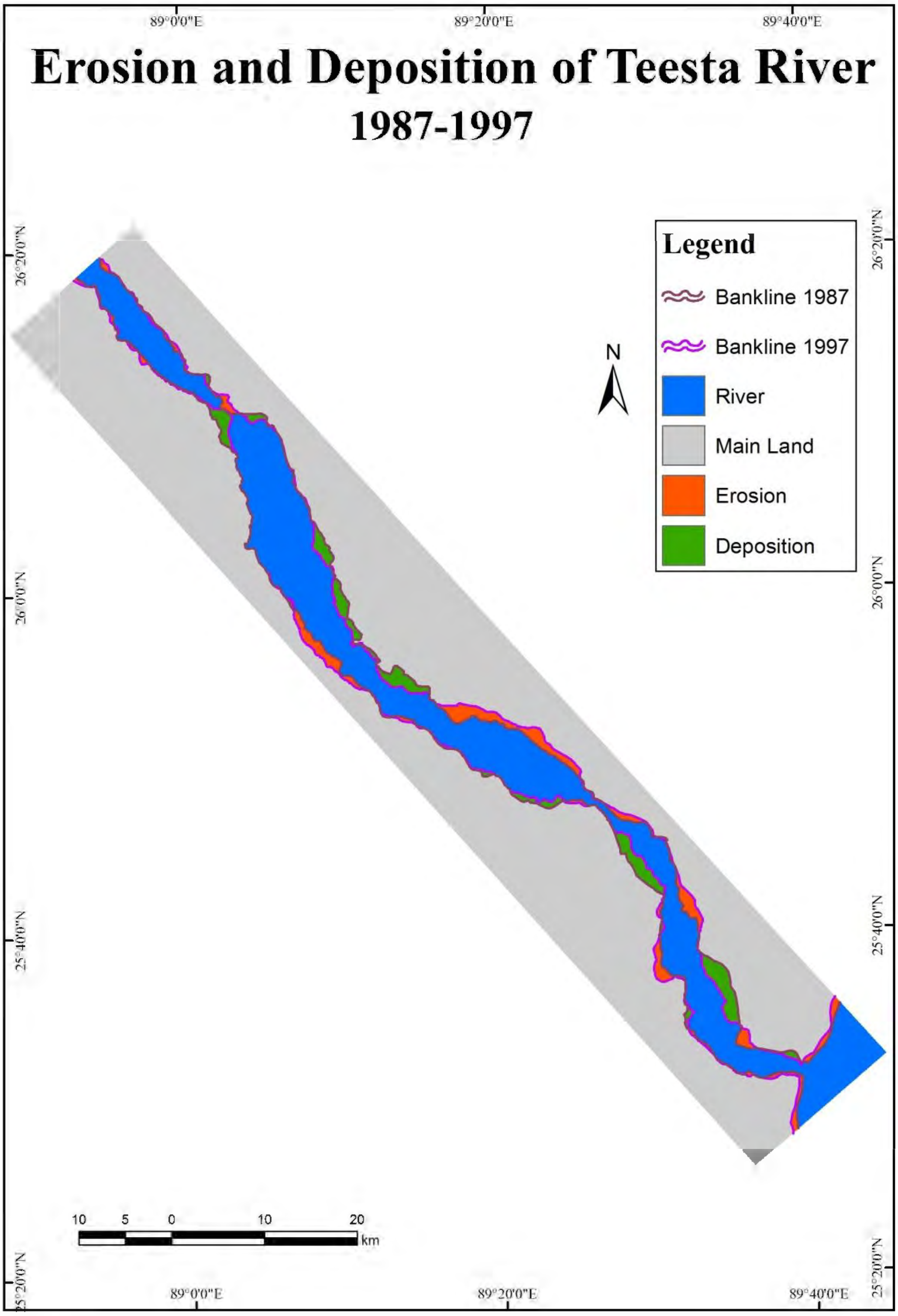
Table 5.2 Right and left bank deposition of Teesta

Year	Right bank deposition (in sq.km)	Left bank deposition (in sq.km)
1975-1987	33.90	37.32
1987-1997	23.02	37.48
1997-2006	51.10	11.94
2006-2017	61.88	8.09
1975-2017	132.03	33.48

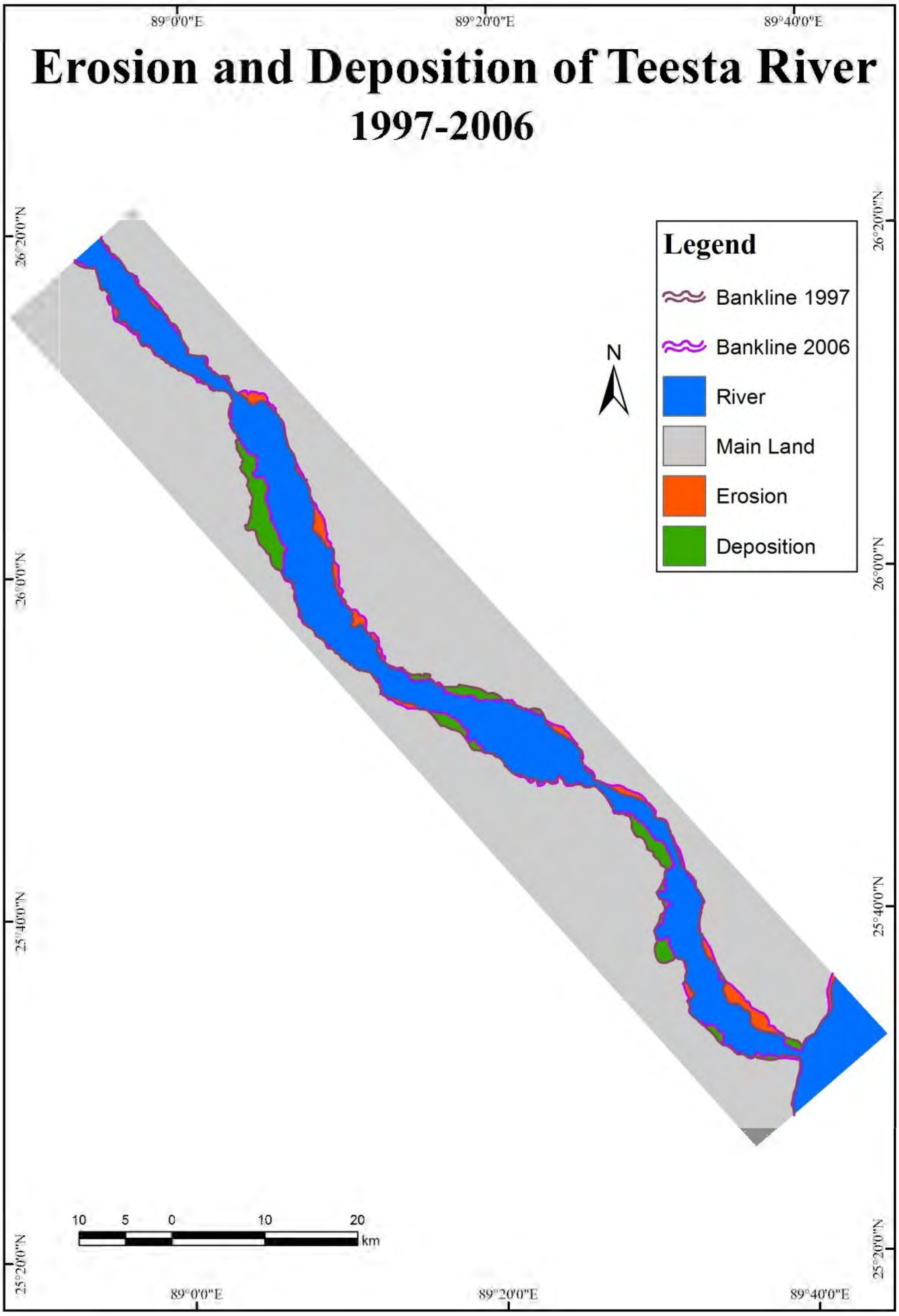
Source: Calculated from Satellite Image


89°0'0"E
89°20'0"E
89°40'0"E
Erosion and Deposition of Teesta River
1975-1987
Legend
Bankline 1975
Bankline 1987
River
Main Land
Erosion
Deposition
N
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
10
5
0
10
20
km

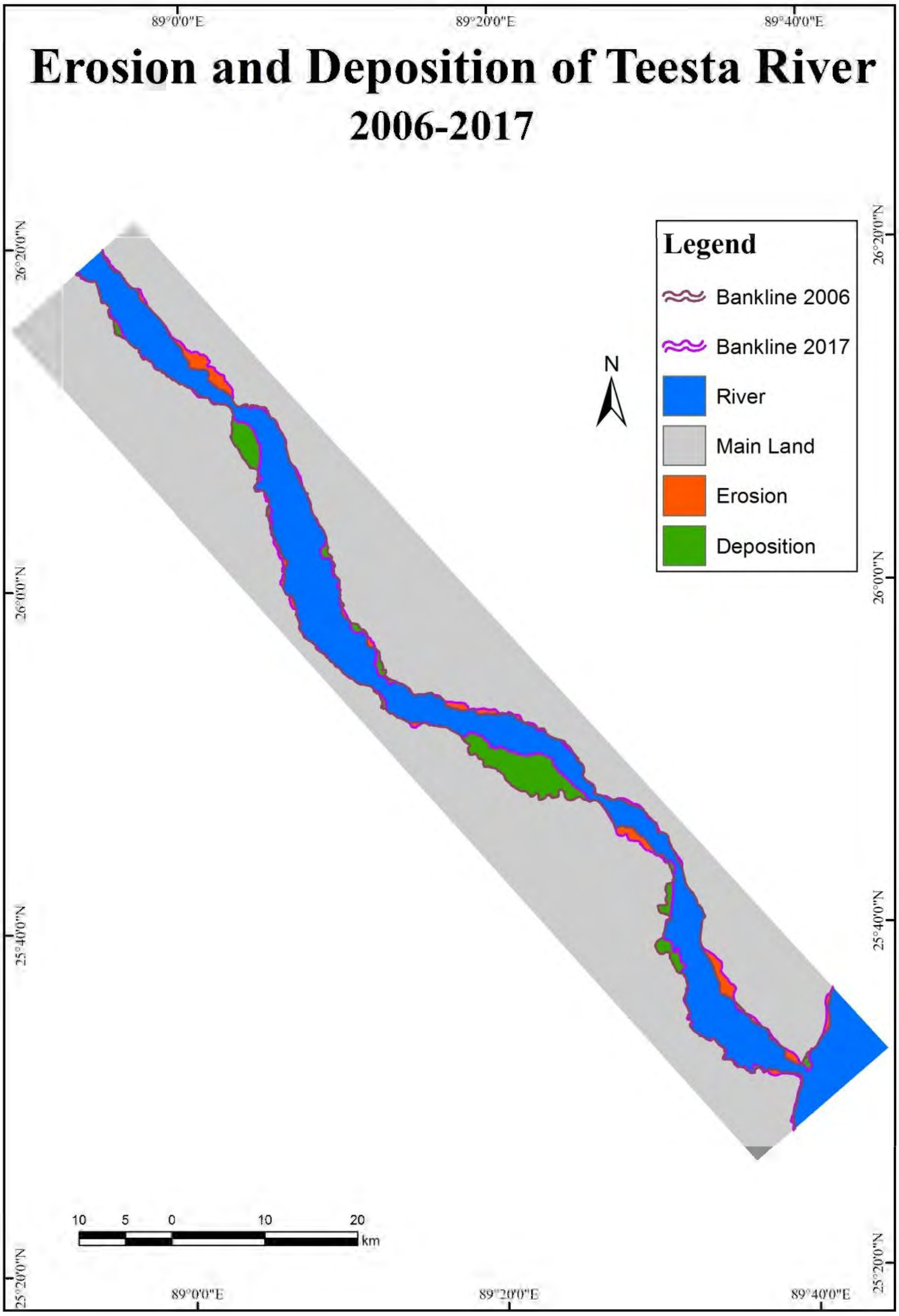
Map 5.2 Bank erosion and deposition of Teesta (1975-1987)


89°0'0"E
89°20'0"E
89°40'0"E
Erosion and Deposition of Teesta River
1987-1997
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline 1987
Bankline 1997
River
Main Land
Erosion
Deposition
N
10
5
0
10
20
km

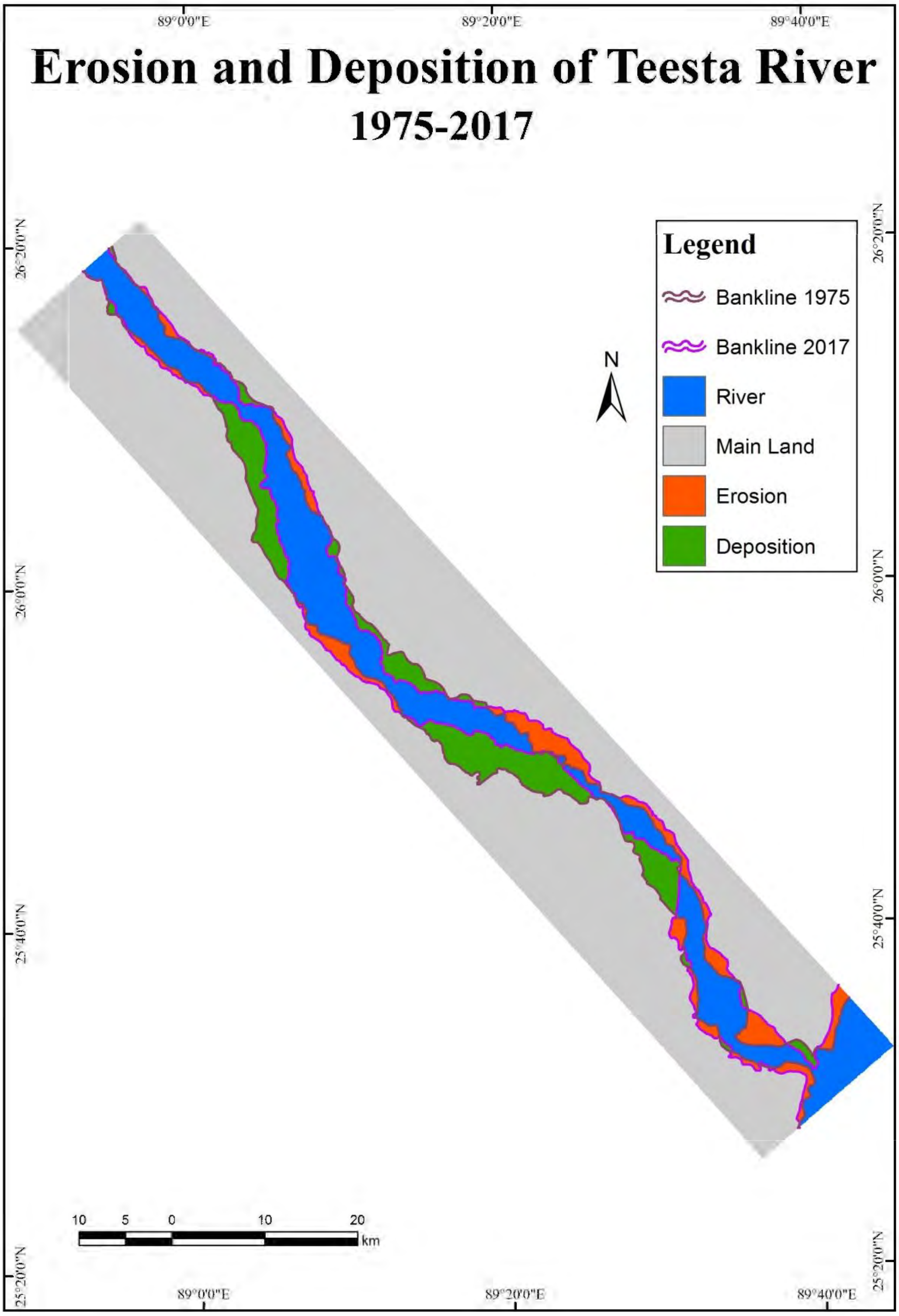
Map 5.3 Bank erosion and deposition of Teesta (1987-1997)


89°0'0"E
89°20'0"E
89°40'0"E
Erosion and Deposition of Teesta River
1997-2006
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline 1997
Bankline 2006
River
Main Land
Erosion
Deposition
N
10
5
0
10
20
km

Map 5.4 Bank erosion and deposition of Teesta (1997-2006)


Erosion and Deposition of Teesta River
2006-2017
Legend
Bankline 2006
Bankline 2017
River
Main Land
Erosion
Deposition
N
10 5 0 10 20
km
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N

Map 5.5 Bank erosion and deposition of Teesta (2006-2017)


Erosion and Deposition of Teesta River
1975-2017
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline 1975
Bankline 2017
River
Main Land
Erosion
Deposition
N
10
5
0
10
20
km

Map 5.6 River morphology change through erosion and deposition of Teesta (1975-2017)

5.3 Changing River Morphology with Bank Line Shifting and River Width

The Teesta river displays its braided channel pattern mainly in the studied decades through its ongoing erosional and depositional status. The Teesta river is liable to continual change in morphology owing to shifting of river channel.

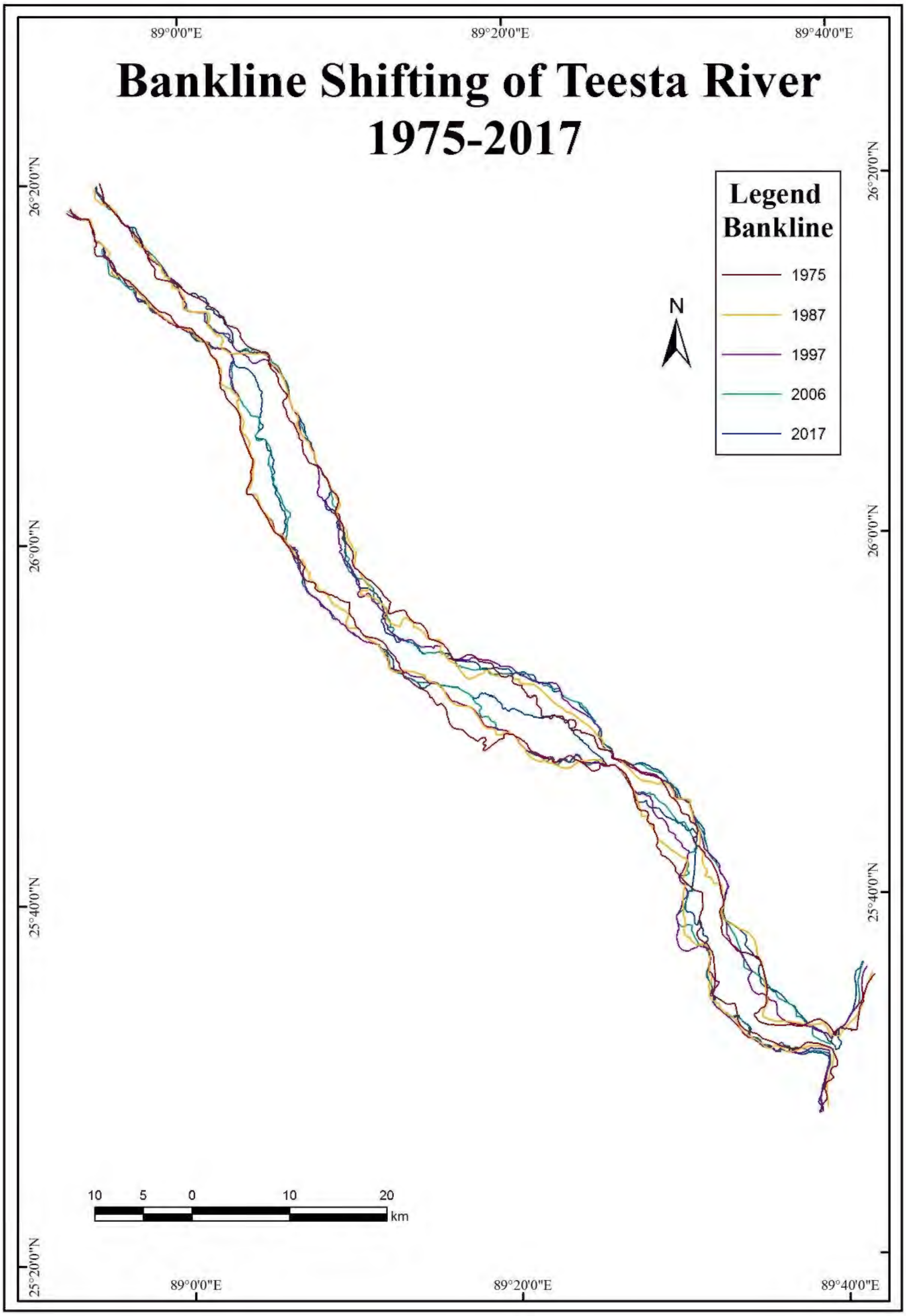
5.3.1 Channel Migration from 1975-2017

In 1975 the river has its wide valley in Nilphamari and Rangpur but the valley was narrow in Kurigram and Gaibandha. During 1975-1987 the river shows eastward movement and channel migration. The river again shifted westward for its chronological shifting mechanism through erosion and deposition in 1987-1997 decade. Bank line shifting and channel migration has been illustrated in Map 5.7. The bank line in 1975 has been demarcated with maroon color and in 1987 it has been delineated through yellow color in Map 5.7. During 1975-1987 study periods, the left bank at Hatibandha upazilla of Lalmonirhat district was east ward (1975) but in 1987 the same bank moved west ward in the upazilla.

In 1997 the river was wide at Jaldhaka (Nilphamari) but it shifted its right bank in 2006 and in that location the river become narrower than before. In 2006 the left bank of Teesta shifted eastward and the river alley become wide than 1997. The river valley was narrow in 2006 than 2017 at Hatibandha (Lalmonirhat). East ward movement of left bank at Hatibandha upazilla has been observed from 2006-2017. The right bank shifted eastward at jaldhaka upazilla of Nilphamari district during 2006-2017. In Rangpur district the river valley become narrower in 2017 than 2006 and the right bank shifted eastward in that location.

5.3.2 Change in river width

River bank erosion and sediment deposition in bank causes the change in river width as well as bank line shifting or channel migration. Channel widening occurs in the Teesta river due to extreme flood and 8.1% large area has been detected in Teesta in 2010 than 1930s (Prokop and Sarker, 2012). To detect the river width, the river has been segmented through nine width measuring line and labeled from A-I. Table 5.3 indicates the width of Teesta river in the study decades. In 1975, segment G shows lowest width (0.74 km) and segment C shows highest width (7.46 km). The highest width (7.21 km.) in 1987 has been also depicted in segment C and lowest in segment G (0.73 km). The Teesta river denotes


Bankline Shifting of Teesta River
1975-2017
Legend
Bankline
1975
1987
1997
2006
2017
N
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
10
5
0
10
20
km

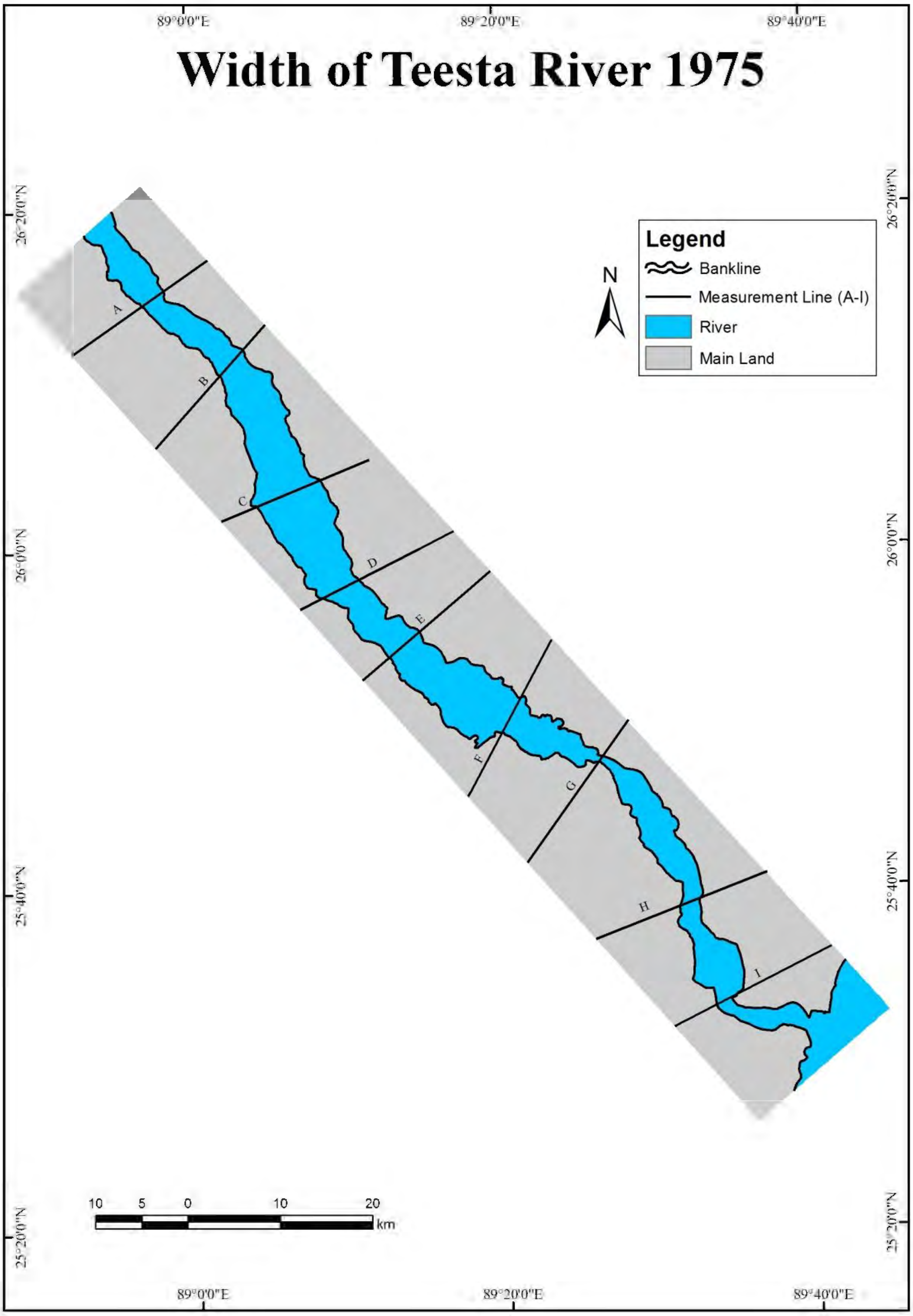
Map 5.7 Bank line shifting and channel migration (1975-2017)

7.46 km (highest) width in segment C in 1975 and 0.62 km. width (lowest) in segment G in the year 1997 among the study decades. The change in width of Teesta river has been shown in Map 5.8, 5.9, 5.10, 5.11 and 5.12. In 2006, the highest width of Teesta has been noticed in segment F (5.84 km) and lowest in segment G (0.70 km). Thus, the study shows highest width in segment C in all the decades except 2006 (highest width in segment F). On the other hand, lowest widths have been depicted in the segment G in all the decades. Therefore, the study explores that segment G is less active in erosion-accretion process. Alternatively, the other segments are active erosion-accretion prone zone of the river. The changing river width also indicates the bank line shifting tendency of Teesta river from 1975-2017 study period.

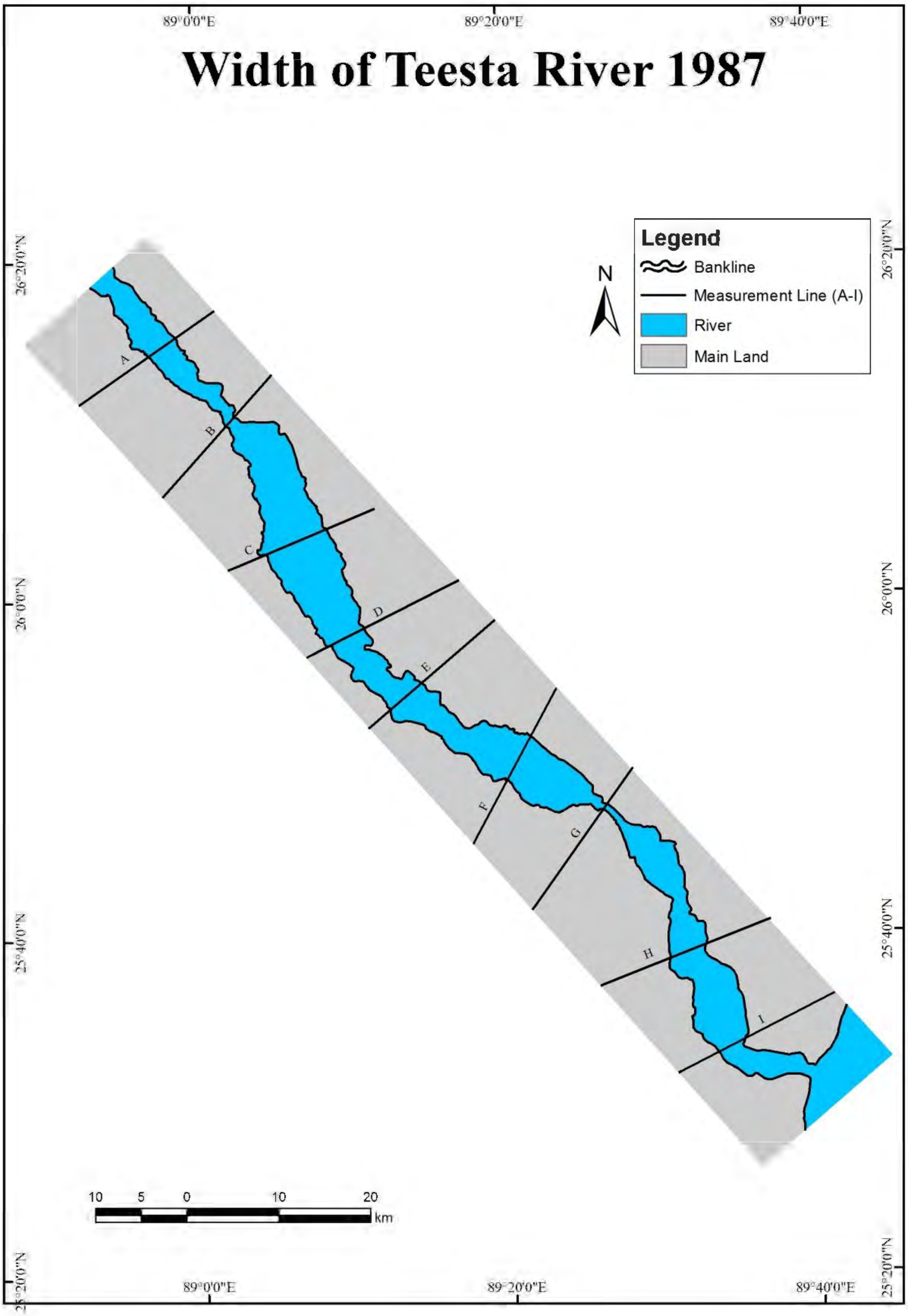
Table 5.3 Changes in Teesta river width

Width measuring line (A-I)	**Width (in km)**				
	1975	1987	1997	2006	2017
A	2.86	3.59	3.77	4.07	4.11
B	3.76	1.36	1.11	1.28	1.69
C	7.46	7.21	7.01	4.92	5.03
D	4.38	4.23	4.63	4.81	4.78
E	4.27	4.40	3.07	2.52	2.34
F	4.31	5.46	5.95	5.84	3.48
G	0.74	0.73	0.62	0.70	0.67
H	2.29	4.19	4.97	4.88	3.21
I	2.42	3.20	4.70	4.59	4.93

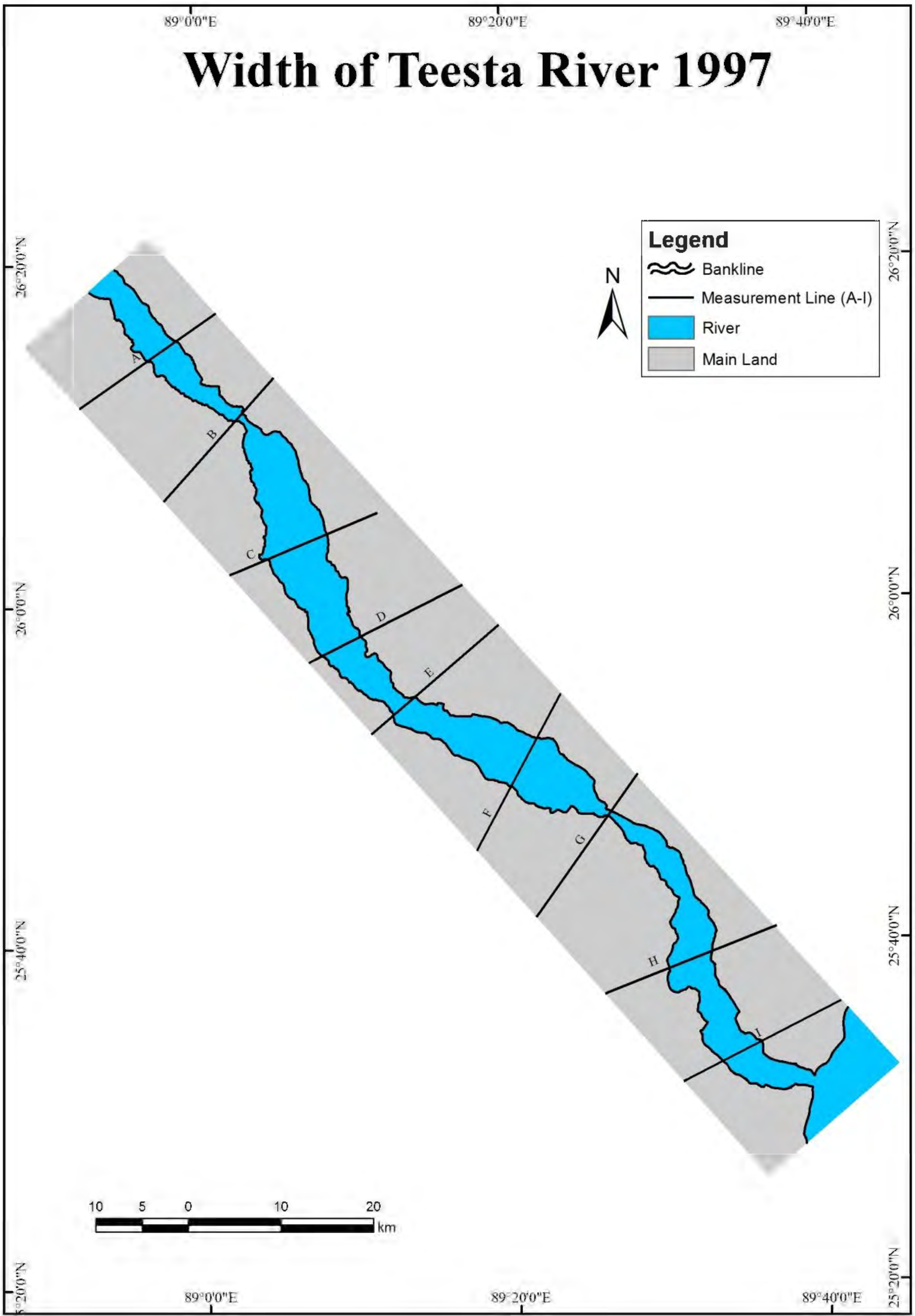
Source: Calculated from Satellite Image


Width of Teesta River 1975
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline
Measurement Line (A-I)
River
Main Land
N
A
B
C
D
E
F
G
H
I
10
5
0
10
20
km

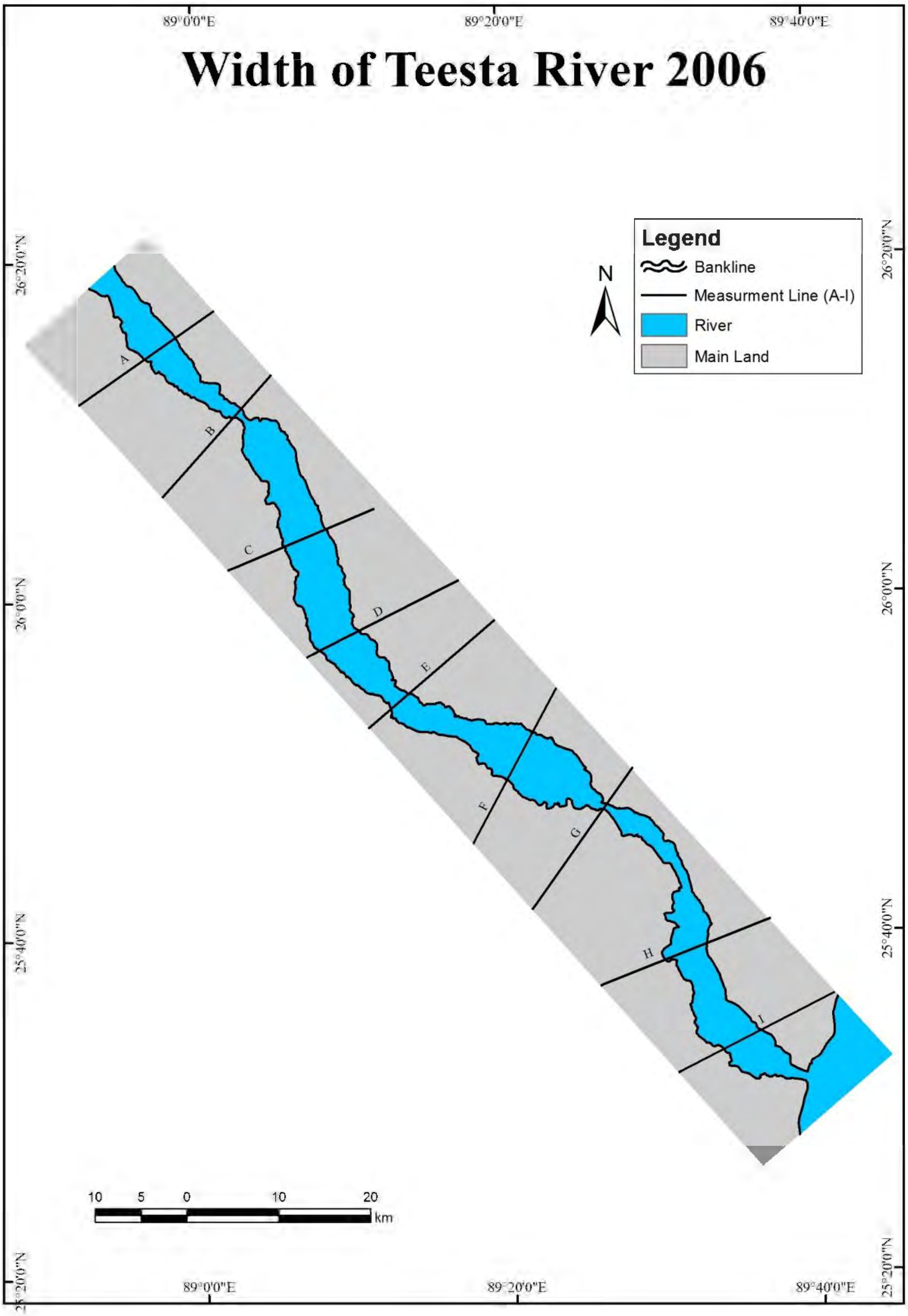
Map 5.8 Width of Teesta river in 1975


89°0'0"E
89°20'0"E
89°40'0"E
Width of Teesta River 1987
Legend
Bankline
Measurement Line (A-I)
River
Main Land
N
A
B
C
D
E
F
G
H
I
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
10
5
0
10
20
km

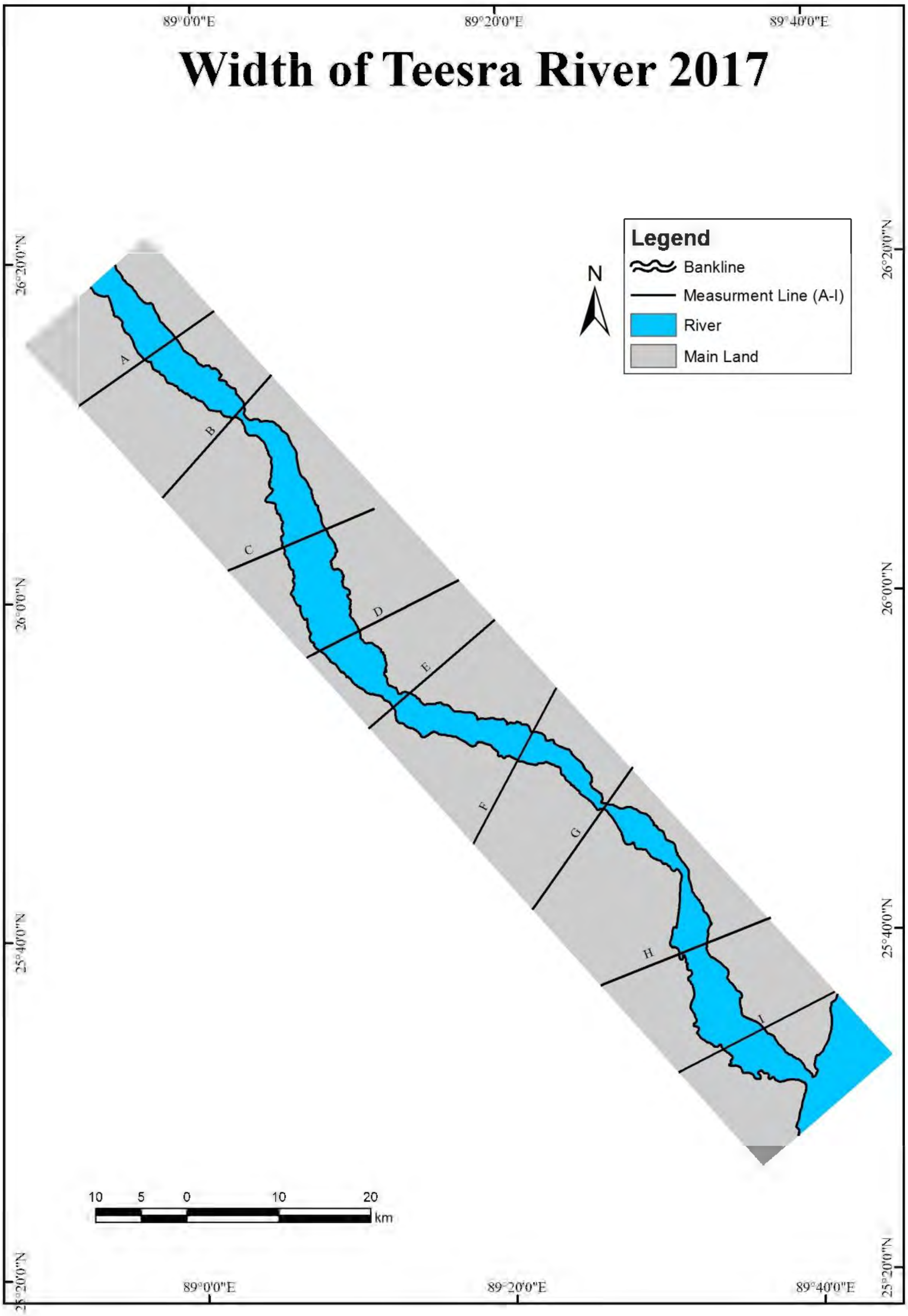
Map 5.9 Width of Teesta river in 1987


Width of Teesta River 1997
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline
Measurement Line (A-I)
River
Main Land
N
A
B
C
D
E
F
G
H
I
10
5
0
10
20
km

Map 5.10 Width of Teesta river in 1997


Width of Teesta River 2006
89°0'0"E
89°20'0"E
89°40'0"E
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline
Measurment Line (A-I)
River
Main Land
N
A
B
C
D
E
F
G
H
I
10
5
0
10
20
km

Map 5.11 Width of Teesta river in 2006


89°0'0"E
89°20'0"E
89°40'0"E
Width of Teesra River 2017
26°20'0"N
26°0'0"N
25°40'0"N
25°20'0"N
Legend
Bankline
Measurment Line (A-I)
River
Main Land
N
A
B
C
D
E
F
G
H
I
10
5
0
10
20
km

Map 5.12 Width of Teesta river in 2017

5.4 District wise river morphology change during 1975-2017

Spatio-temporal change in river morphology has been detected in the study districts. District wise erosion and sediment deposition of Teesta river along with erosion and deposition rate in per sq.km has been analyzed in the present study.

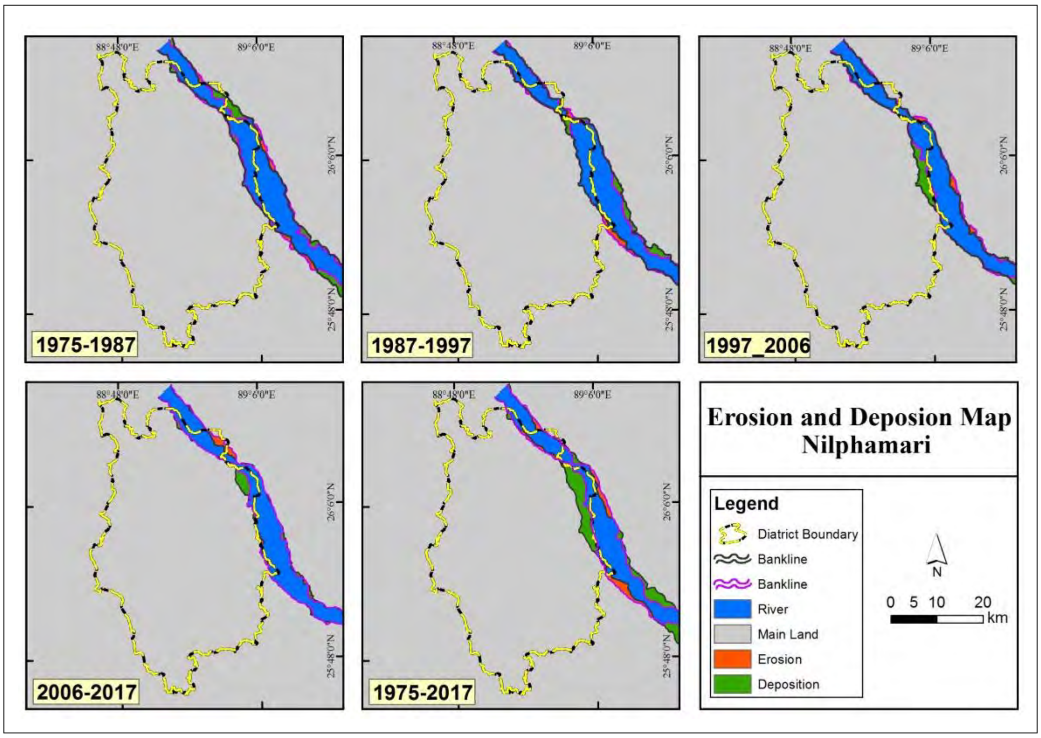
5.4.1 Erosion and deposition in Nilphamari district

The trans-boundary Teesta river entered into Bangladesh through Nilphamari district. Table 5.4 shows the erosion and deposition (in sq.km) of Teesta river in Nilphamari district. The temporal change in erosion pattern of Nilphamari district shows highest erosion (7.41 sq.km) in 2006-2017 and lowest (2.47 sq.km) in 1975-1987. The analyzed data shows highest deposition (24.35 sq.km) in 1997-2006 and lowest deposition (6.84 sq.km) in 1987-1997. The table indicates that during 1975-2017 in Nilphamari district sediment deposition is higher (46.21 sq.km) than erosion (6.47 sq.km) in the Teesta river. In Nilphamari district highest erosion rate/year is 0.67 sq.km in 2006-2017 and highest deposition rate is 2.70 in 1997-2006. Map 5.13 illustrates the condition of erosion and deposition of Teesta in Nilphamari district.

Table 5.4 Erosion and deposition (sq.km) in Nilphamari district

Year	Erosion (sq. km)	Erosion rate/ year (sq. km)	Deposition (sq. km)	Deposition rate/ year (sq. km)
1975-1987	2.47	0.20	12.84	1.07
1987-1997	4.71	0.47	6.84	0.68
1997-2006	3.23	0.35	24.35	2.70
2006-2017	7.41	0.67	13.56	1.23
1975-2017	6.47	0.15	46.21	1.10

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
88°48'0"E
89°6'0"E
26°6'0"N
25°48'0"N
Erosion and Deposion Map Nilphamari
Legend
Diatrict Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 5 10 20 km

Map 5.13 Erosion and deposition of Teesta in Nilphamari district

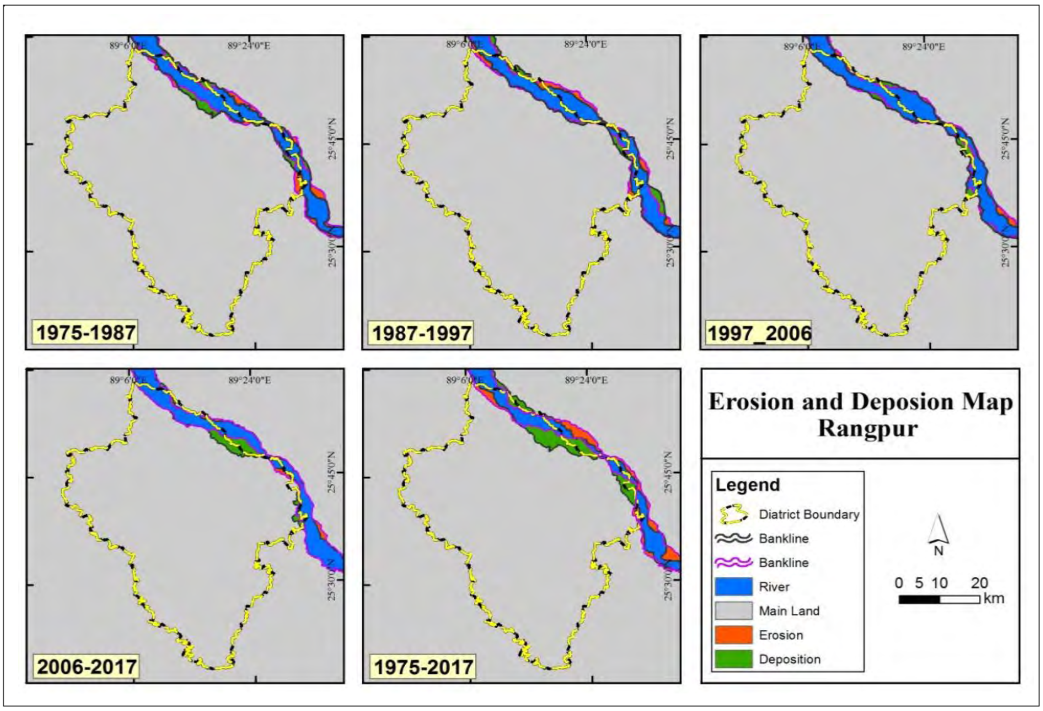
5.4.2 Erosion and deposition in Rangpur district

The spatio-temporal variation of erosion and deposition of Teesta river in Rangpur district designates that during 1975-2017 deposition (66.48 sq.km) is four times higher than erosion (15.32 sq.km). The Table 5.5 shows highest erosion (18.08 sq.km) in 1975-1987 and the erosion rate is 1.50 sq.km per year. The decade 1997-2006 indicates lowest erosion (4.89 sq. km) in the district. Highest sediment deposition in Rangpur district has been observed 30.58 sq.km during 2006-17 and lowest deposition has been detected 17.15 sq.km in the time period of 1987-1997. Map 5.14 shows the condition of erosion and deposition of Teesta in Rangpur district.

Table 5.5 Erosion and deposition (sq.km) in Rangpur district

Year	Erosion (sq. km)	Erosion rate/ (year sq. km)	Deposition (sq. km)	Deposition rate/ (year sq. km)
1975-1987	18.08	1.50	30.60	2.55
1987-1997	17.17	1.71	17.15	1.71
1997-2006	4.89	0.54	19.03	2.11
2006-2017	6.06	0.55	30.58	2.78
1975-2017	15.32	0.36	66.48	1.58

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°6'0"E
89°24'0"E
25°45'0"N
25°30'0"N
Erosion and Deposion Map
Rangpur
Legend
Diatrict Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 5 10 20
km

Map 5.14 Erosion and deposition of Teesta in Rangpur district

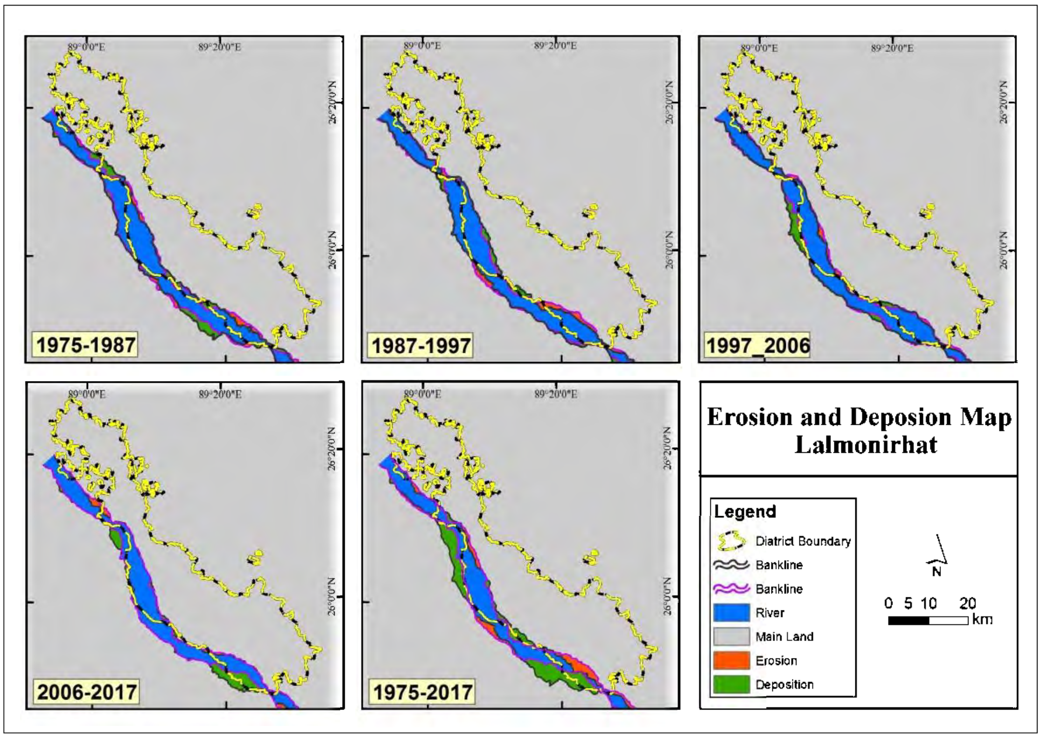
5.4.3 Erosion and deposition in Lalmonirhat district

Map 5.15 displays the condition of erosion and deposition of Teesta river in Lalmonirhat district. The erosion and deposition of Teesta river during 1975-1987 and 1987-1997 shows almost parallel pattern. But erosion is almost two times higher (15.87 sq.km) than deposition (8.56 sq.km) during 1997-2006 and deposition is also more than two times higher (21.67 sq.km) than erosion (9.32 sq.km) during 2006-2017. Highest erosion (18.89 sq.km) has been observed in 1975-1987 and lowest erosion (9.32 sq.km) has been detected in 2006-2017. Simultaneously highest deposition (21.67 sq.km) has been identified in 2006-2017 and lowest deposition (8.56 sq.km) has been noticed in 1997-2006. The study result of 42 years (1975-2017) erosion and deposition of Teesta river in Lalmonirhat district displays that erosion has been occurred 31.72 sq.km and deposition has been happened in 40.17 sq.km (Table 5.6).

Table 5.6 Erosion and deposition (sq.km) in Lalmonirhat district

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	18.89	1.57	20.17	1.68
1987-1997	17.12	1.71	19.42	1.94
1997-2006	15.87	1.76	8.56	0.95
2006-2017	9.32	0.84	21.67	1.97
1975-2017	31.72	0.75	40.17	0.95

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°0'0"E
89°20'0"E
26°20'0"N
26°0'0"N
Erosion and Deposion Map Lalmonirhat
Legend
Diatrict Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 5 10 20
km

Map 5.15 Erosion and deposition of Teesta in Lalmonirhat district

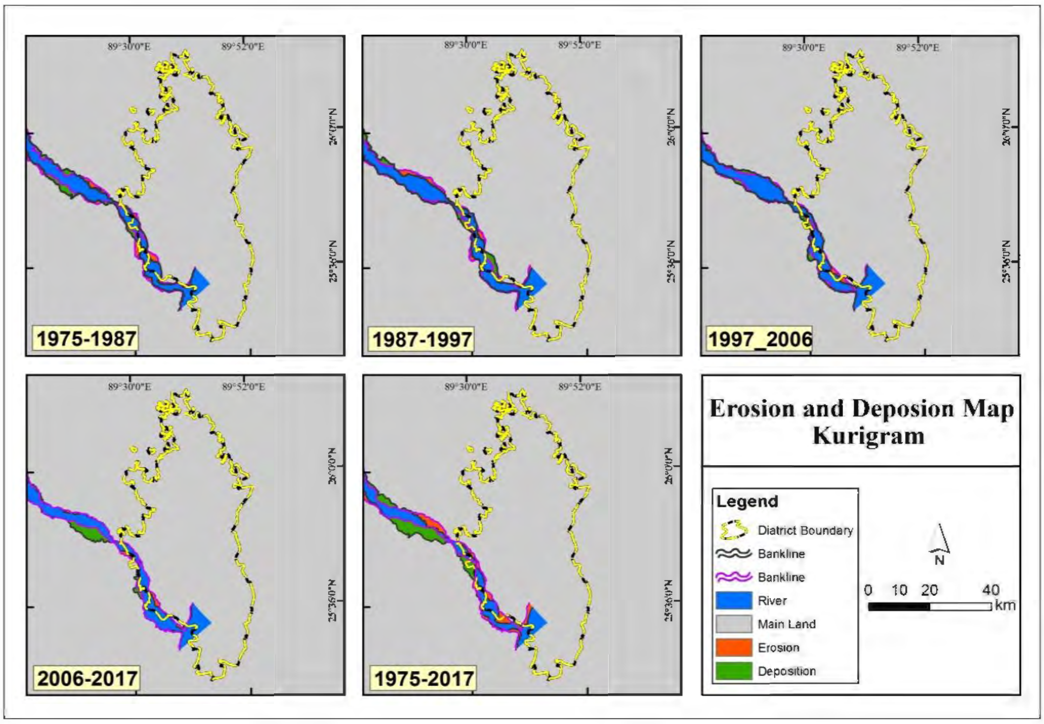
5.4.4 Erosion and deposition in Kurigram district

The erosional and depositional status of Kurigram district highlights that erosion is higher than deposition during the study decades except the decade of 1987-1997 when deposition (14.07 sq.km) is higher than erosion (12.01 sq.km). During the whole study period (1975-2017) erosion is four times higher (29.11 sq.km) than deposition (7.39 sq.km) in Kurigram district. Highest erosion (14.26 sq.km) has been noticed in 1975-1987 and lowest erosion (9.23 sq.km) has been identified in 2006-2017. On the other hand, highest deposition (14.07) has been detected in 1987-1997 and lowest deposition (1.65 sq.km) has been observed in 2006-2017 (Table 5.7). Map 5.16 portrays the condition of erosion and deposition of Teesta river in Kurigram district.

Table 5.7 Erosion and deposition (sq.km) in Kurigram district

Year	**Erosion sq. km**	**Erosion rate/ year sq. km**	**Deposition sq. km**	**Deposition rate/ year sq. km**
1975-1987	14.26	1.18	4.38	0.36
1987-1997	12.01	1.20	14.07	1.40
1997-2006	11.17	1.24	4.86	0.54
2006-2017	9.23	0.83	1.65	0.15
1975-2017	29.11	0.69	7.39	0.17

Source: Calculated from Satellite Image


89°30'0"E
89°52'0"E
26°0'0"N
25°36'0"N
1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
Erosion and Deposion Map
Kurigram
Legend
Diatrict Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 10 20 40
km

Map 5.16 Erosion and deposition of Teesta in Kurigram district

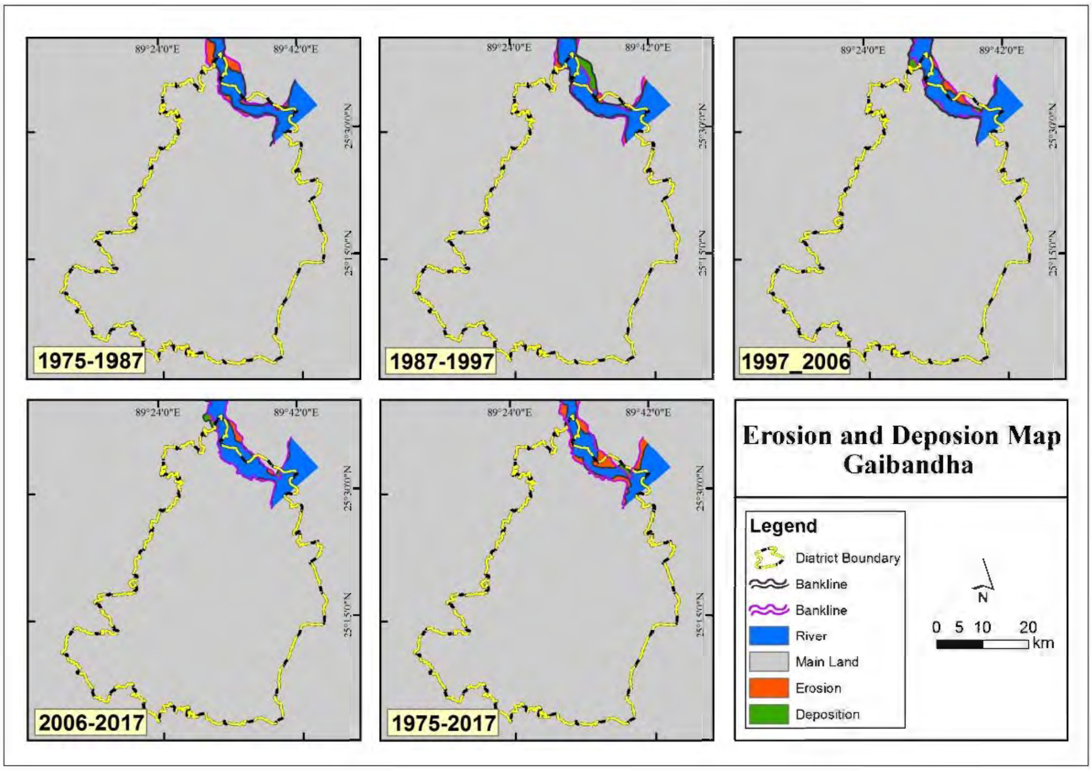
5.4.5 Erosion and deposition in Gaibandha district

Table 5.8 represents the condition of erosion and deposition (in sq.km) in Gaibandha district. Among the study decades erosion is highest (12.12 sq.km) during 1975-87 and lowest (4.23 sq.km) during 2006-17 in Gaibandha district. The district follows lowest deposition (2.18 sq.km) in the study period 1975-1987 and highest deposition (6.07 sq.km) during 1997-2006. During the 42 years (1975-2017) morphological change in Gaibandha district erosion is 4 times higher (21.30 sq.km) than deposition (5.26 sq.km). The condition of erosion and deposition of Teesta in Gaibandha district has been depicted in Map 5.17.

Table 5.8 Erosion and deposition (sq.km) in Gaibandha district

Year	**Erosion sq. km**	**Erosion rate/ year sq. km**	**Deposition sq. km**	**Deposition rate/ year sq. km**
1975-1987	12.12	1.01	2.18	0.18
1987-1997	7.8	0.78	2.85	0.28
1997-2006	5.78	0.64	6.07	0.67
2006-2017	4.23	0.38	2.77	0.25
1975-2017	21.30	0.50	5.26	0.12

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°24'0"E
89°42'0"E
25°30'0"N
25°15'0"N
Erosion and Deposion Map
Gaibandha
Legend
Diatrict Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 5 10 20
km

Map 5.17 Erosion and deposition of Teesta in Gaibandha district

5.4.6 Comparison of morphological change among the study districts

Satellite image analysis of morphological change in the five districts of Teesta river illustrates that the erosional and depositional status of the studied river has an equilibrium. In Bangladesh, the upstream districts like Rangpur (66.48 sq.km) and Nilphamari (46.21 sq.km) shows highest deposition than erosion during 1975-2017. The third highest deposition has been detected in Lalmonirhat district (40.17 sq.km). Simultaneously, the downstream districts followed the opposite condition and depict higher erosion than deposition. But the district of Lalmonirhat portrays almost balanced erosion (31.72 sq.km) and deposition (40.17 sq.km) during the study period. Highest erosion has been observed in Lalmonirhat district. The second and third highest eroded districts are Kurigram (29.11 sq.km) and Gaibandha (21.30 sq.km). Questionnaire survey and FGDs among the respondents identified the causes behind downstream erosion and upstream deposition of Teesta river. The study identifies the causes of erosion in the downstream are weak soil condition, dam and barrage construction, stone collection from the river bed, flood and excessive water discharge from the upstream in the monsoon. On the other hand, the study also finds out flood, erosion, human activities and upstream flow of silt causes sediment deposition in the Teesta river. Table 5.9 represents the erosion and deposition of the five districts during 1975-2017 at a glance.

Table 5.9 Comparison of erosion and deposition in the study districts (1975-2017)

District	Erosion (sq.km)	Deposition(sq.km)
Nilphamari	6.47	46.21
Rangpur	15.32	66.48
Lalmonirhat	31.72	40.17
Kurigram	29.11	7.39
Gaibandha	21.30	5.26

Source: Calculated from Satellite Image

5.5 River morphology change at the study unions

The studied union's experiences frequent erosional and depositional activities of the Teesta river. Erosion and deposition occurs simultaneously in the study area. These characteristic morphological features recognized the Teesta river as a braided river. Union wise erosion and deposition has been identified in the present study to detect river morphology change through satellite image analysis.

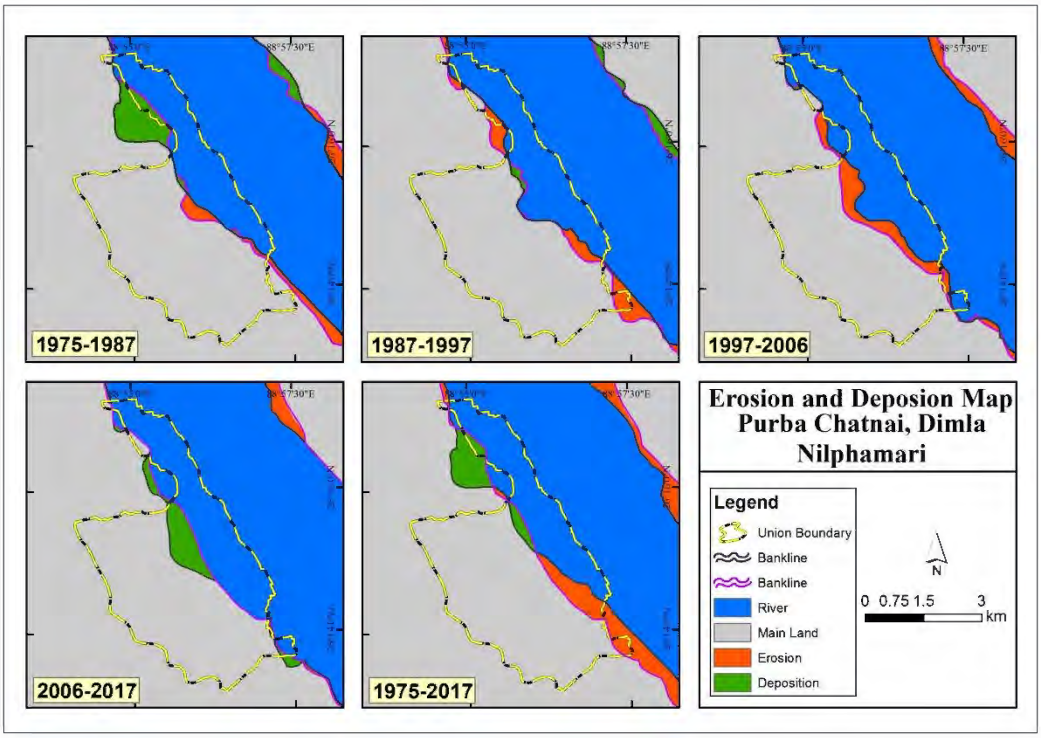
5.5.1 River morphology change at Purba chatnai union

River morphology change at Purba chatnai union of Dimla upazilla of Nilphamari district has been depicted in Table 5.10. Highest erosion (1.27sq.km) at Purba chatnai union has been identified during 1997-2006 among the other studied decades. Sediment deposition in the study union revealed highest deposition during 2006-2017 which is 1.20 sq.km. During the whole study period erosion is higher (1.13 sq.km) than deposition (0.45 sq.km). The table represents the erosion and deposition of Teesta river at Purba chatnai union. Map 5.18 shows the spatio-temporal change of erosion and deposition at Purba chatnai union.

Table 5.10 Erosion and deposition (in sq.km) at Purba chatnai union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	0.39	0.033	0.34	0.028
1987-1997	0.68	0.068	0.13	0.028
1997-2006	1.27	0.14	0.004449	0.00049
2006-2017	0.0044	0.00040	1.20	0.10
1975-2017	1.13	0.026	0.45	0.010

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997-2006
2006-2017
1975-2017
88°57'30"E
Erosion and Deposion Map
Purba Chatnai, Dimla
Nilphamari
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.75 1.5 3
km

Map 5.18 Erosion and deposition of Teesta at Purba Chatnai union

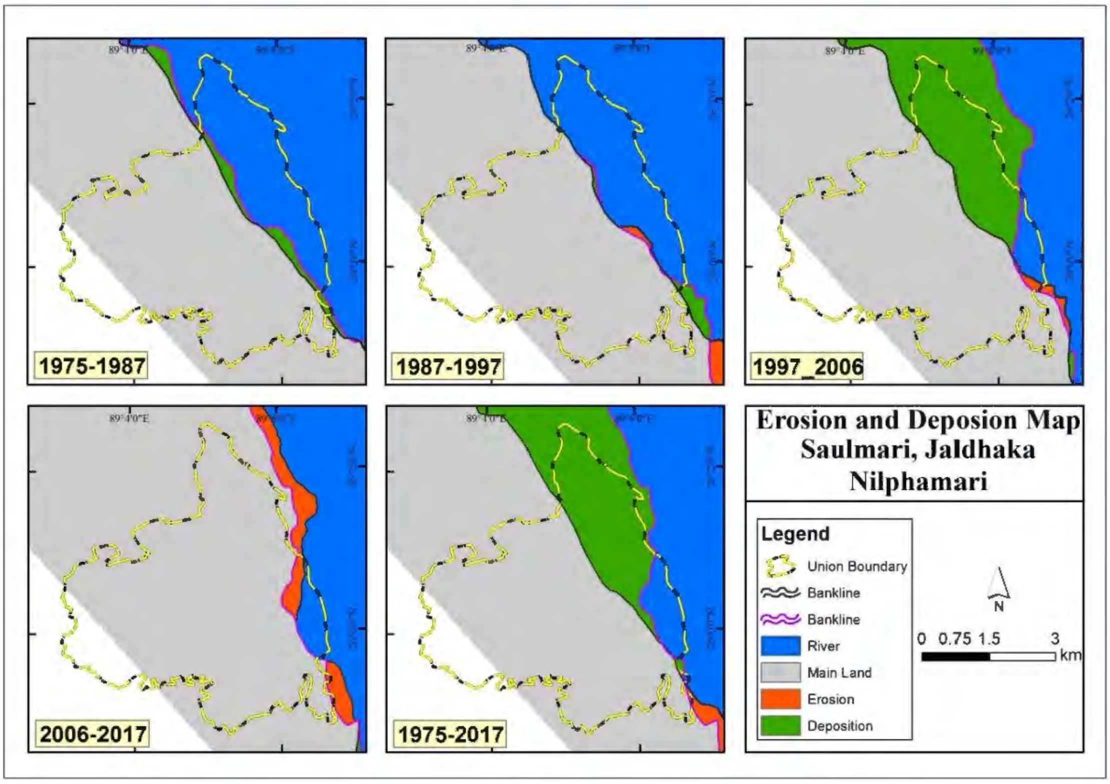
5.5.2 River morphology change at Saulmari union

Map 5.19 shows the river morphology change through erosion and deposition of Teesta at Saulmari union. During 1975-87 no erosion (0.00 sq.km) has been occurred at Saulmari union. Highest erosion (.46 sq.km) has been detected during 2006-2017. The study area possesses more deposition (5.23 sq.km) than erosion (0.029 sq.km) during the studied period (1975-2017). Among the studied decades 1997-2006 shows highest deposition (5.03 sq.km) at Saulmari union (Table 5.11).

Table 5.11 Erosion and deposition (in sq.km) at Saulmari union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	0.00	0.00	0.77	0.06
1987-1997	0.13	0.01	0.11	0.01
1997-2006	0.11	0.01	5.03	0.55
2006-2017	0.46	0.04	0.00	0.00
1975-2017	0.029	0.0007	5.23	0.12

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°40'E
Erosion and Deposion Map
Saulmari, Jaldhaka
Nilphamari
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.75 1.5 3
km

Map 5.19 Erosion and deposition of Teesta at Saulmari union

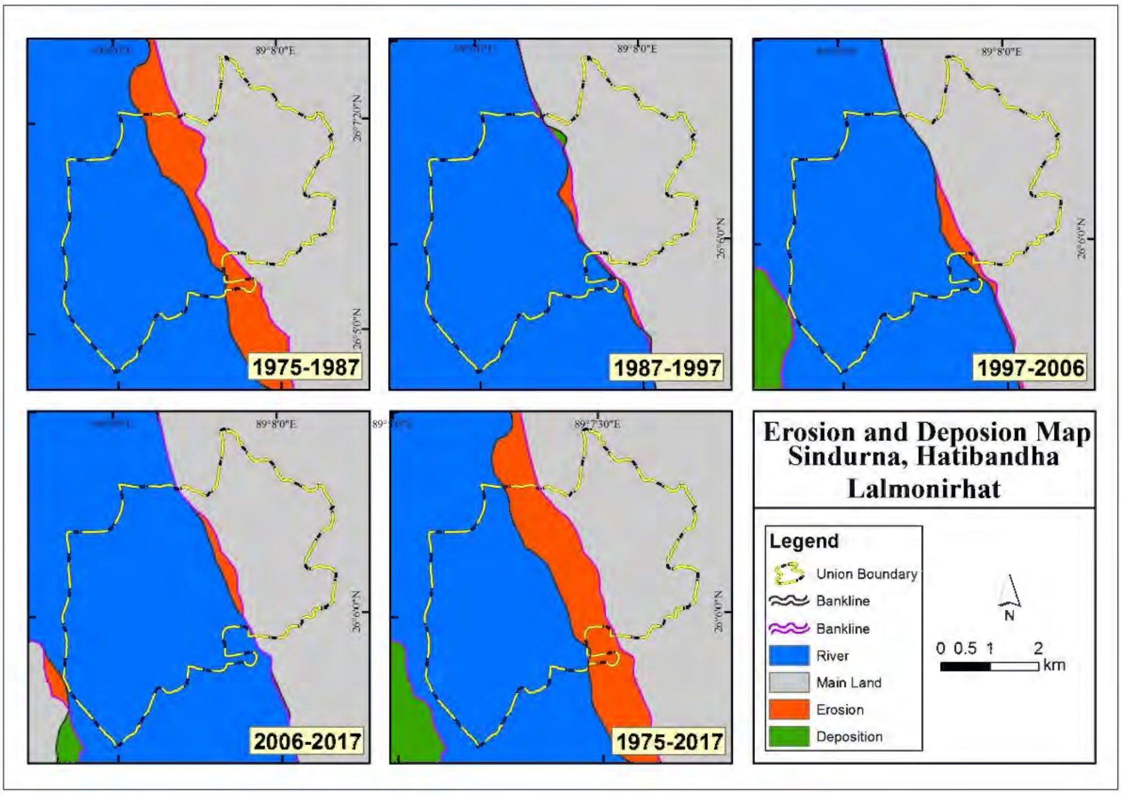
5.5.3 River morphology change at Sindurna union

Among the studied unions Sindurna is exceptional because it shows almost no deposition during 1975-2017, except few negligible depositions during 1987-1997 (0.07sq.km) and during 2006-2017 (0.0008 sq.km). Highest erosion (1.97sq.km) at Sindurna union has been identified during 1975-1987 and lowest erosion (0.21sq.km) has been observed in 1987-1997 (Map 5.20). Sindurna union has been observed 2.94 sq.km erosion during the whole study period (1975-2017). Table 5.12 represents erosion and deposition (in sq.km) at Sindurna union during the studied decades.

Table 5.12 Erosion and deposition (in sq.km) at Sindurna union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	1.97	0.16	0.00	0.00
1987-1997	0.21	0.02	0.07	0.007
1997-2006	0.44	0.04	0.00	0.00
2006-2017	0.39	0.03	0.0008	0.00
1975-2017	2.94	0.07	0.00	0.00

Source: Calculated from Satellite Image


89°8'0"E
1975-1987
1987-1997
1997-2006
2006-2017
89°7'30"E
1975-2017
Erosion and Deposion Map
Sindurna, Hatibandha
Lalmonirhat
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.5 1 2
km

Map 5.20 Erosion and deposition of Teesta at Sindurna union

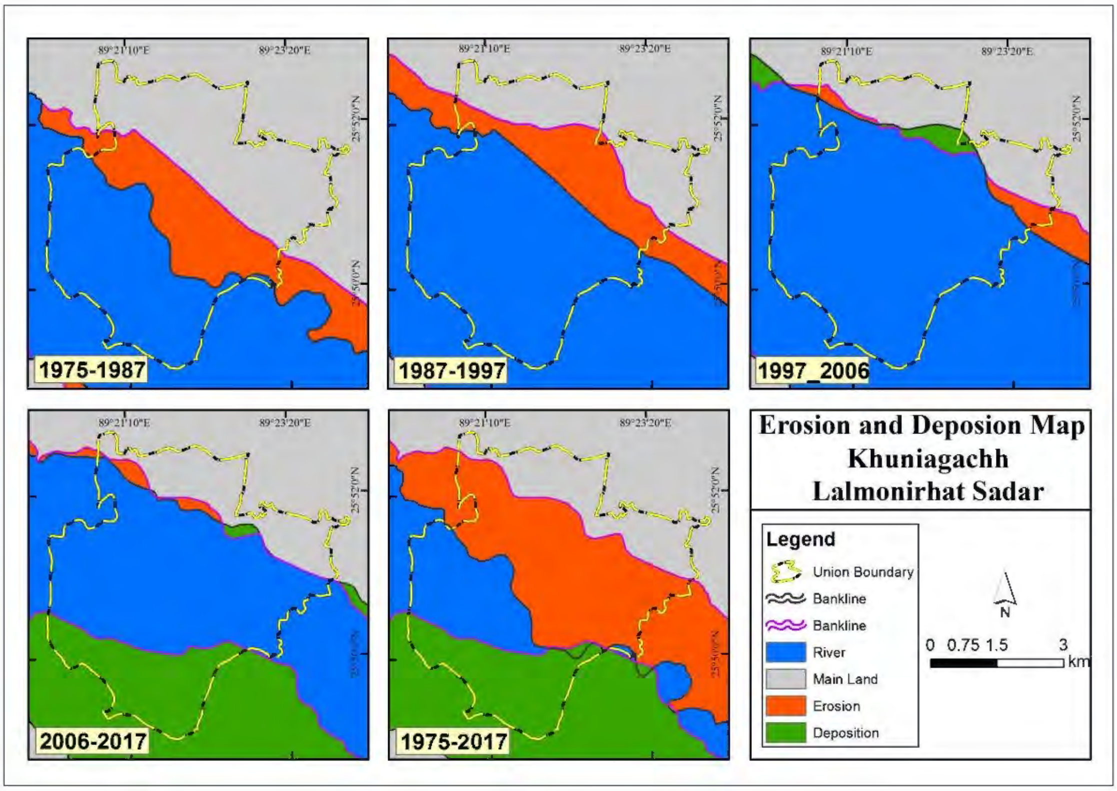
5.5.4 River morphology change at Khuniagachh union

Khuniagachh is an erosive union. Among the studied decades, 1975-1987 shows highest erosion (5.95 sq.km) and 2006-2017 indicates lowest erosion (0.56 sq.km). About 4.81 sq.km land has been lost due to erosion at Khuniagchh union during the year 1987-1997. The left bank of Teesta at Khuniagachh union has totally eroded during 1975-1987 and 1987-1997 (Map 5.21). There has been no sediment deposition occurred in the study decades of 1975-1987 and 1987-1997 at Khuniagchh union. Highest sediment deposition (5.67 sq.km) has been observed in the union during 2006-2017 (Table 5.13). Thus, the Khuniagchh union has been affected by 11.23 sq.km erosion and 5.35 sq.km depositions in the period of 1975-2017.

Table 5.13 Erosion and deposition (in sq.km) at Khuniagachh union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	5.95	0.49	0.00	0.00
1987-1997	4.81	0.48	0.00	0.00
1997-2006	0.88	0.09	0.66	0.07
2006-2017	0.56	0.05	5.67	0.51
1975-2017	11.23	0.26	5.35	0.12

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°21'10"E
89°23'20"E
25°52'0"N
25°50'0"N
Erosion and Deposion Map
Khuniagachh
Lalmonirhat Sadar
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.75 1.5 3
km

Map 5.21 Erosion and deposition of Teesta at Khuniagachh union

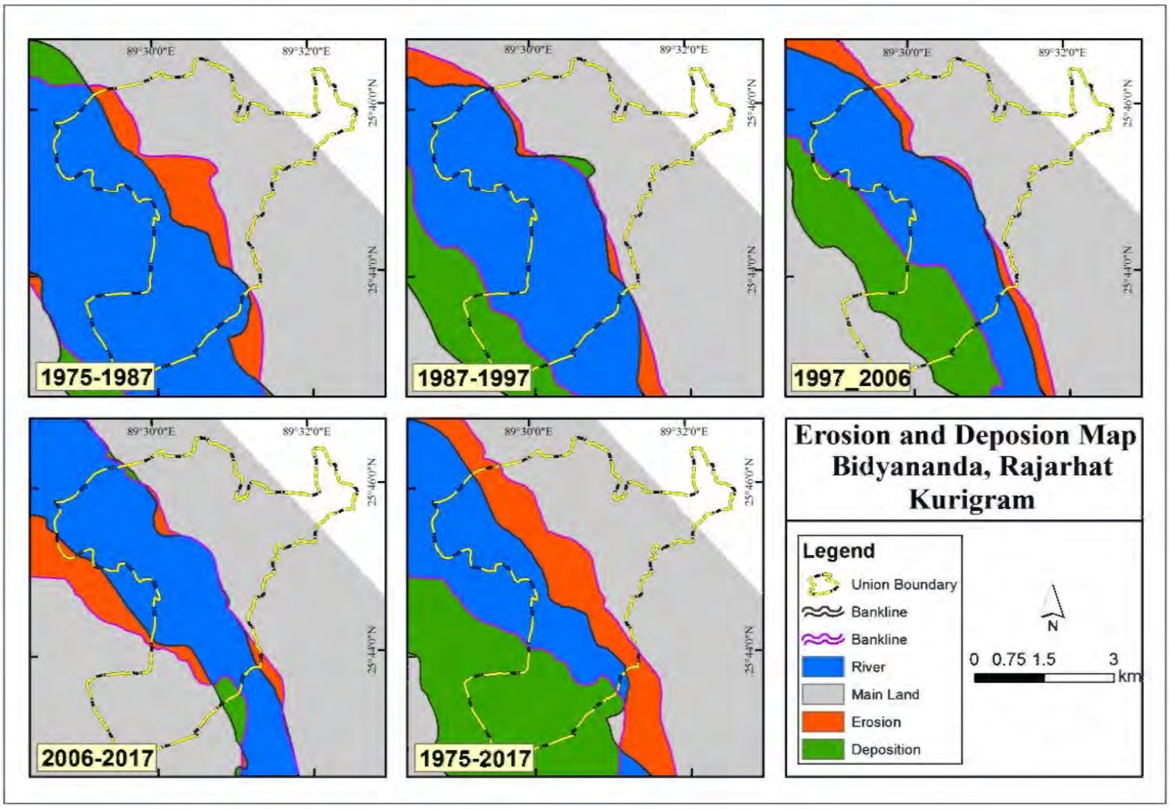
5.5.5 River morphology change at Bidyananda union

Prominent erosion has been observed in the Bidyananda union through 1975-1987 but this decade shows 0.00 deposition rate in per sq.km. 0.44, 0.62 and 0.72 sq.km erosion has been noticed in the study decades of 1987-1997, 1997-2006 and 2006-2017 respectively. Highest deposition (3.02 sq.km) has been detected during 1997-2006 at Bidyananda union. The erosion (0.09 sq.km) and deposition rate (0.10 sq.km) has been identified almost same in the studied union during 1975-2017 (Table 5.14). Map 5.22 illustrates the decadal variation of erosion and deposition (in sq.km) at Bidyananda union.

Table 5.14 Erosion and deposition (in sq.km) at Bidyananda union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	2.87	0.23	0.00	0.00
1987-1997	0.44	0.04	1.85	0.18
1997-2006	0.62	0.06	3.02	0.33
2006-2017	0.72	0.06	0.26	0.024
1975-2017	3.96	0.09	4.48	0.10

Source: Calculated from Satellite Image


89°30'0"E
89°32'0"E
25°46'0"N
25°44'0"N
1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
Erosion and Deposion Map
Bidyananda, Rajarhat
Kurigram
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.75 1.5 3
km

Map 5.22 Erosion and deposition of Teesta at Bidyananda union

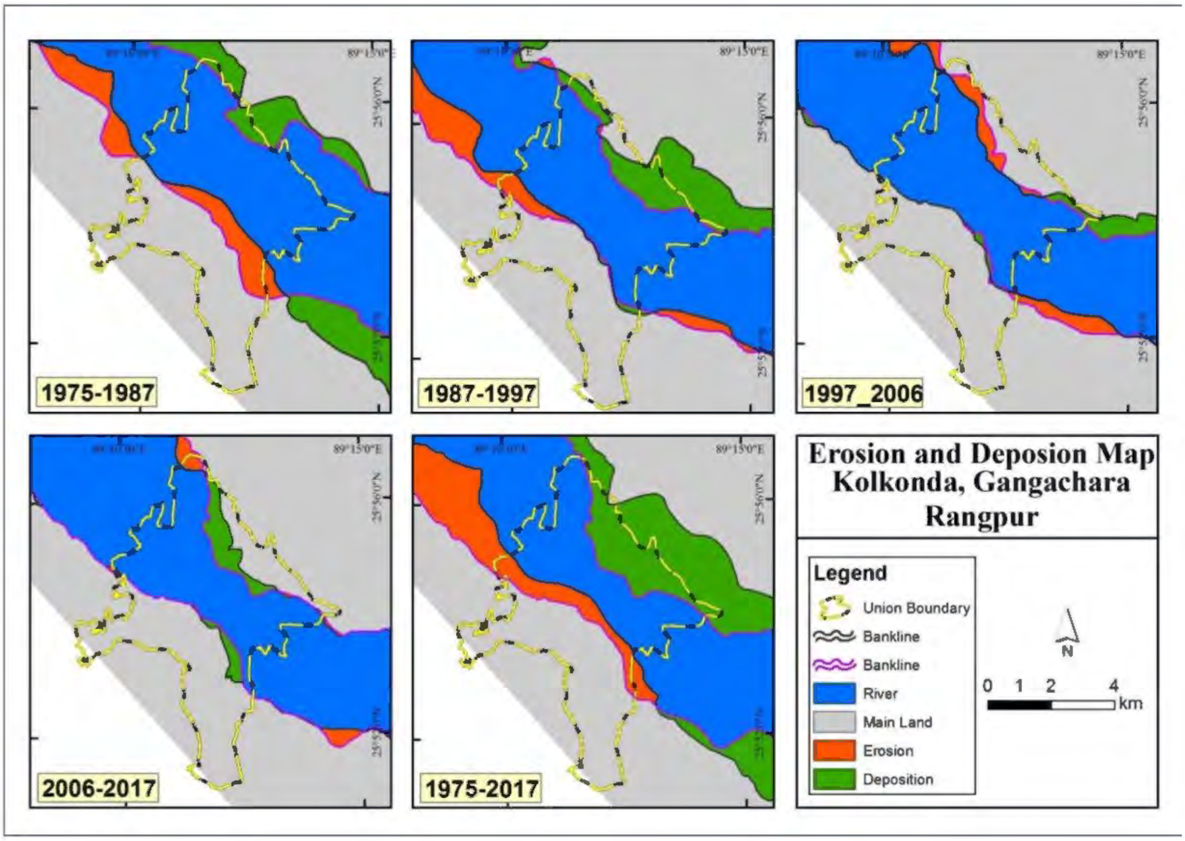
5.5.6 River morphology change at Kolkonda union

Comparison between erosion and deposition at Kolkonda union indicates that during 1975-2017 deposition (5.21sq.km) is higher than erosion (2.79 sq.km). Lowest erosion (0.32 sq.km) occurred during 2006-2017 and highest erosion (2.75 sq.km) occurred from 1975-1987 study periods (Table 5.15). Kolkonda union possesses highest deposition (3.69 sq.km) through 1987-2017 and lowest deposition (0.57 sq.km) during 1997-2006. Map 5.23 represents the decadal variation of river morphology changes of Kolkonda union.

Table 5.15 Erosion and deposition (in sq.km) at Kolkonda union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	2.75	0.22	0.99	0.08
1987-1997	1.13	0.11	3.69	0.36
1997-2006	1.43	0.15	0.57	0.064
2006-2017	0.32	0.029	2.80	0.25
1975-2017	2.79	0.066	5.21	0.12

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
Erosion and Deposion Map
Kolkonda, Gangachara
Rangpur
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 1 2 4
km
89°15'0"E
25°56'0"N

Map 5.23 Erosion and deposition of Teesta at Kolkonda union

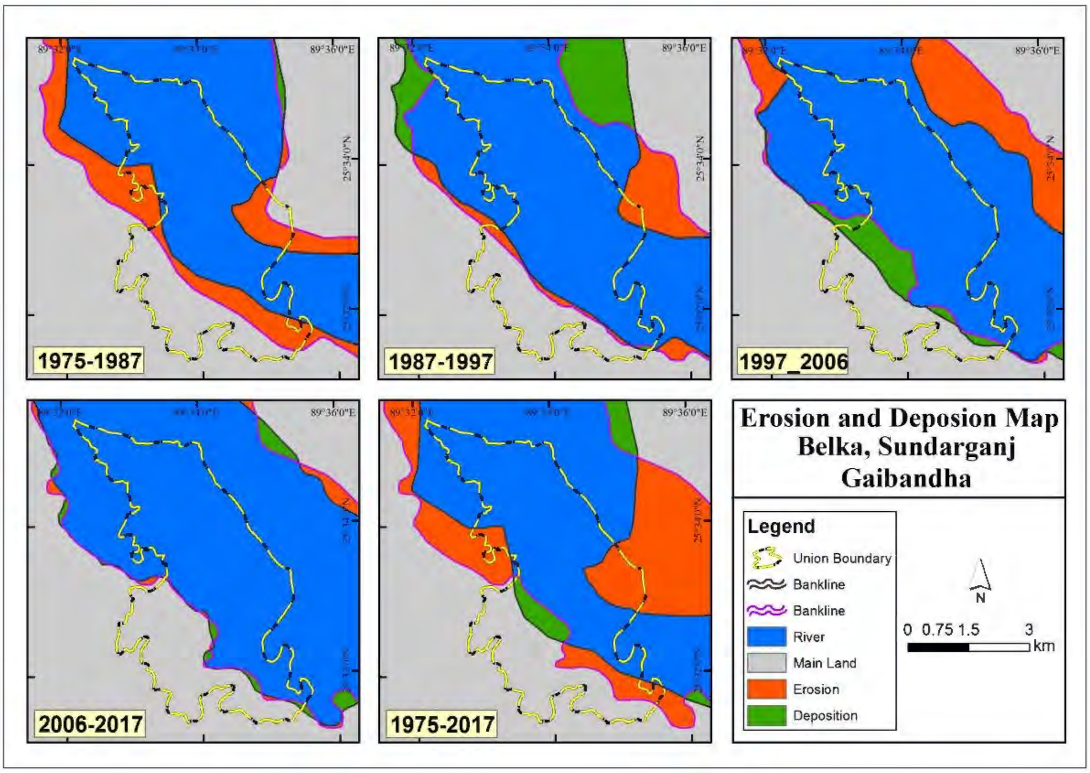
5.5.7 River morphology change at Belka union

The Belka union is the most downstream union of Teesta basin among the studied unions. The union experienced highest erosion (3.64 sq.km) during 1975-1987 and no erosion occurred during 1997-2006 (Table 5.16). Highest deposition (1.93 sq.km) has been detected in the decade 1997-2006. Erosion is higher (3.11 sq. km) than deposition (0.83 sq.km) in the entire study period (1975-2017). The morphological change at Belka union has been presented in Map 5.24

Table 5.16 Erosion and deposition (in sq.km) at Belka union

Year	Erosion sq. km	Erosion rate/ year sq. km	Deposition sq. km	Deposition rate/ year sq. km
1975-1987	3.64	0.30	0.00	0.00
1987-1997	0.81	0.081	0.041	0.004
1997-2006	0.00	0.00	1.93	0.21
2006-2017	0.080	0.0073	0.29	0.026
1975-2017	3.11	0.074	0.83	0.019

Source: Calculated from Satellite Image


1975-1987
1987-1997
1997_2006
2006-2017
1975-2017
89°36'0"E
25°34'0"N
Erosion and Deposion Map
Belka, Sundarganj
Gaibandha
Legend
Union Boundary
Bankline
Bankline
River
Main Land
Erosion
Deposition
N
0 0.75 1.5 3
km

Map 5.24 Erosion and deposition of Teesta at Belka union

5.5.8 Comparison of morphological change among the study unions from 1975-2017

Table 5.17 presents the condition of erosion and deposition in the seven study unions during the study period of 1975-2017. Among the study unions the most eroded union is Khuniagachh (11.23 sq.km). The second and third highest erosion prone unions are Bidyananda (3.96 sq.km) and Belka (3.11 sq.km) respectively. The lowest erosion prone unions are Saulmari (0.029 sq.km), Purba Chatnai (1.13 sq.km) and Kolkonda (2.79 sq. km). Erosion is lowest at Saulmari and Purba Chatnai union because the unions are highly protected with embankments. The data presented in the table indicates that the most eroded Khuniagachh union is also the highest deposited union (5.35 sq.km). Thus, the study finds out the balancing condition of river morphology through deposition to compensate the high erosion rate of Khuniagachh union. The second and third highest deposition has been noticed at Saulmari union (5.23 sq.km) and Kolkonda union (5.21 sq.km) respectively. Among the study unions Sindurna shows 0.00 sq.km of deposition which indicates future deposition at the union to reach in the equilibrium because Sindurna possess (2.94 sq.km) of erosion in the whole study period. Other than Sindurna, lowest deposition have been detected in Purba Chatnai (0.45 sq.km) and Belka (0.83 sq.km) unions.

Table 5.17 Comparison of morphological change among the study unions from 1975-2017

Study unions	Erosion (sq.km)	Deposition (sq.km)
Purba Chatnai	1.13	0.45
Saulmari	0.029	5.23
Bidyananda	3.96	4.48
Khuniagachh	11.23	5.35
Kolkonda	2.79	5.21
Sindurna	2.94	0.00
Belka	3.11	0.83

Source: Calculated from Satellite Image

5.6 Geomorphological features created by the erosion and deposition of Teesta river

Development of a river drainage network produces a variety of landforms. Landforms produced by rivers are not permanent in nature and morphological change occurs in river systems. The study area is occupied by numerous stream channels flowed from the Himalaya and few channels from the local sources. All the morphological features of the study area have its fluvial origin. The landform features of the Teesta river basin has been identified from field investigation, topo sheet study and satellite images. The identification of geomorphological features through satellite image has been presented in Map 5.25 (Site A, page 111). The other images have been illustrated in Appendix 6 (Site B-M). The basic landforms are the erosional and the depositional landform features. Both types of morphological features have designated the Teesta river as an unique landscape modifier. The morphological features of the Teesta river is as follows:

5.6.1 Active channel

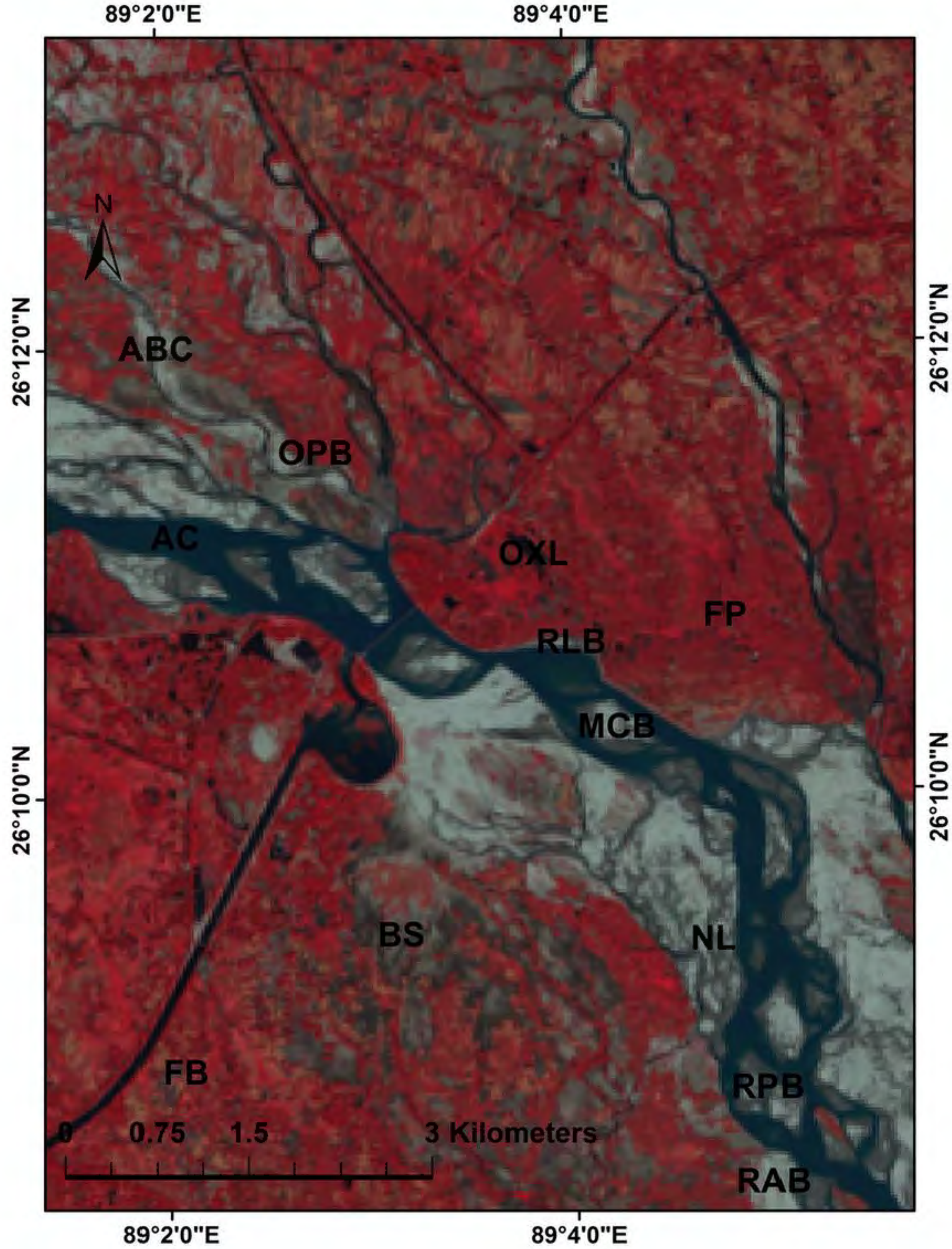
The Teesta river displays its multi-threated channel pattern in dry season. The channel also shows its meandering pattern in some areas. The Teesta, Sati, Buri Teesta, Jamuneshori, Ghagat has water flow all around the year. The active channels of Teesta are both meandering and braided in nature. The Teesta is mainly Braided channel but in some locations it shows meandering channel pattern. Braided stream channels are also termed as multi-threaded stream channels. High water discharge in monsoon and low water flow in the dry period generates the sediment concentration anomalies which designate the Teesta river as braided stream Appendix 7 (pic. 1. a). The tributary and the distributary stream channels of Teesta are meandering in nature. The Teesta floodplain forms meandering channel in the alluvial plains Appendix 7 (pic. 1. b). The active channel of the Teesta flows in the districts of Nilphamari, Lalmonirhat, Kurigram, Rangpur and Gaibandha.

5.6.2 Abandoned channel/ Palaeo channel

Palaeo channel or abandoned channel is the channel that was the former channel which is now chocked with mud Appendix 6 (Site J). The Teesta river is an unique example of channel shifting and landscape development. Numerous abandoned channels are recognized in the entire basin during field survey. The evolution of abandoned channel occurs for course change in the Teesta river. The abandoned channels of the Teesta are the Bulosula river, Suti, a small distributary of Dara river in Mohiskhoca union (Lalmonirhat), Ganesh, Ballar, Auli khora (Nilphamari), an unnamed channel from Teesta falls into the Brahmaputra (crossing Ulipur shadar), Burail river (Kaunia and Pirgacha), Bural (Mithapukur) etc.

5.6.3 Oxbow lake

Oxbow lake forms through the neck cut of a meander loop in a meandering river Appendix 6 (Site I). The floodplain of Teesta river has a unique characteristics of numerous oxbow lakes. The oxbow lakes have been cut down from meander during floods. Frequent channel changes and meander cut offs in the western side of Rangpur is known as mara (dead) or Buri (Old) Teesta (Rashid, 1991). The oxbow lakes are deeply flooded during monsoon and plays very important role in irrigation and fishing activity as well as natural flood water retention pond. In the dry season the dried lakes used as food crop production field. The oxbow lake also provides recreational facilities to the rural communities. Moreover it is a great source of aquatic vegetation and the poor community collects waterborne food from the lakes. Notable oxbow lakes in the study area are: Sundarganj chara, Bamandanga Ghargharia, (Gaibandha), Barhwal (Nilphamari), Salmara, Adhirom, Chandmari, Mashankura, Mandaltari, Ruhea, Mominpur, Ganakanai (Rangpur), Sallar, Sherudanga, Bhagabatipur, Tulshidanga, Dikdari, Bara Kathali (Mithapukur), Dhumer kuth, Chakchaka, Mashankura, Khalea (Kaunia), Gharialdnga, Keteshwar, Gokula, Bhkuarkhuti, (Kurigram) etc.


89°2'0"E
89°4'0"E
N
26°12'0"N
26°10'0"N
ABC
OPB
AC
OXL
FP
RLB
MCB
BS
NL
FB
RPB
RAB
0
0.75
1.5
3 Kilometers

Caption of Map: AC-Active Channel, BSC-Braided Stream Channel, MSC- Meandering Stream Channel, OCB-Old Channel Bar, OLB- Old Lateral Bar, OPB-Old Point Bar, OXL-Oxbow lake, BS-Back swamp, ABC-Abandoned Channel, FB-Flood Basin, FP-Floodplain, MCB-Mid Channel Bar, RPB-Recent Point Bar, RLB-Recent Lateral Bar, NL-Natural Levee, RAB-Recent Alternate Bar.

Map 5.25 Identification of geomorphological features through Satellite Image (Site A)

5.6.4 Back swamp

Back swamps are dominant morphological features in the study area. Depressed lands with numerous channels cut off originate back swamp Appendix 6 (Site G). Geographically the term back swamps are regarded as the swampy condition just beneath the river Appendix 7 (pic. 1. e). Back swamps are moist low lands composed of clayey deposits (Matsuda, 2004). Back swamps are found in the palaeo channels of the Teesta river which once cut off from the main channel by the dynamic activities of the river. The back swamps are found in Kakina, Voetmari, Singimari (Lalmonirhat); Gajghanta, Kolkonda, Mornea, Alambiditar (Rangpur), Purba chatnai, Paschim chatnai, Koimari, (Nilphamari) in the study area.

5.6.5 Depression/ Flood basin/ *Beel*

The study areas possess a wide variety of depressions or saucer- shaped flood basins. *Beel* is a local term which means depressed area and designated as flood basins. The flood basin of the study area has shown in Appendix 7. The flood basins are low-lying areas that are normally dry but deeply flooded in the monsoon. During the winter these flood basins are used as agricultural lands for robi crop cultivation in the Teesta floodplain. The flood basins are poorly drained and having no natural outlet and used for HYV (High Yielding Variety) boro[20] rice and floating aman[21] cultivation in the floodplains. Clay deposits are found in the depressions. These *beels* are used as different livelihood options of the locality. Old flood basins and meander scars are deeply flooded in northern Bangladesh (Islam, 2003). The important *beels* of the study area are: Chatnai *beel*, Kharibari *beel* (Dimla), Shaniajen *beel*, Sonray *beel* (Domer), Singimari *beel*, Sacramacha *beel* Chapa *beel*, Gabrol *beel* (Nilphamari sadar), Hariner *beel*, Kakkuti *beel*, Beker *beel*, Jholshi *beel*, Abhiramer *beel* (Rangpur), Ganna *beel* (Gangachara), Dabra, Dikdari, Patuagari, Chatalia, Bhangni, Bakia, Baisha, Chakchaka, Solaguri, Salma, Kaidahara, Gachulkani, Chouddhovubon,Chilmari, Bara Phalia and Chhota Phaliar *beel*, (Mithapukur), Jaorani *beel*, Naoduli, Kachana, Birdal *beel*, Harisware *beel*, Bara Gagra, Chhota Gagra, Deodoba, Bherbheria *beel* (Lalmonirhat), Barabeel, Gajgoali beel(Pirganj), Kutgulli *beel* Hardanga *beel*, Salmra, Nayara, Khalish kuri, Mahadari, Mandira, Butia (Kaunia), Kachihara *beel*, Hasal beel, Bururogi *beel*, Chatia *beel*, Baradhm *beel*, Shapmari *beel* (Kurigram), Kumlia *beel*, Haldidoba *beel*, Nalbari beel, Ghrghria (Sundarganj), etc.

5.6.6 Pothole

Pot hole is an erosional landform feature produced by the works of running water. Pot holes are hollow in the floodplains, river bed or bank Appendix 7 (Pic. 1. J). Pot holes are created by local scouring due to action of water. The community people of Teesta basin locally termed pot hole as ‘Kola’. When water depth decreases the pot holes are used for fishing ground by the local community. Pot holes are very common landform feature found in the Teesta river valley.

5.6.7 Ridge

Ridges are marked from a land by its narrow raised band. Erosion in outer meander bend and deposition in inner bend forms the ridges. The ridges are composed of both silt and sand in the Teesta basin. The ridges are used as settlements in different parts of the Teesta floodplain Appendix 7 (Pic. 1. k) . River flow and sediment discharge determines the height, width and shape of relief features like ridges. Flood is the preliminary element of forming floodplain ridges. Flood water also changes the shape and sizes of the ridges in the river basin. (Brammer, 1996).

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[20] Boro is a variety of paddy planted in the flood basins.

[21] Aman is a variety of transplanted paddy and floating Aman paddy grows with the height of flood water.

5.6.8 River terrace

In alluvial plains river terrace is a dominant morphological feature. In a rejuvenated river a state of equilibrium occurs due to sedimentation alters its procedure to erosion and regular erosion-sedimentation mechanism occurs to form river terraces (Matsuda, 2004). The river terraces are clearly visible in the dry season Appendix 7 (Pic. 1. l). A river terrace designates different heights of a river and also marked as river platforms or steps. Both erosional and depositional activities are involved to develop the river terraces. The Teesta river also experiences erosional and depositional terraces in its basin. In some places the upper most step of terrace is not visible for its erosional activities but the lower most step is evident for depositional activities of the river. The bottom layer of the river terrace is filled with coarse sediments and the upper level of terrace contains medium to fine grained sediments which is responsible for lateral cutting. As a result the Teesta river terraces are unpaired rather than paired terraces.

5.6.9 Natural levee

Natural levees are high lands with continuous sediment deposition that protect the floodplains from normal flood Appendix 7 (Pic. 1. d). The natural levee of the Teesta floodplain is elongated in the channel banks. Natural levees are found parallel to the river course and its height decreases gradually from the bank (Islam, 1990). The natural levee of the study area also formed with sandy, silty and clayey materials. The concave river banks are examples of thickest alluvial deposits. When river bank erodes laterally it become convex and it causes destruction of natural levee. Repeated deposition of sediments for flood is responsible for natural levee formation in the river banks. Natural levee is a dominant morphological landform feature found in the Teesta floodplain.

5.6.10 Bar/*Char*

Sediment deposition in river bed forms river islands which are locally designated as *Char*. Academically the *chars* are named as bars. These bars are characterized by point bar, mid channel bar, sand bar etc. Appendix 7 (Pic. 1. g , h, i). The Teesta river conveys old stage in Bangladesh. Valley widening through bank erosion and sediment deposition in river bed labeled the Teesta river as a braided river. These bars are also responsible for annabranching[22]. The established or permanent *char*s in the Teesta river are *char* salapak, Laxmitary, Khokar *char*, etc. The *char*s in Teesta river bed are mostly flat without topographic variations. Flood, sedimentation and erosion is a common feature in the *char*. The semi-permanent *char*s of Teesta rise from the river in the dry period and used for cultivation and cattle grazing. Mid channel bars are very common in the Teesta river. These bars are created by the split of water flow of channel. Mid channel bars are found in the flow junctions (Ashworth, *et al*., 2000). The Lateral bar/ Point bars are found in the mender bends. Lateral bars are the bars which have connection with the main land. These bars of the Teesta floodplain are formed with non-cohesive soils. The lateral bars of the study area are densely populated though these bars are vulnerable to bank failure. Both the right and left banks of the Teesta river has longitudinal alignment lateral bars. The old bars are stable but the recent or newly formed bars are unstable in type.

5.6.11 Flood plain

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[22] Annabranching means multi-threaded river channel pattern.

Of all the geomorphological landscapes, floodplain is the largest unit of the Teesta river basin Appendix 7 (Pic. 1. f). Floodplain is the adjoining area of river basin occupied by flood water during stream overflow its banks. Most of the land mass of Northern Bangladesh occupies the Teesta river floodplain. The Teesta floodplain lies between the old Himalayan piedmont Plain and the Young Brahmaputra-Jamuna floodplain. The Ganges Brahmputra and Meghna (GBM) floodplain is less than 10 meters above the sea level (Rashid, 1991). Floodplain is a composite accumulation of landforms which covers the area next to a river channel and inundates with floodwater (Middelkoop, 2005). The Teesta floodplain area occupies 10304 sq. km. which is 7.11% of the total physiographic regions of Bangladesh (UNDP and FAO, 1988). The Teesta floodplain extends up to the Bangali-Karatoya floodplain in the south. The active floodplain of Teesta river is 3-6 km wide and predominantly affected by flood. Northern part of the floodplain is occupied by sandy ridges and in the south a long outlier spreads down to the town sherpur of Bogra district lengthways the ancient Teesta river (Rashid,1991).

The eastern Teesta floodplain

These plain extends from the Dudhkumar and the Dharla river in the east and in the west it is bounded by the Teesta.

The western Teesta floodplain

The western Teesta floodplain is bounded by the old Himalayan piedmont plain. The topography is low ridges and shallow basins. The basins are inundated by flash floods. The Atrai, Tangon, Punarbhaba are the important rivers of these floodplain.

The northern Teesta floodplain

The northern Teesta floodplain is occupied by a complex pattern of landmass with the sediments of various tributaries and distributaries of Teesta and other rivers. The basin is raised than the other parts of the Teesta floodplain because it is situated in the foothills of the Himalayas.

The southern Teesta floodplain

The southern part of the Teesta floodplain is considered as the Bangali-Karatoa floodplain. The ridges and the basins of the floodplain are flooded more than 90 m. In some places there exists the Pleistocene terrace (Barind tract) in the southern Teesta floodplain which is above flooding depth. The floodplain is designated by its most spectacular depression the Chalan *Beel*. Though the Chalan Beel is a depression it looks like islands in the rainy season for its settlements in the raised lands.

5.6.12 Alluvial Fan

The Teesta is an alluvial river which deposits alluvial fan. Though fan develops in the base of mountains but it extends in the plains. Thus the Teesta river formed alluvial fan named the Teesta mega fan prolonged in India and Bangladesh. The limit of the Teesta fan is bound by the Barind tract in the south, in the east through the Brahmaputra and in the west by the Mahananda river. The mega fan starts in the foothills of the Himalaya and occupies the districts of Northern Bangladesh. The Teesta alluvial fan has been enriched by the silty, sandy and clayey materials of the Teesta as well as the Karatoya, Punarvaba, Atrai, Jamuneshori, Ghagat, Tangon, Kulik etc. rivers. The alluvial fan has braided channel pattern with shallow depth and the bed materials are gravel. Delta formation in the Brahmaputra- Jamuna and Teesta confluence zone is an ongoing process. The Ganges-Brahmaputra river system has started to form delta in the cretaceous period about 125 million years ago (Islam, 2003).

Chapter Six

Respondents Profile and Perception about Morphological Change

6.1 Respondents profile

The respondents of present study are the victims of river morphology change. To analyze the impact of river morphology change and adaptation strategies of the community it is very much crucial to know the respondents profile and their socio-economic condition.

6.1.1 Age, Gender, marital status and education

The age limits of the respondents of the present study are within 25 years to more than 55 years. The age groups are classified into four groups such as 25-35 years, 36-45 years, 46-55 years and more than 55 years. About 35.2% respondents belong to the age group 36-45 years and 48.0% respondent occupies the age group of 46-55 years. The age group of 25-35 years shows highest percentage (15.3%) in Khuniagachh union. Kolkonda union displays highest (42.2%) percentage in the age group of 36-45 years and about 61.8% respondents of Belka union are the representative of the age group of 46-55 which is the highest percentage among the study unions in the respective age group. However, the study investigates that most of the respondents of the study area are working population for surviving river morphology change and there exists difference in the study unions in the condition of age groups. The distribution of age of the respondents is shown in Table 6.1.

Table 6.1 Distribution of age of the respondents in study unions

Study Unions	**Age group**									
	25-35		36-45		46-55		More than 55		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	2	5.9	12	35.3	15	44.1	5	14.7	34	100
Saulmari	2	3.1	23	35.9	31	48.4	8	12.5	64	100
Bidyananda	2	4.9	15	36.6	18	43.9	6	14.6	41	100
Khuniagachh	11	15.3	26	36.1	31	43.1	4	5.6	72	100
Kolkonda	6	9.4	27	42.2	26	40.6	5	7.8	64	100
Sindurna	2	6.7	11	36.7	15	50.0	2	6.7	30	100
Belka	0	0	20	26.3	47	61.8	9	11.9	76	100
All	25	6.6	134	35.2	183	48.0	39	10.2	381	100
Chi-square	χ^2 value= 36.48, df=24, p=.041									

Source: Field survey, 2017

Table 6.2 displays the distribution of gender of the respondents. The households of the study area are male dominated. Among the respondents 95.5% are male and 4.5% are female. The widow and divorced women is the household heads of their family and they are most vulnerable to river morphology change disaster. About 100% male household heads are found in the Kolkonda union and the second highest male respondents are observed in Khuniagachh union. Among the study unions Bidyananda union shows 17.1% female respondents which show highest women dominated households. The study result also signifies the distribution of household head by gender (p=.001).

Table 6.2 Distribution of respondents by gender

Study Unions	**Gender of respondents**					
	Male		Female		Total	
	N	%	N	%	N	%
Purba chatnai	31	91.2	3	8.8	34	100
Saulmari	61	95.3	3	4.7	64	100
Bidyananda	34	82.9	7	17.1	41	100
Khuniagachh	71	98.6	1	1.4	72	100
Kolkonda	64	100.0	0	0	64	100
Sindurna	29	96.7	1	3.3	30	100
Belka	74	97.4	2	2.6	76	100
All	364	95.5	17	4.5	381	100
Chi-square	χ^2 value= 22.09, df=6, p=.001					

Source: Field survey, 2017

About 95.8% respondents are married and 3.7% and .5% respondent is Widow/widower and divorced respectively. Therefore, the study result shows most of the people are married. During field survey, it has been noticed that the people of the study area get early married. The average age of marriage of male and female is 18-20 years and 16-18 years respectively. Table 6.3 illustrates the marital status of the respondents in the study unions.

Table 6.3 Marital status of the respondents

Study Unions	**Marital status of respondents**							
	Married		Widow		Divorce		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	31	91.2	3	8.8	0	0	34	100
Saulmari	61	95,3	2	3.1	1	1.6	64	100
Bidyananda	34	82.9	6	14.6	1	2.4	41	100
Khuniagachh	71	98.6	1	1.4	0	0	72	100
Kolkonda	64	100.0	0	0	0	0	64	100
Sindurna	29	96.7	1	3.3	0	0	30	100
Belka	75	98.7	1	1.3	0	0	76	100
All	365	95.8	14	3.7	2	0.5	381	100
Likelihood Ratio=23.315, df=18, p=.025								

Source: Field survey, 2017

The condition of the respondent's educational background is very bad in the study area. They are deprived from education due to recurrent river morphology change induced economic insolvency. Among the household heads only 1.3% respondents passed the Secondary School Certificate (SSC) examination. About 20.2% respondent's gained primary education and 9.4% have the ability to do signature (Table 6.4). A large portion people (69.0%) of the study area are illiterate and it is the foremost cause of river morphology change disaster vulnerability in the Teesta basin. The present study investigated that due to lake of strong educational background the people of the study area depends on nature based livelihoods such as farming, day laboring in farm and also non-farm activities and become the victim of river morphology change. The study result shows p value is significant in terms of educational status of the respondents in the study unions.

Table 6.4 Educational status of the respondents

Study Unions	**Educational status**									
	Illiterate		Can signature		Primary		SSC		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	19	55.9	7	20.6	7	20.6	1	2.9	34	100
Saulmari	45	70.3	2	3.1	17	26.6	0	0	64	100
Bidyananda	29	70.7	7	17.1	5	12.2	0	0	41	100
Khuniagachh	47	65.3	9	12.5	12	16.7	4	5.6	72	100
Kolkonda	43	67.2	4	6.2	17	26.6	0	0	64	100
Sindurna	25	83.3	0	0	5	16.7	0	0	30	100
Belka	55	72.4	7	9.2	14	18.4	0	0	76	100
All	263	69.0	36	9.4	77	20.2	5	1.3	381	100
Likelihood ratio=36.016, df= 18, p=.007										

Source: Field survey, 2017

6.1.2 Total household member

Total household member is an important variable to collect information about adaptation strategies of the respondents. Large family size is a noticeable feature of the study area. Total household member of the respondents have been shown in Table 6.5. Significant differences (p=.000) have been found in terms of total household member of the study unions.

The study investigated that about 70.6% respondents replied regarding 6-10 household member in their family which is the highest category of family members in the study unions. Likewise, 26.5% respondents answered about 1-5 family member. Among the study unions, Belka and Khuniagachh represents highest and second highest percentage of household member 81.6% and 80.6% respectively in the category of 6-10 household member.

Table 6.5 Total household member

Study Unions	**Total household member**							
	1-5		6-10		More than 10		Total	
	N	%			N	%	N	%
Purba chatnai	15	44.1	19	55.9	0	0	34	100
Saulmari	19	29.7	45	70.3	0	0	64	100
Bidyananda	21	51.2	20	48.8	0	0	41	100
Khuniagachh	13	18.1	58	80.6	1	1.4	72	100
Kolkonda	20	31.2	41	64.1	3	4.7	64	100
Sindurna	2	6.7	24	80.0	4	13.3	30	100
Belka	11	14.5	62	81.6	3	3.9	76	100
All	101	26.5	269	70.6	11	2.9	381	100
Likelihood ratio = 47.759, df=12, p=.000								

Source: Field survey, 2017

6.1.3 Absent household number and Cause of absence

The study area possesses a highest value of absent household member to earn their livelihood. When river morphology change occurs it disrupts the only earning source of the people of Teesta basin. Therefore, the adults of each household migrate in towns and cities to earn livelihoods. Sometimes the adolescent girl goes to work in garments factory or work in the urban areas as housemaid. Hence, the study reveals more than one absent household member in the study households for river morphology change disaster recovery. The study unveils 3.4% households have no absent members. About 49.5% household has 1, 34.1% household has 2, 11.5% household has 3 and 1.6% has 4 absent household members for income earning in the big cities and towns of the country.

Table 6.6 Absent household member of respondent’s family

Study union	**Absent household member**											
	0		1		2		3		4		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Purba chatnai	3	8.8	19	55.9	11	32.4	1	2.9	0	0	34	100
Saulmari	2	3.1	39	60.9	19	29.7	4	6.2	0	0	64	100
Bidyananda	0	0	24	58.5	12	29.3	4	9.8	1	2.4	41	100
Khuniagachh	0	0	24	33.3	33	45.8	13	18.1	2	2.1	72	100
Kolkonda	0	0	36	56.2	18	28.1	9	14.1	1	1.6	64	100
Sindurna	3	10.0	15	50.0	8	26.7	3	10.0	1	3.3	30	100
Belka	4	5.3	32	42.1	29	38.2	10	13.2	1	1.3	76	100
All	12	3.1	189	49.5	130	34.1	44	11.5	6	1.6	381	100
Likelihood ratio=42.524, df= 24, p= .011												

Source: Field survey, 2017

Table 6.6 represents the absent household member of respondent's family and the likelihood ratio regarding absence in the respective unions. Among the study unions Khuniagachh union illustrates highest percentage (45.8% and 18.1%) in absent household member of 2 and 3respectively.

Due to the impact of river morphology change on livelihood, the people of the study area change their occupation and migrate temporarily or permanently to cope with the adverse condition. Sometimes, the houses remain empty with no male members and the females are the only residents of the house. The respondents were asked about the cause of absence of the household members from the family. Only 2.6% respondents have given their opinion about the members cause of absence from house is, they went abroad for more income earning. About 94.2% family members of the respondents were absent from house for river morphology change to manage their household expenditure. Table 6.7 illustrates the cause of absence of household members which indicates p value is .013.

Table 6.7 Cause of absence of household members

Union	**Cause of absence**							
	River morphology change		Went abroad		No absence		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	31	91.2	0	0	3	8.8	34	100.0
Saulmari	62	96.9	0	0	2	3.1	64	100.0
Bidyananda	39	95.1	2	4.9	0	0	41	100.0
Khuniagachh	71	98.6	1	1.4	0	0	72	100.0
Kolkonda	61	95.3	3	4.7	0	0	64	100.0
Sindurna	26	86.6	1	3.3	3	10.0	30	100.0
Belka	69	90.7	3	3.9	4	5.2	76	100.0
All	359	94.2	10	2.6	12	3.1	381	100.0
Likelihood ratio= 25.322, df=12, p=.013								

Source: Field survey, 2017

6.2 Occupation and asset information

Occupation and assets are most vulnerable sector for river morphology change. Field survey result shows that there exists significant difference in present and past occupation due to river morphology change.

6.2.1 Respondents past occupation

Before disastrous effects of river morphology change a large portion of respondents of the study area were engaged in farming. Besides agricultural activities other economic activities which the respondents performed was wage labor (farm), wage labor non-farm (earth work, rickshaw/van puller, housemaid etc.), petty business and service. Table 6.8 represents the past occupation type of the respondents. The study represents that among the past occupation type, farmer shows highest percentage (87.1%). It reveals that farming was the dominating occupation type in the study area before river morphology change impacts on the respondents. All the study union shows more than 80% people engaged in farming. Significant differences has been found among the study unions in terms of past occupation type of the respondents. The other occupation types was wage labor farm (3.9%), wage labor non-farm (2.8%), petty business (4.1%) and service (1.8%).

Table 6.8 Past occupation of the respondents

Union	**Past occupation of the respondents**										
	Wage labor farm		Wage labor non-farm		Famer		Petty business		Service		Total
	N	%	N	%	N	%	N	%	N	%	N
Purba chatnai	1	2.9	0	0	30	88.2	2	5.8	1	2.9	34
Saulmari	3	4.7	3	4.7	55	85.9	1	1.5	2	3.1	64
Bidyananda	5	12.2	1	2.4	35	85.3	0	0	0	0	41
Khuniagachh	2	2.7	5	6.9	59	81.9	3	4.1	3	4.1	72
Kolkonda	1	1.5	0	0	62	96.8	1	1.5	0	0	64
Sindurna	1	3.3	2	6.6	24	80.0	3	10.0	0	0	30
Belka	2	2.6	0	0	67	88.1	6	1.5	1	1.31	76
All	15	3.9	11	2.8	332	87.1	16	4.1	7	1.8	381
Likelihood Ratio = 39.834, df= 24, p= .022											

Source: Household survey, 2017

6.2.2 Respondent’s current occupation

The communities of Teesta river basin are always in threat of change their occupation and rely on secondary earning sources. Seasonal unemployment is a recurrent issue in the study area. Based on field survey the present study identified wage labor (Farm), wage labor (non-farm) and petty business are the major livelihood groups at present. Profile of current occupation in the study area is presented in Table 6.9. From the study it is evident that the present and past condition of different occupation has significant change due to river morphology alteration. At present about 10.8 percent of the respondents face seasonal unemployment problem owing to river morphology change. 34.4% respondents were engaged in wage labor (farm) or agricultural labor in the study area which is the most dominating occupation type at present. Field investigation data shows that most of the people of the study area are currently engaged in agricultural labor including growing crops, livestock rearing, poultry, harvesting, threshing, boiling and husking crops. Agricultural activities of rural working class embraced through animal husbandry, poultry, threshing, boiling, drying and husking crops with food processing and preserving. (Islam, 2003). The agricultural labors are poorly paid. Agricultural labors of the Teesta basin are unskilled and paid low wages (Elahi and Ara, 2008).According to Islam, 2003 three types of day labor are found in rural Bangladesh: causal day labor, annual contract labor and seasonal labor. The study area also possesses these 3 types of agricultural day labor. The causal labors are vulnerable because they works for few days and gets low payment. Annual contract labors stay at the employer's house and get cash wage, cloths and food as per their contract. (Islam, 2003). Most of the agricultural labors of the study area are seasonal labors. They migrates from their house to a shorter or longer distance for harvesting crops in the winter season and saw crops in rainy season. At present the second and third highest occupation groups in the study area are wage labor non-farm (22.8%) and petty business (20.4%) respectively. The most prevailing feature of the study is at present only 9.7% respondent's occupation is farmer though it was the highest occupation group in the study area before the change. The analysis of the present study represents significant differences (p=.000) in terms of present occupation of the respondents.

Table 6.9 Current occupation of the respondents

Union	**Current occupation of the respondents**												
	Seasonally unemployed		Wage labor farm		Wage labor non-farm		Famer		Petty business		Service		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N
Purba chatnai	5	14.7	13	38.2	4	11.7	7	20.5	4	11.7	1	2.9	34
Saulmari	15	23.4	23	35.9	7	10.9	3	4.6	14	21.8	2	3.1	64
Bidyananda	2	4.8	15	36.6	15	36.5	2	4.8	7	17.0	0	0	41
Khuniagachh	4	5.6	17	23.6	15	20.8	5	6.9	28	38.8	3	4.1	72
Kolkonda	3	4.7	23	35.9	19	29.6	9	14.0	10	15.6	0	0	64
Sindurna	3	10.0	9	30.0	5	16.6	4	13.3	9	30.0	0	0	30
Belka	9	11.8	31	40.8	22	28.9	7	9.2	6	7.8	1	1.3	76
All	41	10.8	131	34.4	87	22.8	37	9.7	78	20.4	7	1.8	381
Likelihood Ratio = 66.706, df= 30, p= .000													

Source: Field survey, 2017

6.2.3 Changes in occupation

Change in occupation in the study area is not a new phenomenon but it is as old as the alteration of the Teesta river morphology. Due to the river morphology change the people of the study area are forced to change their occupation for their existence. Before morphological change the largest livelihood group was farmer (87.1%) but at present it is only 9.7%. On the other hand, before the change wage labor farm was 3.9% and non-farm wage labor was 2.8% which is at present 34.4 % and 22.8% respectively (Table 6.8 and Table 6.9). These major occupational changes occurred in farmer and wage labor livelihood group due to the loss of agricultural land for river morphology change. After land property and livelihood loss, the farmers are forcefully engaged in wage labor farm and wage labor non-farm activities. Table 6.10 represents the cross tabulation of past and current occupation of the respondents which represents p value is significant.

Table 6.10 Cross tabulation of past and current occupation

Current occupation	Past occupation					
	Wage labor farm	Wage labor non-farm	Farmer	Petty business	Service	Total
	N	N	N	N	N	N
Seasonally unemployed	0	2	37	2	0	41
Wage labor farm	8	3	103	7	0	131
Wage labor non-farm	2	0	85	0	0	87
Farmer	2	0	33	3	0	38
Petty business	3	6	64	4	0	77
Service	0	0	0	0	7	7
All	15	11	332	16	7	381
Likelihood ratio=97.48, df= 20, p= .000						

Source: Field survey, 2017

6.2.4 Secondary occupation

In addition to primary occupation the respondents have secondary occupation. About 36.4% respondents have given their response about wage labor (farm), 34.3% wage labor (non-firm), 15.7% petty business, 7.0% sharecropping and 6.2% other income sources as their secondary occupation. The female respondents have limited income opportunity and they are not engaged in secondary occupation. Table 6.11 exemplifies the secondary occupations of the respondents. In the study area non-farm wage labor includes rickshaw/ van puller, stone collection/crushing, sand mining, brick making, working in restaurant etc. Petty business is considered as an important livelihood category in terms of secondary occupations and the respondents engage in fish trading, grocer, hawker, vegetable seller, cow dung collection and sell, tailor, cobbler, barber etc. The people who lost land for river morphology change, involves in share cropping in others land. Moreover, fishing, Cattle rearing and religious education teacher is also found as secondary occupation in the study unions which fall into the income group of others in Table 6.11. Secondary occupation of the respondents show significant differences (p=.000).

Table 6.11 Secondary occupation of the respondents

Union	Secondary occupation										
	Wage labor farm		Wage labor non-farm		Petty business		Share cropper		Others		Total
	N	%	N	%	N	%	N	%	N	%	N
Purba chatnai	15	44.1	8	23.5	10	29.4	0	0	1	2.9	34
Saulmari	26	40.6	26	40.6	6	9.3	3	4.6	3	4.6	64
Bidyananda	11	26.8	17	41.6	8	19.5	2	4.8	3	7.3	41
Khuniagachh	23	31.9	25	34.7	7	9.7	8	11.1	9	12.5	72
Kolkonda	27	42.2	15	23.4	6	9.6	13	20.3	3	4.6	64
Sindurna	14	46.7	9	30.0	5	16.6	0	0	2	6.6	30
Belka	23	30.3	31	40.7	18	23.6	1	1.3	3	3.9	76
All	139	36.4	131	34.3	60	15.7	27	7.0	24	6.2	381
Likelihood ratio= 56.128, df= 24, p=.000											

Source: Field Survey, 2017

6.2.5 Change in present and past farming type

According to Bangladesh Bureau of Statistics (2006) farm holding size is categorized into four major groups such as marginal (0.02-0.20 hectare), small (0.20-0.40 or 1 hectare), medium (1-3.03 hectare) and large (more than 3.03 hectare).As the agricultural land has been gone into the river womb for river morphology change, the farming type of the study area has been significantly changed. The study recognized that there is no large farmer among the respondents in the study area. Among the respondents 6.3% farmer was land less but at present 81.6% farmer is landless due to river morphology change. 80.1% farmer of the study area was marginal farmer but at present the percentage of marginal farmer is only 17.8%. Table 6.12 shows 10.5% respondents were small farmer but at present it decreased into .3% owing to river morphology change. The study result indicates that marginal farmers were highest (84.7%) in Khuniagachh union but at present it is highest (22.4%) in Belka union (Table 6.13). The past landless farmer type shows very low percentage but at present all the study union shows high percentage in landlessness. Hence, the study result indicates that most of the people of the study area was marginal farmer but at present they become landless owing to river morphology change

Table 6.12 Past farming type

Union	**Past farming type**								
	Landless		Marginal		Small		Medium		Total
	N	%	N	%	N	%	N	%	N
Purba chatnai	3	8.8	28	82.4	2	5.9	1	2.9	34
Saulmari	3	4.7	54	84.4	5	7.8	2	3.1	64
Bidyananda	5	12.2	32	78.0	4	9.8	0	0	41
Khuniagachh	4	5.6	61	84.7	4	5.6	3	4.2	72
Kolkonda	5	7.8	49	76.6	9	14.1	1	1.6	64
Sindurna	1	3.3	21	70.0	6	20.0	2	6.6	30
Belka	3	3.9	60	78.9	10	13.2	3	3.9	76
All	24	6.3	305	80.1	40	10.5	12	3.14	381

Source: Field survey, 2017

Table 6.13 Present farming type

Union	**Present farming type**								
	Landless		Marginal		Small		Medium		Total
	N	%	N	%	N	%	N	%	N
Purba chatnai	30	88.2	4	11.8	0	0	0	0	34
Saulmari	56	87.5	8	12.5	0	0	0	0	64
Bidyananda	32	78.0	9	22.0	0	0	0	0	41
Khuniagachh	56	77.8	15	20.8	1	1.4	0	0	72
Kolkonda	52	81.2	11	17.2	0	0	1	1.6	64
Sindurna	26	86.7	4	13.3	0	0	0	0	30
Belka	59	77.6	17	22.4	0	0	0	0	76
All	311	81.6	68	17.8	1	.3	1	.3	381

Source: Field survey, 2017

6.2.6 Cause of occupation/socio economic change

The socio economic conditions of all the respondents were altered through river morphology change. With few exceptions most of the respondents changed their occupation. The exceptions were occurred in the farmer of huge land property who did not changed their occupation but converted from one farmer type to another due to land loss. From the field investigation it has been revealed that 96.6% respondent's socio economic change occurred owing to river morphology change, 0.8% changed their occupation for physical barrier and 2.6% changed occupation for more income generation. Table 6.14 denotes the cause of occupation/socio economic change of the respondents in the study unions. Moreover, significant differences (p=.003) has been observed in the study unions in the condition of cause of occupation/socio economic change.

Table 6.14 Cause of occupation/socio economic change

Union	**Cause of occupation/socio economic change**						
	River morphology change		Physically unfit for work		For more income generation		Total
	N	%	N	%	N	%	N
Purba chatnai	33	97.0	0	0	1	2.9	34
Saulmari	63	98.4	1	1.6	0	0	64
Bidyananda	39	95.1	0	0	2	4.9	41
Khuniagachh	72	100.0	0	0	0	0	72
Kolkonda	61	95.3	0	0	3	4.6	64
Sindurna	29	96.7	0	0	1	3.3	30
Belka	71	93.4	2	2.6	3	3.9	76
All	368	96.6	3	0.8	10	2.6	381
Likelihood ratio = 29.8, df=12, p= .003							

Source: Field Survey, 2017

6.2.7 Ownership of trees and bamboo clump

Trees and bamboo clumps are important household assets which help to cope with changing river morphology. Among the studied households 52.4% house has trees and 47.5% house has no trees as household assets. The reason behind having no trees in the studied houses is the damage of households for river morphology change and shifting of homestead in a new place. Newly build houses were planted trees but they have no monetary value for small size. The respondents opined that if they anticipate that their house must collapse into the river in the forthcoming morphological change incident, then they try to sell the trees to recover the loss of trees.

Table 6.15 Ownership of trees

Study Unions	**Ownership of trees**					
	Yes		No		Total	
	N	%	N	%	N	%
Purba chatnai	9	26.5	25	73.5	34	100
Saulmari	36	56.2	28	43.8	64	100
Bidyananda	22	53.7	19	46.3	41	100
Khuniagachh	55	78.6	17	23.6	72	100
Kolkonda	29	45.3	35	54.6	64	100
Sindurna	10	33.3	20	66.7	30	100
Belka	39	51.3	37	48.7	76	100
All	200	52.4	181	47.5	381	100
χ^2 value= 39.231,df=12 p=.000						

Source: Field survey, 2017

Table 6.15 shows the percentage of ownership of trees. About 52.4% respondents have ownership of trees. The type of fruit trees in the surveyed households are mango, jackfruit, guava, betel nut, coconut, banana etc. The homesteads are also occupied by different wood trees such as mahogany, rain tree, eucalyptus etc. The Table also represents the χ^2 value of ownership of trees of the respondents which designates that significant relationship exists in terms of ownership of trees in the study unions.

Bamboo clump plays vital role in the life of the communities inhabiting in Teesta river basin. About 64.7% household has bamboo clump in and around their house and 35.3% households has no bamboo clump to construct their house after river morphology change hazard (Table 6.16). The respondents stated that bamboo clump acts as an essential factor for their coping with river morphology alteration. They use bamboo for house reconstruction for post flood and erosion causality, sell bamboo during morphological change and earn money to survive in the crucial moment. Moreover, they help many victims with their bamboo in the vulnerable condition. Among the study unions Purba chatnai shows highest percentage (85.2%) and Bidyananda shows second highest percentage (75.6%) regarding ownership of bamboo clump.

Table 6.16 Ownership of bamboo clump

Study Unions	**Ownership of bamboo clump**					
	Yes		No		Total	
	N	%	N	%	N	%
Purba chatnai	29	85.2	5	14.8	34	100
Saulmari	41	64.0	23	36.0	64	100
Bidyananda	31	75.6	10	24.4	41	100
Khuniagachh	50	69.4	22	30.6	72	100
Kolkonda	38	59.3	26	40.6	64	100
Sindurna	19	63.4	11	36.6	30	100
Belka	37	48.7	39	51.3	76	100
All	245	64.7	136	35.3	381	100

Source: Field survey, 2017

6.2.8 Savings after expenditure

The respondents of the study area were asked about their savings after expenditure. Among the respondents 89.5% have no savings. The respondents speak out that they spend their life with hardship and stays hand to mouth. Therefore, it is quiet impossible for them to manage their livelihood and save money. The people who have small amount of saving also exhausted owing to recurrent river morphology change. About 10.5% respondents have savings and they are the solvent farmers and business man. Table 6.17 shows the condition of savings of the respondents in the study unions.

Table 6.17 Savings after expenditure

Study Unions	**Savings after expenditure**					
	Yes		No		Total	
	N	%	N	%	N	%
Purba chatnai	2	5.9	32	94.1	34	100
Saulmari	2	3.1	62	96.9	64	100
Bidyananda	4	9.7	37	90.2	41	100
Khuniagachh	8	11.1	64	88.9	72	100
Kolkonda	8	12.5	56	87.5	64	100
Sindurna	7	23.3	23	76.6	30	100
Belka	9	11.8	67	88.1	76	100
All	40	10.5	341	89.5	381	100

Source: Field survey, 2017

6.3 Socio-cultural information

The society and culture of the respondents are determined by the Teesta river. The section socio-cultural information includes the condition of house, House building material, causes of making particular type of house, Source of drinking water and Toilet facilities.

6.3.1 Condition of house

Most of the houses of the study area are *kancha* house[23]. Field survey result shows that 93.2% are *kancha* house,.8% are *pacca* house [24] and 3.9% are semi-*pacca* house[25] . Few respondents told their extreme poorness and vulnerability unto river morphology change. Among them, the widow woman who have no children or whose son/daughter are not willing to take care of their mother, stays in worst situation. They live in other people's

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[23] *Kancha* house refers to the household made with mud, bamboo, jute stick, straw, corrugated iron sheet etc.

[24] *Pacca* house means the houses made with brick and cement.

[25] Semi-*pacca* houses are constructed with both kancha and pacca house building materials.

(neighbor's) house. About 2.1% people who lost their house(no house) due to river morphology change have to live with the kindness of the neighbors. Table 6.18 demonstrates the condition of house of the respondents. The union wise distribution of type of house shows that, all the study union displays more than 90% households are *kancha* except Sindurna union.

Table 6.18 Condition of house of the respondents

Union	**Condition of house of the respondents**									
	Kancha		Semi-*pacca*		*Pacca*		No house		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	31	91.2	3	8.8	0	0	0	0	34	100
Saulmari	59	92.2	2	3.1	0	0	3	4.7	64	100
Bidyananda	38	92.7	0	0	0	0	3	7.3	41	100
Khuniagachh	68	94.4	3	4.2	1	1.4	0	0	72	100
Kolkonda	58	90.6	2	3.1	2	3.1	2	3.1	64	100
Sindurna	26	86.7	4	13.3	0	0	0	0	30	100
Belka	75	98.7	1	1.3	0	0	0	0	76	100
All	355	93.2	15	3.9	3	.8	8	2.1	381	100

Source: Field Survey, 2017

6.3.2 House building material

Table 6.19 shows the roof materials of the respondents. The dominating roof materials of the study area are corrugated iron sheet (86.8%). Both semi-pacca and kacha houses were constructed with the roof material of corrugated iron sheet for its resilience to river induced disaster. 12.3% respondents use thatch as roof materials. The use of concrete as roof material is rare in the study area and only .8% respondents replied about concrete roof in their house. Among the study unions highest percentage (93.1%) of corrugated iron sheet made roof materials has been observed in Khuniagachh union. On the other hand highest thatch made house has been found in Saulmari union.

Table 6.19 Roof materials of the respondents

Union	**Roof materials**							
	Corrugated iron sheet		Thatch		Concrete		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	30	88.2	4	11.8	0	0	34	100
Saulmari	45	73.8	16	26.2	0	0	61	100
Bidyananda	35	92.1	3	7.9	0	0	38	100
Khuniagachh	67	93.1	4	5.5	1	1.4	72	100
Kolkonda	51	82.3	9	14.5	2	3.2	62	100
Sindurna	27	90.0	3	10.0	0	0	30	100
Belka	69	90.8	7	9.2	0	0	76	100
All	324	86.8	46	12.4	3	.8	373	100

Source: Field Survey, 2017

Likewise, the community of the study area also prefers to use corrugated iron sheet as wall materials. Among the respondent about 80.7% use corrugated iron sheet for wall construction of their house. About 8% use thatch, 7.8% use jute stick and 3.5% use brick as wall material in the study area (Table 6.20). The ultra-poor people of Teesta basin use jute stick and brick as wall material due to its salvaging capacity.

Table 6.20 Wall materials of the respondents

Union	**Wall materials**									
	Corrugated iron sheet		Jute stick		Thatch		Brick		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	26	76.5	4	11.8	4	11.8	0	0	34	100
Saulmari	40	65.6	8	13.1	13	21.31	0	0	61	100
Bidyananda	35	92.1	2	5.3	1	2.6	0	0	38	100
Khuniagachh	60	83.3	4	5.6	4	5.6	4	5.6	72	100
Kolkonda	49	79.0	8	12.1	1	1.6	4	6.5	62	100
Sindurna	23	76.7	1	3.3	2	6.7	4	13.3	30	100
Belka	68	89.5	2	2.6	5	6.5	1	1.3	76	100
All	301	80.7	29	7.8	30	8.0	13	3.5	373	100

Source: Field survey, 2017

The floor of the respondent's house is mud made. Recurrent river morphology change disrupts the houses of the community of Teesta basin. Therefore, the victim community tries to make low cost house with mud made floor. The study result shows that about 95.7% respondents replied regarding houses with mud made floor (Table 6.21). The houses made with corrugated iron sheet, jute stick and thatch contains mud made floor which brings sufferings of the respondents in the flooding situation. The foot of the people is attacked with fungal infection. Only 3.3% respondents answered about floor with brick base and 1.0% replied on floor made with plaster.

Table 6.21 Floor materials of the respondents

Union	**Floor materials**							
	Mud		Brick		Plaster		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	31	91.2	3	8.8			34	100
Saulmari	56	91.8	3	8.8	2	3.3	61	100
Bidyananda	38	100.0	0	0	0	0	38	100
Khuniagachh	69	95.8	2	2.8	1	1.4	72	100
Kolkonda	58	93.5	3	4.8	1	1.6	62	100
Sindurna	30	100.0	0	0	0	0	30	100
Belka	75	98.7	1	1.3	0	0	76	100
All	357	95.7	12	3.3	4	1.0	373	100

Source: Field Survey, 2017

6.3.3 Causes of making house mainly with corrugated iron sheet

The respondents choose friendly house building materials regarding river morphology change. The people of the study area are conscious enough to build their house with a resilient way. The river victims of Teesta basin make their house with durable materials to minimize their economic loss. Hence, the community of Teesta basin uses corrugated iron sheet and thatch as house building material for disaster recovery. Corrugated iron sheet and thatch housing materials have resalable value and salvaging means in response to river bank erosion (Haque, 1991). The Table 6.22 signifies the cause of making house with corrugated iron sheet. The respondents were asked about the cause of making house with portable materials. About 15.0% respondents opined about the availability of materials and 4.3% respondents told about low making cost are the causes for making house with corrugated iron sheet. The study result displays that among the respondents, 80.7% made their house with corrugated iron sheet because the materials are durable and easy to remove during river morphology change. This is one of the best survival technique adopted by the Teesta riverine communities from generation to generation. The study result implies that, the people of the study area mostly depend upon corrugated iron sheet to minimize the impacts of river morphology change. Likewise, corrugated iron sheet is such a type of house building material that has both salvaging capacity and durability. Moreover, when houses drowned in flood, people take shelter in top of corrugated iron sheet. Therefore, corrugated iron sheet plays an important role in adaptation with river morphology change.

Table 6.22 Causes of making house mainly with corrugated iron sheet

Union	**Causes of making house mainly with corrugated iron sheet**							
	Low making cost		Availability of materials		Salvaging capacity and durability of the materials		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	0	0	8	23.5	26	76.5	34	100
Saulmari	1	1.6	20	32.8	40	65.6	61	100
Bidyananda	0	0	3	7.9	35	92.1	38	100
Khuniagachh	4	5.5	8	11.1	60	83.3	72	100
Kolkonda	6	9.6	7	11.3	49	70.0	62	100
Sindurna	4	13.3	3	10.0	23	76.7	30	100
Belka	1	1.3	7	9.2	68	89.5	76	100
All	16	4.3	56	15.0	301	80.7	373	100
Chi-square	χ^2 value=46.381, df=18, p=.000							

Source: Field survey, 2017

6.3.4 Drinking water and toilet facilities

The respondents of the present study face problems for drinking water and toilet facilities owing to river morphology change. 12.8% respondents collect drinking water from neighbor's tube well and their tube well had drowned into the river in the previous year's river morphology change. 69.3% people have own tube well as a source of pure drinking water. At present 17.9% respondent's tube well departed in the river womb for current river morphology change situation. Table 6.23 displays the condition of drinking water facilities in the study unions.

Table 6.23 Drinking water facilities

Union	Drinking water facilities							
	Own tube well		Neighbors tube well		Tube well departed in the river womb		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	20	58.8	5	14.7	9	26.5	34	100
Saulmari	45	70.3	12	18.8	7	10.9	64	100
Bidyananda	20	48.7	6	14.7	15	36.6	41	100
Khuniagachh	53	73.6	7	9.7	12	16.7	72	100
Kolkonda	48	75.0	6	9.4	10	15.6	64	100
Sindurna	21	70.0	3	10.0	6	20.0	30	100
Belka	57	75.0	10	13.1	9	11.9	76	100
All	264	69.3	49	12.8	68	17.9	381	100

Source: Field Survey 2017

The condition of toilet facilities of the study union indicates that most of the respondents (74.3%) use *kancha* toilet. Among the respondent about 7.9% use sanitary latrine (Table 6.24). The study finds out that about 17.8% respondents lost their toilet in the current river morphology change condition. Among the study unions Bidynanda shows highest frequency of toilet destruction in the river womb. Because it is one of the most affected union of river morphology change in 2017 flood.

Table 6.24 Toilet facilities of the respondents

Union	Toilet facilities							
	Kancha		Sanitary latrine		Destroyed in the river womb		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	23	67.6	2	5.9	9	26.5	34	100
Saulmari	50	78.2	7	10.9	7	10.9	64	100
Bidyananda	25	60.9	1	2.5	15	36.6	41	100
Khuniagachh	56	77.8	4	5.5	12	16.7	72	100
Kolkonda	49	76.6	5	7.8	10	15.6	64	100
Sindurna	20	66.6	4	13.4	6	20.0	30	100
Belka	60	78.9	7	9.3	9	11.8	76	100
All	283	74.3	30	7.9	68	17.8	381	100

Source: Field Survey 2017

6.4 Morphological change in respondents view

The people of the study area have close interaction with the Teesta river. They have own perception, knowledge and views about river morphology and its dynamism. Living in the Teesta basin and observation of the water discharge, sedimentation, bank failure, sinuosity of the river, they gained the knowledge of when, how and why the river changes its morphology. The present section reveals the views of the respondents regarding river morphology change.

6.4.1 Approximate distance of Teesta river from residence

The people of the study area lives in close distance of the Teesta river. Among the respondents 39.6% lives in the bank of the river. They live in the bank because the banks are protected by embankments. But the natural levees of the river banks are also recognized linear settlements of river victims. Distance of Teesta river from residence of the respondents have been shown in Table 6.25. About 30.7% respondents live within 100 meter distance, 22.0% live within 200 meter distance and 7.6% live more than 200m distance from the river. Among the study unions highest percentage (68.3%) of the respondent's house is located in the bank of the river in Bidyananda union. Therefore, the study finds out that the people of Bidyananda union is more vulnerable to the ongoing river morphology change incidence. The Table also shows the chi-square result of distance of Teesta river from residence of the respondents in the study unions. The test result shows that p value is significant.

Table 6.25 Distance of Teesta river from residence of the respondents

Union	Distance of Teesta river from residence									
	House is in the bank		100 meter distance		200 meter distance		More than 200 meter distance		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	12	35.3	12	35.3	6	17.6	4	11.8	34	100
Saulmari	26	40.6	24	37.5	8	12.5	6	9.4	64	100
Bidyananda	28	68.3	7	17.0	4	9.7	2	4.8	41	100
Khuniagachh	23	31.9	13	18.0	32	44.4	4	5.6	72	100
Kolkonda	25	39.1	29	45.3	10	15.6	0	0	64	100
Sindurna	8	26.7	13	43.3	7	23.3	2	6.7	30	100
Belka	29	38.2	19	25.0	17	22.3	11	14.4	76	100
All	151	39.6	117	30.7	84	22.0	29	7.6	381	100
Chi Square	χ^2 value=75.893, df=30, p=.000									

Source: Field Survey, 2017

6.4.2 Duration of staying at present house

The community of Teesta basin shifts their house several times due to river morphology change. The shifting occurs in the monsoon and post monsoon season. From the field investigation it has been revealed that the respondents shifted their house from their previous destination 0 year (Today) 1.8%, 0.02 year .8%, 0.03 year .8%, 0.04 year 1.0%, 0.05 year 2.1%, 0.06 year 1.0%, 0.07 year .8%, 0.08 year .3%, 0.1 year .5%, .12 year 1.3%, 0.2 year .3%, .22 year .3%,0.25 year 1.3%, 0.3 year 1%. Therefore the study result indicates that 12.6% respondents have been staying at the current location less than one year, 29.1% staying 1-4 year, 36.2% staying from 5-8 year in the present location. The study signifies the internal displacement of the respondents from one location to another location. Table 6.26 illustrates the percentage of Time of staying in present house/ location.

Table 6.26 Time of staying at present house/ location

Time of stay in present house	N	%	Time of stay and %
Less than one year	48	12.6	0 year(Today) 1.8%, 0.02 year .8%, 0.03 year .8%, 0.04 year 1.0%, 0.05 year 2.1%, 0.06 year 1.0%, 0.07 year .8%, 0.08 year .3%, 0.1 year .5%, .12 year 1.3%, 0.2 year .3%, .22 year .3%,0.25 year 1.3%, 0.3 year 1%
1-4 year	111	29.1	1 y 3.1%, 2 y 11.3%, 3y 8.7, 4y 6.0
5-8 year	138	36.2	5 y 21.0%, 6 y 3.1%, 7 y 6.8%, 8 y 5.2%,
9-12 year	66	17.3	9 y 1.0%, 10y 11.8%, 12y 4.5%
13-16 year	18	4.8	13 y 1.6%, 15y 2.9%, 16y .3%
Total	381	100.0	

Source: Field survey, 2017

6.4.3 Causes and place of displacement of the respondents

The study tries to investigate the reason for displacement and relocation of house. The most important impact of river morphology change is homestead displacement of the community of the study area. To know the reason for displacement, the respondents were asked about the causes of their household shifting. 98.7% respondents answered the cause behind household shifting was due to river morphology change. Only .3% and .5% respondents opined about the reason for homestead displacement was personal problem and marriage respectively.

Likewise, field survey result regarding place of displacement shows that 51.7% respondents came to the new destination from another location of this union, 31.5% came from char and 16.8% from another union. Hence, the study result highlights that, most of the people of the study area relocate their house into another location of their own union. The people of the study area shifts their house due to river morphology change from one union to another union, one village to another village, from char to main land and from main land to char land. But they do not leave their source destination and lives near to the source region for the hope of the eroded land must be raise again. Old maps and previous literature shows new settlement develops in the bank of new channel for vested property (Mallick, 2016). Therefore, the river displaces relocate house close to their source region due to socio-economic reason. River bank erosion displaces resettle house in char and within upazilla for socio-cultural adaptation (Elahi and Rogg, 1990). Table 6.27 represents the place of displacement of the respondents. The chi-square test result shows significant differences (p=.000) in terms of place of displacement of the respondents.

Table 6.27 Place of displacement of the respondents

Union	Place of displacement							
	From another location of this union		From char		From another union		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	13	38.2	15	44.1	6	17.6	34	100
Saulmari	22	34.4	29	45.3	13	20.3	64	100
Bidyananda	22	53.7	16	39.0	3	7.3	41	100
Khuniagachh	32	44.4	28	38.9	12	16.7	72	100
Kolkonda	36	56.2	14	21.9	14	21.9	64	100
Sindurna	15	50.0	9	30.0	6	20.0	30	100
Belka	57	75.0	9	11.8	10	13.2	76	100
All	197	51.7	120	31.5	64	16.8	381	100
Chi-square	χ^2 value= 37.177, df=12, p=.000							

Source: Field Survey, 2017

6.4.4 Respondents views about flooding situation

The respondents are familiar to the category and frequency of flood of Teesta river. The vulnerability of river morphology change varies with the type and frequency of flood, flood occurrence in a single year, average depth of inundation and time of flood water inundation. The present study demonstrates the respondent's views about flooding situation.

6.4.4.1 Type of flood in the study area

According to the respondents,, the study area experiences flash floods and monsoon flood. Among the respondents about 54.0% opined for monsoon flood and 46.0% speak out for flash flood occurrences. Monsoon flood is dominant in the study area which increases vulnerability towards river morphology change. But pre Monsoon and post Monsoon flash flood also destroys property and causes change in river morphology. Table 6.28 shows the flood types in the study area. Flash flood occurs due to the physiographic condition of the study area. Moreover, torrential rainfall in the upstream causes flood in the study area.

Table 6.28 Type of flood occurrences

Union	Type of flood occurrences					
	Monsoon flood		Flash flood		Total	
	N	%	N	%	N	%
Purba chatnai	14	41.2	20	58.8	34	100
Saulmari	15	23.4	49	76.6	64	100
Bidyananda	28	68.3	13	31.7	41	100
Khuniagachh	35	48.6	37	51.4	72	100
Kolkonda	40	62.5	24	37.5	64	100
Sindurna	10	33.3	20	66.7	30	100
Belka	64	84.2	12	15.8	76	100
All	206	54.0	175	46.0	381	100

Source: Field Survey 2017

6.4.4.2 Frequency of flood

The frequent flood occurrence in the study area make the poor people vulnerable to cope with the pre, during and post flooding condition. According to the field investigation 82.2% respondents gave their opinion that flood occurs almost every year. Table 6.29 shows the frequency of flood in the study area. The people who lives relatively high land of Teesta basin face flood after 1-2 years (12.6% respondents) and occurrence of flood after 2-3 years (5.2% respondents). Hence, the study result shows that flood is a recurrent hydro-meteorological event in Teesta basin. Repeated flood disaster in the study area causes frequent changes in river channels through erosion and sediment deposition.

Table 6.29 Frequency of flood in the study area

Union	Frequency of flood							
	Occurs every year		Occurs after 1-2 years		Occurs after 3-4 years		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	23	67.6	8	23.5	3	8.8	34	100
Saulmari	48	75.0	13	20.3	3	4.7	64	100
Bidyananda	35	85.4	4	9.8	2	4.9	41	100
Khuniagachh	62	86.1	10	13.9	0	0	72	100
Kolkonda	54	84.4	6	9.4	4	6.2	64	100
Sindurna	27	90.0	1	3.3	2	6.7	30	100
Belka	64	84.2	6	7.9	6	7.9	76	100
All	313	82.2	48	12.6	20	5.2	381	100

Source: Field Survey 2017

6.4.4.3 Flood occurrence in each year

Flood is a regular event which attacks several times in each year in the study area. The respondents express their miserable situation that sometimes they experiences 2-3 times flood hit in a year. The year 2017 is such a year which they experienced 3 times flood attack. Flood usually occurs in the months of May to October (*Jaishtha- Aswin*). First flood occurrence happens in mid May to mid June (*Jaishtha)*, second flood followed in mid June to mid September *(Ashar-Bhadra*[26]) and third time flood takes place in the month of mid September to mid October *(Ashwin*) (Shafie and Rahman, 2009). The respondents were asked about the occurrence of flood in a year. About 67.2% respondents mentioned that they experience two times flood in each year. Three times flood attack and one time flood occurrence have the opinion of 25.2% and 7.6% respondents respectively. Table 6.30 represents flood occurrence in a year in the study area.

Table 6.30 Flood occurrence in each year

Union	**Flood occurrence (in each year)**							
	Once		Two times		Three times		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	3	8.8	22	64.7	9	26.5	34	100
Saulmari	6	9.4	42	65.6	16	25.0	64	100
Bidyananda	4	9.8	26	63.4	11	26.8	41	100
Khuniagachh	5	6.9	45	62.5	22	30.6	72	100
Kolkonda	4	6.2	43	67.2	17	26.6	64	100
Sindurna	2	6.7	21	70.0	7	23.3	30	100
Belka	5	6.6	57	75.0	14	18.4	76	100
All	29	7.6	256	67.2	96	25.2	381	100

Source: Field survey, 2017

6.4.4.4. Depth of inundation

Flood inundates the homesteads of the Teesta floodplain. Normal flood water inundates houses for 2-3 days. But extreme flood blockage occurs from one week to several weeks as per the severity of floods. The depth of inundation also recognized from 1-more than 4 feet. The questionnaire survey result displays that most of the respondents (76.6%) have been strike by inundation of 3-4 feet. Table 6.31 also indicates that 15.7% argued about 1-2 feet and 7.6% speak out about more than 4 feet inundation occurs for flood which effects on river morphology change.

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[26] *Ashar-Bhadra* are the two months of Bengali calendar. *Ashar* is the first month of Rainey Season and *Bhadra* is the first month of Autumn season.

Table 6.31 Depth of inundation

Union	Depth of inundation							
	1-2 feet		3-4 feet		More than 4 feet		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	9	26.4	17	50.0	8	23.5	34	100
Saulmari	14	21.8	42	65.6	8	12.5	64	100
Bidyananda	4	9.8	34	82.9	3	7.3	41	100
Khuniagachh	15	20.8	55	76.4	2	2.8	72	100
Kolkonda	11	17.1	50	78.1	3	4.6	64	100
Sindurna	3	10.0	26	86.6	1	3.3	30	100
Belka	4	5.3	68	89.4	4	5.3	76	100
All	60	15.7	292	76.6	29	7.6	381	100

Source: Field survey, 2017

6.4.5 Respondents perception about river bank erosion and bank failure

The communities of Teesta basin are the victims of river morphology change owing to bank erosion. The local people observe the condition of bank erosion whether it is increasing or decreasing, the situation is bad or worse or worst. The respondents express their worries, vulnerabilities and sufferings for river bank erosion. The people of the study area also identify the intensity and month of erosion occurrences.

6.4.5.1 Condition of river bank erosion

The people of the study area are the victim of river bank erosion. Repeated flood attack make them panic towards river bank erosion and loss of homestead, property, livelihood damage as well. The respondents have been asked about the condition of river bank erosion of recent floods. 28.9% respondents gave their opinion about the condition of river bank erosion is low. Low condition of erosion has been observed in Purba chatni and Belka union. The attitude towards worst condition of river bank erosion has been determined by 29.7% of respondents in Bidyananda and Khuniagachh union. Moderate river bank erosion has been categorized by 41.5% of respondents which is observed in Saulmari, Kolkonda and Sindurna union. Respondents answer regarding the current condition of erosion in the respective unions is depicted in Table 6.32. The table also signifies (p=.000) the condition of erosion in the study unions.

Table 6.32 Condition of river bank erosion in recent floods

Union	Condition of river bank erosion							
	Low		Moderate		Worst		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	34	100.0	0	0	0	0	34	100
Saulmari	0	0	64	100.0	0	0	64	100
Bidyananda	0	0	0	0	41	100.0	41	100
Khuniagachh	0	0	0	0	72	100.0	72	100
Kolkonda	0	0	64	100.0	0	0	64	100
Sindurna	0	0	30	100.0	0	0	30	100
Belka	76	100.0	0	0	0	0	76	100
All	110	28.9	158	41.5	113	29.7	381	100
Likelihood ratio=826.138, df=12, p=.000								

Source: Field Survey 2017

6.4.5.2 Intensity of river bank erosion

Intensive bank erosion occurs in the study area. Among the respondents 15.0% answered regarding river bank erosion incident in their union is once in a year and 21.8% respondents replied about the intensity of bank erosion is it occurs two times in a year (Table 6.33). Due to more than one times flood occurrence in the study area, river bank erosion is also acute in temporal scale. The study finds out that about 63.3% of respondents have their observation about depending on flood frequency erosion occurs several times in each year. Devastating flood causes intensive river bank erosion but normal flood also grounds for bank collapse in each year. In the flood of 2017, most of the people of the study area faced three times flood hit and the community experienced several times erosion. The chi square test result signifies the intensity of river bank erosion (in a year) in the study unions.

Table 6.33 Intensity of river bank erosion (in each year)

Union	**Intensity of river bank erosion**							
	Once		Two times		Several times		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	1	2.9	8	23.5	25	73.5	34	100
Saulmari	7	10.9	8	12.5	49	76.6	64	100
Bidyananda	4	9.8	9	20.0	28	68.3	41	100
Khuniagachh	15	20.8	19	26.4	38	52.8	72	100
Kolkonda	14	21.9	11	17.2	39	60.9	64	100
Sindurna	4	13.3	6	20.0	20	66.7	30	100
Belka	12	15.8	22	28.9	42	55.3	76	100
All	57	15.0	83	21.8	241	63.3	381	100
Chi square	χ^2 value=18.897, df=12, p=0.91							

Source: Field Survey 2017

6.4.5.3 Month of erosion occurrences

Erosion usually occurs in the monsoon and post monsoon seasons. According to the respondents erosion takes place when flood water retreats. The bank materials of the Teesta river loose its compactness with flood water and erosion happens in the Bengali months from *Ashar- Agrahayan* [27](June-November). But most frequent erosion occurring months are *Ashar- Sravan*[28] (mid June-mid August). Almost 57.5% respondents gave their opinion about erosion occurs in *Ashar- Sravan* months (mid June-mid August). Sometimes erosion occurs in the months of *Vadro- Aswin* (mid August-mid October) which is opined by 27.0% respondents (Table 6.34). The respondents argued that without any cause suddenly erosion takes place in the months of Kartik- Agrahyan (mid october-mid December) and ripen paddy, other crops as well as vegetable enters into the river gorge. Likewise, 15.5% respondents opined about erosion occurrence in the month of *Kartik-Agrahayan*.

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[27] *Agrahayan* means the Bengali month of Late Autumn season. It is known as the month of golden paddy.

[28] *Sravan* refers to the second month of Rainy season.

Table 6.34 Month of severe erosion occurrences

Union	Month of severe erosion occurrences							
	mid June-mid August		mid August-mid October		mid october-mid December		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	19	55.9	11	32.4	4	11.8	34	100
Saulmari	29	45.3	25	39.1	10	15.6	64	100
Bidyananda	21	51.2	14	34.1	6	14.6	41	100
Khuniagachh	40	55.6	22	30.6	10	13.9	72	100
Kolkonda	40	62.5	12	18.8	12	18.8	64	100
Sindurna	19	63.3	7	23.3	4	13.3	30	100
Belka	51	67.1	12	15.8	13	17.1	76	100
All	219	57.5	103	27.0	59	15.5	381	100

Source: Field Survey 2017

6.4.6 Degradation activity by Teesta river

Degradation activities of the Teesta river occurs to balance the aggradation activities. Hence frequent degradation takes place in the river due to anthropogenic impact over the last few decades. Multiple response analysis about the degradation activity of the Teesta river shows that the people of the study area have highly responded for channel shifting, erosion, bank failure and river valley widening. The foundation behind the high responses lies in the impacts of degradation activities on the local people. Table 6.35 presents the multiple response analysis of degradation activities by the river. Multiple responses regarding degradation activities of Teesta river indicates 24.7% channel shifting, 25.2% erosion, 25.2% bank failure and 24.7% river valley widening occurs in the study area. The study result implies that the degradation activities such as channel shifting, erosion, bank failure and river valley widening happens almost same degree and intensity in the study area.

Table 6.35 Degradation activities of Teesta river

Union	Degradation activities									
	Channel shifting		Erosion		Bank failure		River valley widening		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	31	24.0	34	26.3	34	26.3	30	23.2	129	100
Saulmari	64	25.6	63	25.2	63	25.2	60	24.0	250	100
Bidyananda	41	25.1	41	25.1	41	25.1	40	24.5	163	100
Khuniagachh	71	24.9	72	25.2	72	25.2	70	24.5	285	100
Kolkonda	62	24.7	64	25.4	64	25.4	61	24.3	251	100
Sindurna	25	24.2	26	25.2	26	25.2	26	25.2	103	100
Belka	68	23.9	70	24.6	70	24.6	76	26.7	284	100
All	362	24.7	370	25.2	370	25.2	363	24.7	1465	100

Source: Field Survey, 2017 (Percentages and totals are based on responses)

6.4.7 Aggradation activity by Teesta river

The dynamic Teesta river changes its morphology through its aggradation activities. Aggradation activities of floodplain rivers are the outcomes of neo tectonics and overbank spilling for heavy rainfall and land use change (Wasson, 2003). Sediment accumulation in bank or bed, effects on river morphology. Sediment transport capacity of alluvial river impacts on river planform pattern change (Singh, 2014). The people of the Teesta basin are well known with the aggradation activities of the river. Multiple response analysis of questionnaire survey regarding aggradation activities has unveiled that highest number (381) and percentage of (26.1) respondents opined about the char formation process of the river. Table 6.36 proves the percentage of accretion in the bank/ natural levee, under water shoal and sediment transport anomalies 23.8%, 24.4%, and 25.4% respectively. All the study union represents nearly similar responses in terms of natural levee, char formation, under water shoal, sediment transport anomalies in the study area.

Table 6.36 Aggradation activities of Teesta river

Union	**Aggradation activities of Teesta river**									
	Natural levee		Char formation		Under water shoal		Sediment transport anomalies		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	25	20.6	34	28.0	32	26.4	30	24.7	121	100
Saulmari	53	21.9	64	26.5	62	25.7	62	25.7	241	100
Bidyananda	41	25.0	41	25.0	41	25.0	41	25.0	164	100
Khuniagachh	70	24.7	72	25.4	70	24.7	71	25.0	283	100
Kolkonda	58	24.3	64	26.8	53	22.2	63	26.4	238	100
Sindurna	28	23.9	30	25.6	29	24.7	30	25.6	117	100
Belka	72	24.7	76	26.1	69	23.7	74	25.4	291	100
All	347	23.8	381	26.1	356	24.4	371	25.4	1455	100

Source: Field Survey, 2017 (Percentages and totals are based on responses)

6.4.8 Condition of sediment deposition

Sedimentation is a familiar process to the people of Teesta basin. Among the respondents 24.7% replied about low sediment accumulation in their union. Moderate sediment deposition has been replied by 30.7% of respondents. Downstream location of Teesta in Bangladesh has been detected high sediment accretion due to bank erosion and upstream sediment transportation. Both satellite image analysis and questionnaire survey results regarding sedimentation shows high sediment deposition in the bank. About 44.6% respondents answered regarding high sediment deposition in the respective unions (Table 6.37). The study result depicts that the condition of deposition is high at Purba chatnai, Khuniagachh and Kolkonda union.

Moreover, low deposition has been observed by the respondents at Saulmari and Sindurna union. On the other hand, moderate condition of deposition has been found at Bidyananda and Belka union. Significant differences (p=.000) has been found in the condition of sediment deposition in recent floods in the study unions.

Table 6.37 Condition of sediment deposition in recent floods

Union	Condition of sediment deposition							
	Low		Moderate		High		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	0	0	0	0	34	100	34	100
Saulmari	64	100	0	0	0	0	64	100
Bidyananda	0	0	41	100	0	0	41	100
Khuniagachh	0	0	0	0	72	100	72	100
Kolkonda	0	0	0	0	64	100	64	100
Sindurna	30	100	0	0	0	0	30	100
Belka	0	0	76	100	0	0	76	100
All	94	24.7	117	30.7	44.6	170	381	100
Likelihood ratio=7.620, df=12, p=.000								

Source: Field survey, 2017

6.4.9 Respondents views about channel shifting

The Teesta river frequently changes its morphology through channel shifting mechanism. The respondents mentioned their experience about how the river shifts channel. They shared views about river morphology change which they observed from their childhood. The respondents expressed their opinion about situation of channel shifting and level of channel shifting of Teesta river.

6.4.9.1 Situation of channel shifting

Channel shifting has been observed by the local community of Teesta river basin. Among the respondents 37.0% replied that now the river is nearest to their house. They experienced different channel shifting behavior of Teesta river in their life. During field survey people shared their opinion regarding channel shifting such as now my house is nearest to the river for erosion but few years ago it was far from the river. Again they answered that when they were children the river was near to house but now the river is far from their house due to sediment deposition. Questionnaire survey result indicates that about 9.9% respondents answered when they were child the river was near to their house but now the river is far from house due to sediment accretion in the bank (Table 6.38). About 39.4% respondents opined that recently their house gone under the river womb. Among the respondents 13.6% opined that few years ago river was 1-2 km away from their house but now a very short distance exists between the two. The study result also signifies (p=.000) the situation of channel shifting in the study area.

Table 6.38 Situation of channel shifting

Union	Situation of channel shifting									
	Recently house collapsed into the river		Now the river is nearest to my house		Few years ago river was 1-2 km far from house		In childhood river was near to house		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	17	50.0	4	11.7	6	17.6	7	20.5	34	100
Saulmari	21	32.8	31	48.4	7	10.9	5	7.8	64	100
Bidyananda	28	68.3	11	26.8	0	0	2	4.8	41	100
Khuniagachh	25	34.7	23	31.9	14	19.4	10	13.8	72	100
Kolkonda	22	34.4	21	32.8	13	20.3	8	12.5	64	100
Sindurna	8	26.7	19	63.3	3	10.0	0	0	30	100
Belka	29	38.2	32	42.1	9	11.8	6	7.8	76	100
All	150	39.4	141	37.0	52	13.6	38	9.9	381	100
Chi Square	χ^2 value=65.612, df=24, p=.000									

Source: Field survey, 2017

6.4.9.2 Level of channel shifting

According to the respondents the Teesta river frequently changes its channel. They called it arrival of new *nala*[29] (channel). The respondent's view about level of channel shifting has been illustrated in Table 6.39. The study illustrates 24.7% responses regarding low-moderate channel shifting process in the study area. Moderate-high channel shifting has been detected by 28.8% of respondents. High to very high channel shifting has been observed by 46.5% of respondents. The likelihood ratio of level of channel shifting also shows that p value is significant. Thus, the study result shows that there exist differences in the study unions in terms of level of channel shifting.

Table 6.39 Level of channel shifting

Union	Level of channel shifting							
	Low-moderate		Moderate-High		High-very high		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	0	0	34	100	0	0	34	100
Saulmari	64	100	0	0	0	0	64	100
Bidyananda	0	0	0	0	41	100	41	100
Khuniagachh	0	0	0	0	72	100	72	100
Kolkonda	0	0	0	0	64	100	64	100
Sindurna	30	100	0	0	100	0	30	100
Belka	0	0	76	100	0	0	76	100
All	94	24.7	110	28.8	177	46.5	381	100
Likelihood ratio=807.811, df=12, p=.000								

Source: Field survey, 2017

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[29] *Nala* is a local term which means the stream channel emerged from the main river after flood, in Teesta river basin.

6.5 Correlation among erosion, deposition and level of channel shifting

Erosion and deposition are the two main activities of a river system which depends upon one another and these activities effects on channel shifting. Spearman rank correlation result indicates that there exists strong relationship with erosion, deposition and level of channel shifting in the study area (Table 6.40). Erosion, deposition and level of channel shifting are positively correlated with one another. Correlation is significant at 0.01 level (2-tailed).

Table 6.40 Correlation among erosion, deposition and level of channel shifting

	River bank erosion	Sediment deposition	Level of channel shifting
River bank erosion	1.0	.180**	.489**
Sediment deposition		1.0	.858**
Level of channel shifting			1.0

**Correlation is significant at 0.01 level (2-tailed)

6.6 Regression analysis for influence of flood occurrence and erosion on current occupation

River morphology change impacts on the occupation of the respondents. The dependent variable of the model is current occupation and the predictors are condition of river erosion in respondents union and flood occurrence in a year. The regression model shows F= 8.186, Std. Error =5.338 and p= .000 which represents the model is significant. Flood occurrence in a year and condition of river erosion in respondents union has significant effect on respondent’s current occupation (Table 6.41). Frequent flood occurrence causes livelihood damage and impacts on current occupation. Condition of river erosion on respondents union also hampers livelihoods and causes change in occupation. The regression model also shows R^2 =0.42 (Adjusted R^2 = 0.36) which indicates 42% variation of the dependent variable explained by the predictors.

Table 6.41 Regression analysis for influence of flood occurrence and erosion on current occupation

Model	Coefficients	Std. Error	t	sig
(Constant)	6.371	1.405	4.533	.000
Flood occurrence in a year	-1.147	.437	-2.624	.009
Condition of river erosion in respondents union	1.046	.358	2.920	.004
R^2=0.42, Adjusted R^2=0.36, F= 8.186, Std. Error =5.338, p=.000				

6.7 Regression analysis for level of channel shifting and hydro-morphological variables

Table 6.42 represents the regression analysis for level of channel shifting and hydro-morphological variables. The hydro-morphological variables included in the regression model are condition of river erosion in respondents union, condition of sediment deposition, intensity of river erosion and situation of channel shifting. The selected four variables have significant impact on level of channel shifting. Condition of sediment deposition is a significant predictor for future river morphology change because level of channel shifting depends upon it. Condition of sediment deposition explains coefficient=.792 p=.000 which means the predictor has significant influence in level of channel shifting. Therefore, sediment deposition seriously changes the morphology of Teesta river which adversely impacts on the agrarian society of the study area.

Condition of river erosion in respondents union also designates significant impact on level of channel shifting (coefficient =.385 and p=.000). Condition of river erosion impacts on level of channel shifting and thus river morphology changes. Intensity of river erosion also appears as an influential variable for channel shifting and thus it changes river morphology. Intensity of river erosion shows p=.022 and situation of channel shifting occupies p=.039. The regression model for level of channel shifting and hydro-morphological variables represents that R^2 =.808, Adjusted R^2 =.806, F = 396.763, Std. Error =.368 and p= .000. Therefore, the model represents 80% variation of the dependent variable explained by the predictors.

Table 6.42 Regression analysis for level of channel shifting and hydro-morphological variables

Model	Coefficients	Std. Error	t	Sig.
(Constant)	-.910	.105	-8.700	.000
Condition of sediment deposition	.792	.024	32.587	.000
Condition of river erosion in respondents union	.385	.025	15.382	.000
Intensity of river erosion	.059	.026	2.301	.022
Situation of channel shifting	.042	.020	2.071	.039
R^2=.808, Adjusted R^2=.806, F=396.763 , Std. Error =.368, p=.000				

6.8 Respondent's perception about causes of morphological change

Several factors and forces are involved to change the morphology of a river system. The hydrology, meteorology and lithological condition of Teesta river basin are favorable to change the river morphology. Moreover anthropogenic causes also accelerate flood, sedimentation and river bank erosion which involves with morphological change. The multiple response analysis of the present study illustrates the causes of flood, river bank erosion, sedimentation and river channel change that influences the river to change its morphology.

6.8.1 Causes of flood

The study identified various causes of flood in the Teesta floodplain that is almost same in the country. In Bangladesh, flood occurs mostly in the monsoon. Moreover, intensive rainfalls in the upstream locations are also responsible for flood in the country. Rainfall in the upper catchment is the main reason of flood in Bangladesh (Choudhury, 1989). Due to the downstream locations of Bangladesh, the rivers of the country are occupied by siltation process which elevates river bed and grounds for flood. One of the major causes of flood in Bangladesh is siltation in the rivers (Rahman *et al*., 2010). Suspended sediment load such as silt and clay is transported and deposited during flood. The extreme flat topography of the study area is the cause of monsoon floods every year. River bed rise for sediment deposition is the inherent cause of perennial flood in the Teesta floodplain. Flash flood occurs due to the location of hilly regions just beneath the study area. Catchment rainfall, low elevation, deforestation, dam construction are the causes of flood in the northern Bangladesh (Shafie and Rahman, 2009). The study result reveals that about 11% respondents claimed heavy rainfall in monsoon is the cause of flood in Teesta basin. Highest number of respondents (344) argued about river bed rise for sediment deposition is the cause of flood. About 46.7% respondents argued that sedimentation elevates river bed which instigates flood. The multiple response analysis also shows 42.3% respondent's opined about the cause of flood lies behind high volume of water discharge from upstream during monsoon (Table 6.43).

Table 6.43 Causes of flood in the study area

Union	Causes of flood							
	Heavy rainfall		High volume of upstream discharge		Elevated river bed for sedimentation		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	5	8.9	22	39.3	29	51.8	56	100
Saulmari	13	10.6	58	47.2	52	42.3	123	100
Bidyananda	9	12.2	30	40.5	35	47.3	74	100
Khuniagachh	21	14.3	61	41.5	65	44.2	147	100
Kolkonda	14	11.0	52	40.9	61	48.0	127	100
Sindurna	7	11.5	26	42.6	28	45.9	61	100
Belka	12	8.1	62	41.9	74	50.0	148	100
All	81	11.0	311	42.3	344	46.7	736	100

Source: Field survey, 2017(Percentages and totals are based on responses)

6.8.2 Causes of river bank erosion

The causes of river bank erosion in Bangladesh are inherent. The downstream location of the three mighty river systems, soil characteristics, tectonics, geology and the old stage of the rivers controls the morphology of rivers. The fluctuations of water in the pre monsoon, monsoon and post monsoon are a major cause of immense river bank erosion. River banks are affected by flood water during flood and in the low flow stage bank erosion occurs for liquefaction of sediments (Rasheed, 2008). The characteristics of bank materials of river are also responsible for erosion. The river bank containing high clay concentration is impervious to slumping (Hooke, 1979). Observations from the field survey suggest that Teesta river bank erosion occurs due to flood, non-cohesive bank material/weak soil and human activities. Table 6.44 denotes the multiple response analysis of causes of river bank erosion in the study area. Flood has been determined the most influential factor for bank erosion according to the respondents. About 36.7% respondents detected flood as the cause of bank erosion. The river basin community represents their opinion towards non cohesive sandy soil (weak soil) condition causes bank erosion. Among the respondents 33.1% replied about unconsolidated soil is liable for river bank erosion in the study area. The Teesta river basin community blamed that human activities such as dam, barrage and bridge construction; stone collection, deforestation, etc. are also responsible for river bank erosion in the study area. Therefore, 30.0% respondents accused that human activities are also the controlling factor for river bank erosion. Hence, the study result implies that flood is the most influential factor for river bank erosion but weak soil and human activities also play significant role for river bank erosion.

Table 6.44 Causes of river bank erosion

Union	**Causes of river bank erosion**							
	Weak soil		Flood		Human activities		Total	
	f	%	*f*	%	*f*	%	N	%
Purba chatnai	30	33.7	32	35.9	27	30.3	89	100
Saulmari	60	34.2	64	36.5	51	29.1	175	100
Bidyananda	40	33.3	41	34.1	39	32.5	120	100
Khuniagachh	70	34.6	72	35.6	60	29.7	202	100
Kolkonda	43	30.4	51	36.1	47	33.3	141	100
Sindurna	15	22.7	28	42.4	23	34.8	66	100
Belka	61	36.0	66	39.0	42	24.8	169	100
All	319	33.1	354	36.7	289	30.0	962	100

Source: Field survey, 2017(Percentages and totals are based on responses)

6.8.3 Causes of sedimentation

Sediment deposition on river bed and river bank depends upon the velocity of water as well as the magnitude of flood and erosion. Fine sediment deposition occurs in the floodplain and flood basin during lower magnitude of flood but accumulation of sand in the river bed is followed by high magnitude of floods. Ice melting, deforestation in the upstream, torrential rainfall and obviously soil erosion conveys important role for the siltation process in the rivers of Bangladesh (Rahman *et al.*, 2010). Multiple response analysis for causes of sedimentation displays that, among the respondents 33.9% opined about river bank erosion and 28.8% answered about human activities are the causes of sedimentation. Accordingly, 37.3% respondents argued that flood and upstream sediment flow are the sources of sedimentation. Table 6.45 highlights the number and percentage of responses on causes of sedimentation of Teesta basin.

Table 6.45 Causes of sedimentation

Union	River bank erosion		Flood and upstream sediment flow		Human activities		Total	
	f	%	*f*	%	*f*	%	N	%
Purba chatnai	28	32.9	32	37.6	25	29.4	85	100
Saulmari	59	34.3	61	35.4	52	30.2	172	100
Bidyananda	40	35.3	41	36.2	32	28.3	113	100
Khuniagachh	64	32.9	72	37.1	58	29.8	194	100
Kolkonda	60	34.6	64	36.9	49	28.3	173	100
Sindurna	26	32.5	30	37.5	24	30.0	80	100
Belka	65	34.3	76	40.2	48	25.3	189	100
All	342	33.9	376	37.3	288	28.8	1006	100

Source: Field survey, 2017(Percentages and totals are based on responses)

6.8.4 Causes of channel shifting

Every river has a particular hydro-morphological settings which causes channel shifting to balance the fluvial condition but human activities also exaggerates channel shifting. River bank protection activities are responsible for change in river systems (Klaassen *et al.*, 2005). The respondents were asked about the causes of channel shifting and surprisingly they answered as a learned person about river morphology. Highest responses (43.6%) have been observed for sediment deposition causes channel shifting. About 35.7% answered that erosion is the cause of river channel shifting which is the second highest observation (Table 6.46). Similarly 19.0% respondents think that human activities such as barrage, spur/groin/ embankment/bridge construction have effects on river channel shifting. The respondents argued that erosion and sediment deposition is the ultimate result of flood. If flood intensity and duration decreases it reduces sedimentation as well as erosion and thus channel shifting also declines. Moreover, 1.6% of respondents argued about earthquake have significant influence on river channel shifting. The old aged respondents shared their perceived knowledge from their previous generation that earthquake causes river channel shifting.

Table 6.46 Causes of channel shifting

Union	**Causes of channel shifting**									
	Erosion		Sediment deposition		Human activities		Earthquake		Total	
	f	%	*f*	%	*f*	%	*f*	%	N	%
Purba chatnai	27	32.5	34	40.9	21	25.3	1	1.2	83	100
Saulmari	52	33.5	64	41.2	39	25.1	0	0	155	100
Bidyananda	38	35.8	41	38.8	25	16.1	2	1.8	106	100
Khuniagachh	67	40.6	72	43.6	23	13.9	3	1.8	165	100
Kolkonda	54	38.2	64	45.3	20	14.1	3	2.1	141	100
Sindurna	27	36.4	30	40.5	16	21.6	1	1.3	74	100
Belka	47	31.5	76	51.0	22	14.7	4	2.6	149	100
All	312	35.7	381	43.6	166	19.0	14	1.6	873	100

Source: Field Survey, 2017

Chapter Seven

Impact of river morphology change

The impact of river morphology change is a cyclic order process which the river basin community gets from birth till death. The female respondent describes their sufferings that they gave birth of child in flooding and bank erosion conditions. The respondents mentioned that when any one dies it is beyond thinking where will be the graveyard because of flooding situation and erosion occurrences. The Teesta river basin community faces economic insolvency due to river morphology change from one generation to another generation. The destruction of river morphology change impacts on homestead, property, livelihood, food habit, education, health, environment and social infrastructures. Therefore, the community manages their livelihood from hand to mouth.

7.1. Impact on economy and agricultural land

The economy and agriculture is the most affected sector for river morphology change. Loss of standing crops; loss of harvested crops; damage and loss of livestock, fishery, trees or garden are the affected sectors in the agriculture based economy of the study area. Loss of income effects on solvency situation of the community. Land holding size reduces enormously owing to river bank erosion. The present study explores the impact of river morphology change on the economy and agriculture of the Teesta basin community

7.1.1 House reconstruction/ repair cost

Every year the people of the study area needs to repair their house for flood and they reconstruct homestead in another place for river bank erosion. The hardcore poor people are most vulnerable to repair and reconstruct house. The misery of widow women and the women who have no children are speechless. They have no ability to rebuild houses and they live in kind neighbor’s house. Among the respondents 7.1% (N=27) have no house reconstruction/ repair cost because their house had not yet affected and the women who live other people’s house were also counted here. 92.9% (N=354) respondents answered about their house reconstruction/repair cost. Table 7.1 designates that among the house reconstruction costs less than 30000 BDT (Bangladeshi Taka) shows highest percentage (42.2%). Likewise, house reconstruction cost of 31000-60000 BDT and more than 60000 BDT shows 38.9% and 18.6% respectively. Significant differences (p=.004) has been found in terms of house reconstruction/repair costs in the study unions. From the above mentioned house repair/reconstruction cost it has been established that the people of the study area is poor and tries to survive with river morphology change with continuous house repair and reconstruction. The Teesta river basin community fall into vulnerable condition for shelter management and spend money to reconstruct and repair house every year due to river morphology alteration.

Table 7.1 House reconstruction/repair cost (in BDT)

Union	House reconstruction/repair cost							
	Less than 30000		30000-60000		More than 60000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	20	62.5	9	28.1	3	9.3	32	100
Saulmari	28	47.4	22	37.2	9	15.2	59	100
Bidyananda	15	42.8	13	37.1	7	20.0	35	100
Khuniagachh	26	38.8	34	50.7	7	10.4	67	100
Kolkonda	19	32.8	19	32.8	20	34.4	58	100
Sindurna	7	24.1	14	48.7	8	27.5	29	100
Belka	35	47.2	27	36.4	12	16.2	74	100
All	150	42.2	138	38.9	66	18.6	354	100
Chi square	χ^2 value=25.913, df=12, p=.004							

Source: Field survey, 2017

7.1.2. Quantity of loss of standing crops

The study area is severely affected by flood and river bank erosion which obstructs on agricultural products. Crops and vegetables such as Boro, Transplanted Aman , onion, nut, tobacco, and jute are always in threats of floods and bank erosion. The farmers face economic loss for standing crop damage in the pre monsoon, monsoon and post monsoon season for monsoon flood, flash flood and bank failure due to extreme erosion. In 15th may, water level increase causes Boro rice production loss which specifies pre-monsoon flood. In the monsoon the seedlings of Transplanted Aman swept away by rain water or the duration of flood also hampers Transplanted Aman crop production. The recession of flood has a significant influence on Aman yield loss (Hassan *et al*., 2007). Standing crop loss is a frequent incident in the study area. Table 7.2 shows the loss of standing crops (in kg) of the respondents. About 18.1% (N=69) respondent answered that they had not suffered for standing crop loss and 81.9% (N=312) respondents suffered for loss of standing crops. Highest percentage of standing crop loss has been mentioned by 51.3% of respondents and their crop loss is more than 1000 kg. The second highest percentage is 34.0% in 500-1000 kg standing crop loss. The chi square value shows significant (p=.022) differences among the study unions in terms of loss of standing crops.

Table 7.2 Quantity of loss of standing crops (in kg)

Union	Loss of standing crops (in kg)							
	Less than 500		500-1000		More than 1000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	3	11.1	6	22.2	18	66.7	27	100
Saulmari	5	9.3	14	25.9	35	64.8	54	100
Bidyananda	2	6.7	12	40.0	16	53.3	30	100
Khuniagachh	12	20.3	25	42.4	22	37.3	59	100
Kolkonda	7	12.7	26	47.3	22	40.0	55	100
Sindurna	2	8.3	8	33.3	14	58.3	24	100
Belka	15	23.8	15	23.8	33	52.4	63	100
All	46	14.7	106	34.0	160	51.3	312	100
Chi square	χ^2 value=23.776, df=12, p=.022							

Source: Field survey, 2017

7.1.3 Loss of livestock

Livestock keeping in houses are practiced in Teesta basin to survive in hazardous situation. But livestock damage occurs owing to flood and erosion. Sudden erosion occurrence causes the domestic animal to fall into the river womb. Death of livestock takes place for different disease due to standing in flood water inundation. Moreover, livestock swept out in bank full stage of river in the monsoon. Among the respondents 31.5% (N=120) answered about their loss of livestock. About 75.0% respondents lost livestock of less than 30000 BDT, 18.3% and 6.7% respondents lost domestic animal of 30000-60000 BDT and more than 60000 BDT respectively. Table 7.3 represents the statistics of the respondent's loss of livestock in the study area due to river morphology change. The study result shows that in terms of loss of livestock the most affected union is Kolkonda. The likelihood ratio of loss of livestock represents significant (p=.000) differences in the study unions.

Table 7.3 Loss of livestock (in BDT)

Union	Loss of livestock (in BDT)							
	Less than 30000		30000-60000		More than 60000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	11	100	0	0	0	0	11	100
Saulmari	10	100	0	0	0	0	10	100
Bidyananda	3	100	0	0	0	0	3	100
Khuniagachh	21	95.5	0	0	1	4.5	22	100
Kolkonda	11	35.5	14	45.2	6	19.4	31	100
Sindurna	11	73.3	3	20.0	1	6.7	15	100
Belka	23	82.1	5	17.9	0	0	28	100
All	90	75.0	22	18.3	8	6.7	120	100
Likelihood ratio=48.688, df=12, p=.000								

Source: Field survey, 2017

7.1.4 Loss of poultry

Death of livestock and poultry for river morphology change makes the poor people more vulnerable as these productive assets pay them money when they need. The elderly of the Teesta basin informed that the agonies of poultry and livestock during flood has no bounds. Lake of domestic animal and poultry feed makes the situation more critical. Sometimes the house owner gives own food to the poultry and livestock though there is still food crisis in the flooding period. The respondents of study area experience death of poultry and livestock for flood. Extended flood grounds death to livestock (Ahmad *et al*., 2000).

The woman of the study area nourishes poultry for economic reason. But these domestic fowl such as hen, duck, pigeon etc. are also affected by river associated disasters. Most painful situation occurs when livestock, a folk of duck and hen washes away in the flood water. That's why the people suffer for economic loss. In the river morphology change event, poultry suffers for food, habitat and disease. The Table 7.4 displays 48% (N=183) respondents have no loss of poultry but 52% (N=198) have lost poultry with a varied magnitude of economic loss. Among the respondents highest percentage of (64.1%) economic loss has been depicted in less than1000 BDT. Accordingly second highest (27.8%) poultry loss has been identified 1000-2000 (BDT) in the study area. More than 2000 BDT economic loss has been observed 8.1% in poultry sector. The study result shows significant (p=.006) difference exists in the study unions in terms of loss of poultry.

Table 7.4 Loss of poultry (in BDT)

Union	**Loss of poultry (in BDT)**							
	Less than 1000		1000-2000		More than 2000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	9	56.2	5	31.2	2	12.5	16	100
Saulmari	33	76.7	8	18.6	2	4.7	43	100
Bidyananda	21	84.0	3	12.0	1	4.0	25	100
Khuniagachh	29	76.3	8	21.1	1	2.6	38	100
Kolkonda	16	53.3	11	36.7	3	10.0	30	100
Sindurna	6	54.5	2	18.2	3	27.3	11	100
Belka	13	37.1	18	51.4	4	11.4	35	100
All	127	64.1	55	27.8	16	8.1	198	100
Likelihood ratio=27.946, df=12, p=.006,								

Source: Field survey, 2017

7.1.5 Loss of tree/ garden/ bamboo clump

The houses of the study area are occupied with trees and the solvent farmers have garden of wood or fruit trees. Moreover bamboo clump have been found in and around the houses. Among the respondents 78.3% (N=298) have lost tree/ garden/bamboo clump due to river morphology change. About 21.7% (N=83) respondents have not lost tree/garden because they sold tree, garden or bamboo before river morphology change to protect the asset. Table 7.5 portrays the loss of tree/garden/bamboo clump (in BDT) in the study area. Highest percentage of respondents (74.5%) replied regarding loss of tree/garden or bamboo clump with economic loss of less than 30000 BDT. Economic loss of 30000-60000 (BDT) has been replied by 13.8% of respondents. About 11.7% respondents answered regarding loss of tree/ garden/bamboo clump of more than 60000 (BDT). The study result also reveals that among the study unions Khuniagachh shows highest percentage (79.0%) in loss of less than 30000 BDT, Bidyananda represents highest percentage (21.6%) in loss of 30000-60000 BDT and Kolkonda union denotes highest percentage (18.2%) in loss of more than 60000 BDT.

Table 7.5 Loss of Tree/garden/bamboo clump (in BDT)

Union	**Loss of Tree/garden/bamboo clump**							
	Less than 30000		30000-60000		More than 60000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	15	62.5	5	20.8	4	16.7	24	100
Saulmari	36	80.0	7	15.6	2	4.4	45	100
Bidyananda	24	64.9	8	21.6	5	13.5	37	100
Khuniagachh	49	79.0	6	9.7	7	11.3	62	100
Kolkonda	32	72.7	4	9.1	8	18.2	44	100
Sindurna	18	75.0	5	20.8	1	4.2	24	100
Belka	48	77.4	6	9.7	8	12.9	62	100
All	222	74.5	41	13.8	35	11.7	298	100

Source: Field survey, 2017

7.1.6 Correlations among economic losses for river morphology change

Enormous economic losses of the respondents have been observed in livelihood and household sector owing to river morphology change. Table 7.6 designates the correlations matrix of economic losses. Except correlation between house reconstruction /repair cost with loss of poultry, as well as loss of livestock and correlation between loss of livestock with loss of tree/ garden/ bamboo clump the correlations among economic losses for river morphology change shows positive correlation and it is significant at 0.01 level and 0.05 level (two tailed).

Table 7.6 Correlations matrix of economic losses

	Loss of standing crops	**House reconstruction /repair cost**	**Loss of poultry**	**Loss of livestock**	**Loss of tree/ garden/ bamboo clump**
Loss of standing crops	1.0	.374**	.153**	.195*	.351**
House reconstruction /repair cost		1.0	.080	.305	.304**
Loss of poultry			1.0	212*	172**
Loss of livestock				1.0	.159
Loss of tree/garden /bamboo clump					1.0

** Correlation is significant at 0.01 level (2-tailed)

* Correlation is significant at 0.05 level (2-tailed)

7.1.7 Change in respondent's income

The most influential impact of river morphology change is it effects on peoples livelihood and thus the situation causes change in respondent's income. Table 7.7 and Table 7.8 shows the respondents past and present income respectively. Field survey result displays that there exist significant differences on respondent's past income (p=.001) and present income (p=.001) due to river morphology change.

Table 7.7 Respondents past income (in BDT)

Union	**Respondents past income**							
	Less than 5000		5000-10000		More than 10000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	8	23.5	23	67.6	3	8.8	34	100
Saulmari	21	32.8	38	59.4	5	7.8	64	100
Bidyananda	22	53.7	16	39.0	3	7.3	41	100
Khuniagachh	22	30.6	43	59.7	7	9.7	72	100
Kolkonda	8	12.5	43	67.2	13	20.3	64	100
Sindurna	11	36.7	13	43.3	6	20.0	30	100
Belka	17	22.4	47	61.8	12	15.8	76	100
All	109	28.6	223	58.5	49	12.9	381	100
Likelihood ratio= 32.322,df=12, p=.001								

Source: Field survey, 2017

Table 7.8 Respondents present income (in BDT)

Union	**Respondents present income**									
	Nil		Less than 5000		5000-10000		More than 10000		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	5	14.7	21	61.8	6	17.6	2	5.9	34	100
Saulmari	14	21.9	40	62.5	10	15.6	0	0	64	100
Bidyananda	2	4.9	34	82.9	4	9.8	1	2.4	41	100
Khuniagachh	5	6.9	47	65.3	18	25.0	2	2.8	72	100
Kolkonda	3	4.8	30	48.4	27	43.5	4	3.2	64	100
Sindurna	3	10.0	16	53.3	7	23.3	4	13.3	30	100
Belka	9	11.8	53	69.7	13	17.1	1	1.3	76	100
All	41	10.8	241	63.3	85	22.3	14	3.6	381	100
Likelihood ratio=43.583, df=18, p=.001										

Source: Field survey, 2017

The study result unveils that before the recent river morphology change incident 12.9% respondent was in the income group of more than 10000 BDT but at present only 3.6% of respondent represents the mentioned income group. This implies that more than 10000 BDT income group has been decreased due to river morphology change. About 28.6%

respondent's income was less than 5000 BDT but at present the same income group represents 63.3% of respondents. Thus it reveals that low income group has been increased after river morphology change. Moreover, before the recent river morphology change 58.5% respondents belongs to the income group 5000-10000 BDT and after the incident the income group denotes 22.3% of respondents. Therefore, the study result highlights declining trend of respondent's earnings in the income group of 5000-1000 BDT. Likewise, most noticeable incident in respondents income is at present 10.8% respondents is unemployed (income is nil). The respondents lost their only earning source in the ongoing river morphology change (2017 flood) condition. After livelihood damage many of the victim people of Teesta basin forced to engage themselves in ill paid earning sources such as wage labor farm and non-farm activities. Hence, the present study proves that substantial changes have been occurred in respondent's income owing to river morphology change.

7.1.8 Migration for earning /job seeking

The people of the study area migrate for their livelihood. Joblessness due to river morphology change pushes them in cities and towns to search earning sources. The multiple response analysis of migration for occupation represents that 53.1% respondent argued for seasonal migration and 46.9% answered for temporary migration. Seasonal migration shows highest percentage because most of the respondents migrate in the countryside for agricultural labor during the harvesting period. A part from that the respondent also migrates in the town or big cities for earning. The respondents replied that the people of the study area temporarily migrate to earn their living through rickshaw or van pulling in the urban areas.

Table 7.9 Migration for earning/job seeking

Union	**Migration for earning/job seeking**					
	Temporary migration		Seasonal migration		Total	
	f	%	*f*	%	*f*	%
Purba chatnai	25	43.9	32	56.1	57	100
Saulmari	56	47.4	62	52.5	118	100
Bidyananda	37	48.0	40	52.0	77	100
Khuniagachh	68	48.5	72	51.5	140	100
Kolkonda	60	48.3	64	51.6	124	100
Sindurna	22	44.8	27	55.2	49	100
Belka	58	45.0	71	55.0	129	100
All	326	46.9	368	53.1	694	100

Source: Field Survey 2017(Percentages and totals are based on responses)

7.1.9 Change in land holding size

Every year landowners become landless owing to river morphology change. About 68% ultra-poor population is absolute landless and 32% embraces a small amount of farm land which designates the marginalization of the rural people of northern Bangladesh (Elahi and Ara, 2008). The study finds out that the farm holding size has been changed such as before morphological change highest percentage was 80.1% in the land holding size 0.02-0.20 hectare but at present it decreased into 17.8%. Before 0.21-1 hectare and more than 1 hectare of land belonged to 10.5%, 3.1% of respondents but at present the same landholding size belongs to .3% and .3% of respondents respectively (Table 7.10 and 7.11). On the contrary, before the recent changes in river morphology only 6.3% respondents were landless but after morphological change 81.6% respondents are landless which brings enormous sufferings to the people of the study area. Thus, the study result unveils that after the recent morphological change incident most of the respondents become landless. The change in land holding size before and after morphological change shows the decreasing trend of land ownership for river morphology alteration in the study area.

Table 7.10 Land holding size before (in hectare)

Union	**Land holding size before the change**								
	Landless		0.02-0.20 hectare		0.21-1 hectare		More than 1 hectare		Total
	N	%	N	%	N	%	N	%	N
Purba chatnai	3	8.8	28	82.4	2	5.9	1	2.9	34
Saulmari	3	4.7	54	84.4	5	7.8	2	3.1	64
Bidyananda	5	12.2	32	78.0	4	9.8	0	0.0	41
Khuniagachh	4	5.6	61	84.7	4	5.6	3	4.2	72
Kolkonda	5	7.8	49	76.6	9	14.1	1	1.6	64
Sindurna	1	3.3	21	70.0	6	20.0	2	6.6	30
Belka	3	3.9	60	78.9	10	13.2	3	3.9	76
All	24	6.3	305	80.1	40	10.5	12	3.1	381

Source: Field survey, 2017

Table 7.11 Land holding size after (in hectare)

Union	**Land holding size after the change**								
	Landless		0.02-0.20 hectare		0.21-1 hectare		More than 1 hectare		Total
	N	%	N	%	N	%	N	%	N
Purba chatnai	30	88.2	4	11.8	0	0	0	0	34
Saulmari	56	87.5	8	12.5	0	0	0	0	64
Bidyananda	32	78.0	9	22.0	0	0	0	0	41
Khuniagachh	56	77.8	15	20.8	1	1.4	0	0	72
Kolkonda	52	81.2	11	17.2	0	0	1	1.6	64
Sindurna	26	86.7	4	13.3	0	0	0	0	30
Belka	59	77.6	17	22.4	0	0	0	0	76
All	311	81.6	68	17.8	1	.3	1	.3	381

Source: Field survey, 2017

7.1.10 Economic value of lost land

The people of the study area lost their valuable agricultural land as well as homestead land. Land loss causes change in socio-economic condition of each landowner. The questionnaire survey result shows that 6.3% (N=24) respondents didn't lost their land because they already have no land (landless) before river morphology change. Table 7.12 represents the economic value of lost land (in BDT) of the rest of the respondents (N=357). Highest and percentage (47.0%) has been detected in the economic value less than 300000 BDT of the lost land because most of the farmers of the study area were marginal before river morphology change. Among the respondents 29.1% and 23.8% replied that the economic value of lost land were 300000-600000 and more than 600000 (BDT) respectively. The study result indicates significant differences (p=.000) in economic value of lost land in the study area.

Table 7.12 Economic value of lost land (in BDT)

Union	Economic value of lost land							
	Less than 300000		300000-600000		More than 600000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	14	45.1	11	35.4	6	19.3	31	100
Saulmari	35	57.3	12	19.6	14	22.9	61	100
Bidyananda	24	66.6	6	16.7	6	16.7	36	100
Khuniagachh	45	66.1	15	22.0	8	11.7	68	100
Kolkonda	12	20.3	29	49.1	18	30.5	59	100
Sindurna	11	37.9	9	31.0	9	31.0	29	100
Belka	27	36.9	22	30.1	24	32.8	73	100
All	168	47.0	104	29.1	85	23.8	357	100
Chi-square	χ^2 value=41.968, df=12, p=.000							

Source: Field Survey 2017

7.1.11 Correlation among land holding size before, after morphological change and economic value of lost land

The table 7.13 represents the correlation coefficient of land holding size before, after morphological change and economic value of lost land. It is evident from the table that the land holding size before and after morphological change along with the economic value of lost land is positively correlated.

Table 7.13 Correlation coefficient of land holding size before, after morphological change and economic value of lost land

	Land holding size before	Land holding size after	Economic value of lost land
Land holding size before	1	.361**	.700**
Land holding size after		1	.469**
Economic value of lost land			1

**. Correlation is significant at the 0.01 level (2-tailed).

7.1.12 Eroded land accretion and ownership

The degradation and aggradation activities of the Teesta river creates erosion and accretion. The respondents who lost their lands for bank erosion have the hope of accretion of the land once. Among 381 sample size 73 respondents (19.2%) answered that their lost land accreted again. In addition, most of the people (80.8%) of the study area claimed that the eroded land is not accreted. Highest percentage of respondents (31.9%) of Khuniagachh union replied that their eroded land again arose from the river bed due to accretion. The second highest percentage (29.6%) of land accretion has been occurred in Kolkonda union. Likewise, the third highest percentage of land accretion has been determined by 26.8% of respondents in Bidyananda union. The union wise accretion of eroded land has been depicted in (Table 7.14). The table also shows the ANOVA test results; F= 1.50, df= 6, 374 and p= .174, which indicate there is no significant difference between unions and the accretion of eroded land of the respondents *i.e.*, the accretion of eroded land of the respondents among the study unions is almost same.

7.14 Land accretion of the respondents

Union	**Land accretion of the respondents**					
	Yes		No		Total	
	N	%	N	%	N	%
Purba chatnai	9	26.5	25	73.5	34	100
Saulmari	7	11.0	57	89.0	64	100
Bidyananda	11	26.8	30	73.1	41	100
Khuniagachh	23	31.9	49	68.0	72	100
Kolkonda	19	29.6	45	70.3	64	100
Sindurna	0	0	30	100	30	100
Belka	4	5.3	72	94.7	76	100
All	73	19.2	308	80.8	381	100
ANOVA test	F= 1.50, df= 6,374, p=0.177					

Source: Field Survey 2017

7.1.12.1 Amount of accreted land: The Table 7.15 depicts the amount of accretion of eroded land in the study area. In the study area land accretion occurs a very little amount than the land owner’s lost their lands. Land loss is many times higher than the land accretion from river bed (Rahman *et al.*, 2010). Highest percentage (46.6%) of land accretion has been detected in the land amount of 0.02-0.20 hectare. About 35.6% respondents replied regarding 0.21-1 hectare of land accretion. More than 1 hectare land accretion has been answered by 17.8% of respondents. The study result also shows that among the study unions highest percentage (72.7%) of land accretion in 0.02-0.20 hectare has been occurred in Bidyannda union. On the contrary highest percentage (55.6%) of land accretion in 0.21-1 hectare has been identified in Purba chatni union. Likewise, More than 1 hectare land accretion has been depicted highest percentage (26.3%) in Kolkonda union.

Table 7.15 Amount of accreted land (in hectare)

Union	Amount of accreted land							
	0.02-0.20 hectare		0.21- 1hectare		More than 1 hectare		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	3	33.3	5	55.6	1	11.1	9	100
Saulmari	4	57.1	3	42.9	0	0	7	100
Bidyananda	8	72.7	1	9.0	2	18.2	11	100
Khuniagachh	10	43.4	8	34.7	5	21.7	23	100
Kolkonda	7	36.8	7	36.8	5	26.3	19	100
Sindurna	0	0	0	0	0	0	0	100
Belka	2	50	2	50	0	0	4	100
All	34	46.6	26	35.6	13	17.8	73	100

Source: Field survey, 2017

7.1.12.2 Lawful ownership of accreted land

Though new land emerges from river bed but the land owners become sufferer to get back the legal tenure of the accreted land. River bank erosion causes land loss of most of the farmers but very few farmers acquire the reemerged land (Halli, 1991). Among the73 respondents of the accreted land owner, all of them have not got the lawful ownership of the land. From the owner of the accreted land 18 respondents (24.7%) got the legality of the accreted land and 55 respondents (75.3%) have not got the legality of the land. (Table 7.16) shows the frequency and percentage of lawful ownership of accreted land.

Table 7.16 Lawful ownership of accreted land

Union	Lawful ownership of accreted land					
	Yes		No		Total	
	N	%	N	%	N	%
Purba chatnai	2	22.2	7	77.7	9	100
Saulmari	2	28.5	5	71.4	7	100
Bidyananda	2	18.1	9	81.8	11	100
Khuniagachh	6	26.0	17	73.9	23	100
Kolkonda	5	26.3	14	73.7	19	100
Sindurna	0	0	0	0	0	100
Belka	1	25.0	3	75.0	4	100
All	18	24.7	55	75.3	73	100

Source: Field survey, 2017

7.1.12.3 Cause for not getting the lawful ownership of accreted land

Most of the people of the study area do not get back the accreted land due to various socio-economic, political and environmental factors such as selling the land before erosion; ownership conflict, recognition of the accreted land as a *khas* land[30] etc. About 20.0% of respondents speak out the cause for not getting the accreted land is they sold their land before erosion Table (7.17). Again 14.5% respondent answered about the land has not accreted properly. 30.9% respondent opined about ownership conflict. Among the respondents 34.5% argued that the accreted land is now a *khas* land which is the highest observation of cause for not getting the lawful ownership of reemerged land. Hence, the study result identifies that the community of Teesta basin become hopeful for the eroded land accretion but most of the victim land owner do not get back the reemerged land due to government act for khas land. Moreover, ownership conflict and land grabbing is a major issue in the study area to get back the legal ownership of accreted land.

Table 7.17 Cause for not getting the lawful ownership of the accreted land

Union	**Cause for not getting the lawful ownership of the accreted land**									
	The accreted land is now a *khas* land		Sold the land before erosion		Ownership conflict		The land has not accreted properly		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	2	28.6	2	28.6	3	42.8	0	0	7	100
Saulmari	0	0	1	20	2	40	2	40	5	100
Bidyananda	4	44.9	2	22.2	2	22.2	1	11.1	9	100
Khuniagachh	5	29.4	4	23.5	5	29.4	3	17.6	17	100
Kolkonda	6	42.8	2	14.2	4	28.6	2	14.2	14	100
Sindurna	0	0	0	0	0	0	0	0	0	100
Belka	2	66.7	0	0	1	33.3	0	0	3	100
All	19	34.5	11	20.0	17	30.9	8	14.5	55	100

Source: Field survey, 2017

7.1.12.4 Condition of cultivation in the accreted land

Among 381 respondents only 73 respondents (19.2%) have opined about their eroded land accreted again. 18 respondents (24.7%) from these 73 respondents answered that they got the legal ownership of the accreted land. About 61.1% of respondents out of these 18 respondents now cultivate the land (Table 7.18). Among the respondents 38.9% opined about the accreted land is covered with sand so they could not cultivate the land though they achieved the legality of the land. Hence, the condition of cultivation in the accreted land shows the physical barrier regarding farming in the reemerged land. Additionally, the study result regarding eroded land accretion, ownership of the accreted land and cultivation in the land investigates that if once a cultivable land erodes it is quite difficult for the farmers to regain the cultivable land.

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[30] *Khas* land refers to the land which has been reemerged from the river bed after twenty years of erosion. The government of Bangladesh acquires the *khas* land and the people whose land is once declared as khas land cannot claim for the legal ownership of the land.

Table 7.18 Condition of cultivation in the accreted land

Union	**Cultivation in the accreted land**					
	Yes, cultivate the land		The land is covered with sand		Total	
	N	%	N	%	N	%
Purba chatnai	2	100	0	0	2	100
Saulmari	1	50	1	50	2	100
Bidyananda	1	50	1	50	2	100
Khuniagachh	3	50	3	50	6	100
Kolkonda	3	60	2	40	5	100
Sindurna	0	0	0	0	0	100
Belka	1	100	0	0	1	100
All	11	61.1	7	38.9	18	100

Source: Field survey, 2017

7.2 Impact on households and agricultural assets

Homestead displacement is a recurrent issue in the study area due to bank erosion. Moreover, damage of different parts of homestead also occurs for flood. The household assets of the respondents were damaged owing to river morphology change. As the households are dependent on agriculture, the respondents are also affected by agricultural asset damage. Section 7.2 describes the impact of river morphology change on households and agricultural assets.

7.2.1 Frequency of homestead displacement for river bank erosion in life time

The people of the study area think river bank erosion and displacement is their fate. They say cheerfully that “I faced 9 times displacement for river bank erosion”. Among the respondents 2.1% displaced less than 3 times. About 15.2% respondents faced 3-6 times homestead shifting owing to river morphology change. Highest percentage (48.6%) has been noticed in displacement of 7-9 times. About 34.1% respondents answered regarding their displacement of more than 9 times. The likelihood ratio regarding homestead displacement for river bank erosion shows significant differences (p=.015) among the study unions. From the occurrence of homestead displacement of the respondents, the present study establishes that river morphology change is a recurrent event that makes the people of Teesta basin destitute in shelter management. Land loss and homestead displacement marks the people as landless river victims. Table 7.19 designates the percentage of respondent’s displacement for river bank erosion.

Table 7.19 Homestead displacement for river bank erosion

Union	**Homestead displacement for river bank erosion**									
	Less than 3 times		3-6 times		7-9 times		More than 9 times		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	0	0	5	14.7	18	52.9	11	32.4	34	100
Saulmari	0	0	6	9.4	26	40.6	32	50.0	64	100
Bidyananda	0	0	4	9.8	25	61.0	12	29.3	41	100
Khuniagachh	0	0	16	22.2	36	50.0	20	27.8	72	100
Kolkonda	4	6.2	14	21.9	32	50.0	14	21.9	64	100
Sindurna	1	3.3	2	6.7	15	50.0	12	40.0	30	100
Belka	3	3.9	11	14.5	33	43.4	29	38.2	76	100
All	8	2.1	58	15.2	185	48.6	130	34.1	381	100
Likelihood Ratio=33.500, df=18, p=.015										

Source: Field survey, 2017

7.2.2 Frequency of house damaged for flood

Flood inundation causes damage of household in the study area. The respondents argued that every year their house damages for flood and it is the part and parcel of their life. Among the respondents 8.4% answered less than three times house damage for flooding. About 38.6% respondent's reaction regarding frequency of house damaged for flood was 3-6 times. The Table 7.20 shows that 53.0% respondent opined about 7-9 times house damaged for flood and it is the highest percentage of the observations. During FGDs the respondents described their sufferings on flooding condition. They replied that the prolonged flood brings enormous miseries in their everyday life and it is the foremost cause of homestead damage. After the recession of flood, the people of Teesta basin work hard to repair the damaged house. The study also shows the significance of chi square value (p=.000) regarding frequency of house damaged for flood in the study unions. Therefore, the study result postulates that the people of the study area have to face varied magnitude of household damage due to floods in Teesta basin.

Table 7.20 Frequency of house damaged for flood

Union	**House damage for flood**							
	Less than 3 times		3-6 times		7-9 times		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	6	17.6	18	52.9	10	29.4	34	100
Saulmari	3	4.7	20	31.2	41	64.0	64	100
Bidyananda	0	0	14	34.1	27	65.9	41	100
Khuniagachh	0	12.5	28	38.9	35	48.6	72	100
Kolkonda	5	7.8	29	45.3	30	46.9	64	100
Sindurna	3	10.0	17	56.7	10	33.3	30	100
Belka	6	7.9	36	47.4	34	44.7	76	100
All	32	8.4	147	38.6	202	53.0	381	100
Chi square	χ^2 value 55.181, df=12, p=.000							

Source: Field survey, 2017

7.2.3 Household goods damage

Household goods such as kitchen kits, furniture, materials of daily use are damaged on the incident of river morphology change. The respondents answered that "sometimes we have no utensils in house to cook food and take meals because all the materials washes away into the river. Moreover, homestead gardens and livestock shelters are also affected on river induced disasters. Table 7.21 illustrates 30.1% respondents replied that the cost of household materials damage in less than 10000BDT. Likewise, about 32.8% of respondents answered 10000-20000 BDT loss in household commodity damage. Highest percentage (37.0%) regarding household goods damage has been observed in more than 20000 BDT. Therefore, the study result indicates that river morphology change causes enormous economic loss in household goods.

Table 7.21 Cost of household asset damage (in BDT)

Union	**Cost of household asset damage**							
	Less than 10000		10000-20000		More than 20000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	9	26.4	15	44.1	10	29.4	34	100
Saulmari	30	46.8	14	21.8	20	31.2	64	100
Bidyananda	12	29.2	17	41.4	12	29.2	41	100
Khuniagachh	18	25.0	29	40.2	25	34.7	72	100
Kolkonda	20	31.2	17	26.5	27	42.1	64	100
Sindurna	10	33.3	9	30.0	11	36.6	30	100
Belka	16	21.0	24	31.5	36	47.3	76	100
All	115	30.1	125	32.8	141	37.0	381	100

Source: Field survey, 2017

7.2.4 Cost of agricultural commodity damage

The agro-based community of Teesta basin suffers for fertilizer, insecticide and seed damage in the river morphology change event. Agricultural goods wash away and rotten seeds are found in the flooding condition. Due to sudden erosion attack, seed, insecticide and fertilizer fall into the river womb which amplifies the farmers grieves. Among 381 respondents 212 (55.6%) didn't claimed about agricultural goods damage. About 44.4% (169 respondents) answered that they suffered for agricultural commodity damage. Table 7.22 displays that about 29.6% respondents lost their agricultural goods of less than 5000 BDT. Simultaneously, 26.0% respondents replied about more than 10000 BDT economic losses for agricultural goods damage. Highest percentage (44.4%) has been recognized in 5000-10000 BDT loss in agricultural commodity destruction. Hence, the study result indicates that river morphology change causes economic losses in agricultural goods. Moreover, the loss hampers the farmer's agricultural production.

Table 7.22 Cost of agricultural commodity damage (in BDT)

Union	Cost of agricultural commodity damage							
	Less than 5000		5000-10000		More than 10000		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	2	20.0	5	50.0	3	30.0	10	100
Saulmari	5	22.7	10	45.5	7	31.8	22	100
Bidyananda	8	28.6	11	39.3	9	32.1	28	100
Khuniagachh	13	31.7	16	39.0	12	29.6	41	100
Kolkonda	10	27.0	19	51.4	8	21.6	37	100
Sindurna	3	37.5	5	62.5	0	0	8	100
Belka	9	39.1	9	39.1	5	21.7	23	100
All	50	29.6	75	44.4	44	26.0	169	100

Source: Field survey, 2017

7.3 Impact on food, health and education

River morphology change impacts on the basic needs of the community of Teesta basin. The community is highly vulnerable to food and nutrition because most of the days they consume food, less than their real need to minimize the impacts of river morphology change. The people of the study area are also susceptible to health hazards due to river morphology change. They are chocked with different diseases such as diarrhea, cough, skin disease, low blood pressure, asthma, allergy, skin rashes etc. around the year which is the after effect of river induced disasters. The respondents argued for diversified illness in different situations of flood inundation, and river bank erosion. Moreover, the condition of education is at risk for the riverine disaster.

7.3.1 Condition of daily food consumption

Table 7.23 signifies (p=.000) the condition of daily food consumption of the respondents of Teesta basin due to river morphology alteration. About 8.9% respondents answered that they eat food three times daily. The study finds out that only the solvent people of the study area takes meal three times daily.

Table 7.23 Condition of daily food consumption

Union	Condition of daily food consumption							
	One time food consumption		Two times food consumption		Three times food consumption		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	9	26.5	23	67.6	2	5.9	34	100
Saulmari	18	28.1	44	68.8	2	3.1	64	100
Bidyananda	9	22.0	28	68.2	4	9.8	41	100
Khuniagachh	3	4.2	64	88.9	5	6.9	72	100
Kolkonda	1	1.6	56	87.5	7	10.9	64	100
Sindurna	3	10.0	21	70.0	6	20.0	30	100
Belka	2	2.6	66	86.8	8	10.5	76	100
All	45	11.8	302	79.3	34	8.9	381	100
Likelihood ratio=51.540, df=12, p=.000								

Source: Field Survey 2017

Thus, the study result reveals that maximum people of the study area do not avail the cost of three times food purchase. During FGDs the people were asked about the cause behind taking food one time and two times daily. The respondents replied that due to recurrent river morphology change their economic condition has been affected significantly. Therefore, they try to cope with the adverse condition through skipping meal. The hardcore poor people replied about eating food one time daily (11.8%) and they try to take relatively cheap items. Most of the people (79.3%) of the study area take food two times daily. It has been noticed during field survey that the people who consumes food daily two times, take their first meal at 10-12 am and take the second meal in the afternoon or evening for survival.

7.3.2 Condition of education of children

River morphology change hampers the condition of education of children. Most of the children take primary education but they cannot afford to continue secondary education due to the effect of river induced disaster. The parents engage the school going children in income generation rather than sending them in school. Moreover, infrastructures of school and collage collapse in the river gorge. Sometimes educational activities have been initiated in temporary shed and under the open sky. The respondents also accused that inaccessible zigzag channel also causes transportation problem for school going children. Moreover, remoteness of char areas also obstructs the education of children. Table 7.24 indicates the condition of education of children of the study area. The study result shows that at present 22.8% children goes to primary school and only 5% children goes to secondary school. About 72.1% children stopped school going. The study finds out that in maximum cases the parents stopped sending the children in secondary school because they thinks that primary education is enough to engage the children in earning sources to cope with river morphology change.

Table 7.24 Condition of education of children

Union	Condition of education of children							
	Goes to primary school		Goes to secondary school		Stopped going to secondary school		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	11	32.4	2	5.8	21	61.8	34	100
Saulmari	15	23.4	0	0	49	76.6	64	100
Bidyananda	8	19.5	3	7.3	30	73.1	41	100
Khuniagachh	14	19.4	2	2.8	56	77.8	72	100
Kolkonda	13	20.3	1	1.6	50	78.1	64	100
Sindurna	8	26.7	4	13.3	18	60.0	30	100
Belka	18	23.6	7	9.2	51	67.1	76	100
All	87	22.8	19	5.0	275	72.2	381	100

Source: Field Survey 2017

7.3.3 Health problem for flood

Various diseases spread around the affected area during and after the recession of flood water. The community of Teesta basin accused that flood causes different water borne disease such as diarrhea, cholera, skin infection, respiratory disease. Moreover, flood also impacts on domestic animal health and causes death of poultry and livestock. Likewise, snake bite is a common issue in a flooded environment. The multiple response analysis of flood induced health problem identifies that 5.7% respondents replied about snake bite, 24.2% replied for respiratory disease and 31.7% respondents answered for skin disease. Respiratory disease during flood includes pneumonia, lung infection, asthma, cough etc. Moreover, skin disease occurs mostly in the hands and legs due to working in flood water. Highest percentage (38.5%) has been depicted in diarrheal disease in the study area for flood (Table 7.25).

Table 7.25 Health problem for flood

Union	**Health problem for flood**									
	Diarrhea		Respiratory disease		Skin disease		Snake bite		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	20	37.0	11	20.4	17	31.5	6	11.1	54	100
Saulmari	54	32.7	43	26.1	61	37.0	7	42.2	165	100
Bidyananda	32	37.2	17	19.8	34	39.5	3	3.5	86	100
Khuniagachh	71	37.6	51	27.0	49	25.9	18	9.5	189	100
Kolkonda	64	43.5	32	21.8	45	30.6	6	4.1	147	100
Sindurna	30	40.0	16	21.3	27	3.0	2	2.7	75	100
Belka	76	40.9	48	25.8	53	28.5	9	4.8	186	100
All	347	38.5	218	24.2	286	31.7	51	5.7	902	100

Source: Field survey, 2017 (Percentages are based on responses)

7.3.4 Sanitation problem during flood

The duration and intensity of flood increases sanitation problem. Flood inundation makes toilet waste float on water. Besides, the respondents replied that during flood sand deposition occurs in the floodplain and the toilets are occupied by sand. Therefore, the community of the study area has to face problems for toilet. Table 7.26 represents the frequency and percentage of sanitation problem during flood. About 39.6% respondents replied regarding toilet goes under water. The multiple response analysis also illustrates 38.3% and 22.0% regarding toilet waste floats on water and toilet is covered by sand respectively.

Table 7.26 Respondents sanitation problem during flood

Union	Respondents sanitation problem during flood							
	Toilet goes under water		Toilet is covered by sand		Toilet waste floats on water		Total	
	f	%	*f*	%	*f*	%	N	%
Purba chatnai	26	33.3	27	34.6	25	32.1	78	100
Saulmari	61	42.1	43	29.7	41	28.3	145	100
Bidyananda	41	34.2	39	32.5	40	33.3	120	100
Khuniagachh	70	38.5	44	24.2	68	37.4	182	100
Kolkonda	63	43.4	18	12.4	64	44.1	145	100
Sindurna	30	46.9	4	6.2	30	46.9	64	100
Belka	65	39.6	23	14.0	76	46.3	164	100
All	356	39.6	198	22.0	344	38.3	898	100

Source: Field survey, 2017(Percentages are based on responses)

7.3.5 Unhygienic situation for flood water

Prolonged flood inundation creates unhygienic condition such as floor damage, cooking problem, increase of insects, spread odor etc. in the study area. Multiple response analysis of unhygienic situation for flood water in the study area has been presented in Table 7.27. The respondents blamed that during flood toilet waste and household waste floats on water and it creates unpleasant environment through bad smell. Likewise, different insects such as fly, mosquito etc. increases. Similarly, frog, snake, earthworm prevails upon house. The respondents told that they become afraid for snake and insect bite. Among the respondents 29.9% agreed with insect, earth worm, frog and snake inhibits in house. During flood the female of the study area face problem for lack of dry place for cooking. About 39.0% respondents replied regarding floor damage and cooking problem which shows highest percentage. The second highest percentage (31.1%) has been detected in spreading odor for waste contamination in flood water.

Table 7.27 Unhygienic situation for flood water

Union	Unhygienic situation for flood water							
	Spread odor		Floor damage and cooking problem		Insect, earth worm, frog and snake inhibits in house		Total	
	f	%	*f*	%	*f*	%	N	%
Purba chatnai	27	31.8	27	31.8	31	36.4	85	100
Saulmari	38	30.4	60	48.0	27	21.6	125	100
Bidyananda	35	31.5	40	36.0	36	32.4	111	100
Khuniagachh	55	29.7	70	37.8	60	32.4	185	100
Kolkonda	54	35.5	57	37.5	41	26.9	152	100
Sindurna	25	32.0	30	38.4	23	29.4	78	100
Belka	50	28.2	72	40.6	55	31.0	177	100
All	284	31.1	356	39.0	273	29.9	913	100

Source: Field survey (Percentages are based on responses)

7.3.6 Effects of erosion on human health

Flood directly effects on human health and causes disease but erosion indirectly effects on health. During erosion the affected people are busy to salvage their housing structures and necessary materials. They have no account of their meal. Moreover, livelihood destruction limits food purchasing capacity. Therefore, maximum people become starved during erosion which causes weakness for insufficient food consumption, malnutrition and low blood pressure. Table 7.28 provides the multiple response analysis of effect of erosion on human health in the study area. Highest percentage has been designated in weakness for insufficient food consumption (36.7%). Among the respondents 36.2% and 26.9% mentioned about malnutrition and low blood pressure respectively.

Table 7.28 Effects of erosion on human health

Union	**Effects of erosion on human health**							
	Weakness		Malnutrition		Low blood pressure		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	26	38.2	25	36.7	17	25	68	100
Saulmari	62	36.9	61	36.3	45	26.7	168	100
Bidyananda	41	37.2	41	37.2	28	25.5	110	100
Khuniagachh	69	35.9	69	35.9	54	28.1	192	100
Kolkonda	60	36.8	59	36.1	44	26.9	163	100
Sindurna	25	35.7	23	32.8	22	31.4	70	100
Belka	64	37.2	64	37.2	44	25.6	172	100
All	347	36.7	342	36.2	254	26.9	943	100

Source: Field survey, 2017(Percentages are based on responses)

7.4 River morphology change impacts on environment

7.4.1 Impact of flood on environment

River morphology change controls human environment but it also impacts on the natural environment. Though flood, river bank erosion, sedimentation, river channel shifting hampers anthropogenic and natural environment, all these river induced hazards have positive sides also. The present study tries to investigate the positive and negative impacts of river morphology change in the study area. Table 7.29 identifies the positive impact of flood on environment. About 47.0% respondents replied that the fertility of land increases owing to flood occurrences. According to 30.0% respondents, flood nourishes plant and animals. During flood branch of trees floats in the river current and gathers in the bank. Therefore, the people of the study area collect fuel wood after flood. Among the respondents 23.0% opined about fuel wood gather in the bank due to flood incidence. Hence, the study result indicates that according to most of the respondents the fertility of agricultural land increases for flood. During FGDs the farmers replied that though flood causes agricultural production loss, it intensifies crop production through siltation process in the land after flood. Besides, different plant species of environment get nutrients from the fertile soil.

Table 7.29 Positive impact of flood on environment

Union	**Positive impact of flood on environment**							
	Fertile agricultural land		Nourishes plant and animals		Fuel wood gather in the bank		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	24	47.0	15	29.5	12	23.5	51	100
Saulmari	35	51.5	19	27.9	14	20.6	68	100
Bidyananda	37	50.0	20	27.0	17	23.0	74	100
Khuniagachh	63	44.4	45	31.7	34	23.9	142	100
Kolkonda	59	46.8	37	29.4	30	23.8	126	100
Sindurna	23	47.9	15	31.3	10	20.8	48	100
Belka	62	45.6	43	31.6	31	22.8	136	100
All	303	47.0	194	30.0	148	23.0	645	100

Source: Field survey, 2017(Percentages are based on responses)

The negative impacts of flood are also demarcated in Table 7.30. The most devastating effect of flood according to the respondents is it erodes river bank extremely (33.1%). Among the respondents 25.6% answered about flood destroys agricultural production. Inundation in agricultural land causes production loss. The respondents answered that long duration flood destroys agricultural production. In addition, sand and debris deposition also hampers crop production. Flood brings debris in agricultural land and cultivation disrupts (Prokop and Sarker, 2012). About 25.3% respondents claimed that inundation occurs due to flood and it causes homestead submerged and it impedes everyday life. During field survey the birds, animals and trees has been noticed devastated in flood water. Destruction of bio-diversity has been justified by 15.9% of respondents of the study area. Therefore, the study scrutinizes the negative impacts of flood which controls the environment of Teesta basin.

Table 7.30 Negative impact of flood on environment

Union	**Negative impact of flood on environment**									
	Inundation		Erodes river bank		Agricultural production loss		Destroys biodiversity		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	20	24.7	34	42.0	13	16.0	14	17.3	81	100
Saulmari	42	26.5	64	40.5	29	18.4	23	14.6	158	100
Bidyananda	29	24.4	41	34.5	31	26.0	18	15.1	119	100
Khuniagachh	62	25.4	72	29.5	70	28.7	40	16.4	244	100
Kolkonda	60	26.7	64	28.4	64	28.4	37	16.5	225	100
Sindurna	26	25.2	30	29.1	27	26.2	20	19.4	103	100
Belka	52	23.6	76	34.5	61	27.7	31	14.0	220	100
All	291	25.3	381	33.1	295	25.6	183	15.9	1150	100

Source: Field survey, 2017(Percentages are based on responses)

7.4.2 Impact of erosion on environment

The people of the study area were asked about the positive impacts of river bank erosion. But they were extremely disagreed about the positive impacts of erosion (96.9%). Only 3.1% respondents replied about the positive impacts of river bank erosion is, it supplies source material for char formation. Table 7.31 represents the negative impact of erosion on environment. The multiple response analysis regarding negative impact of erosion on environment denotes 28.2% and 34.2% of respondents answered about damage of vegetation and wide river valley accordingly. During field survey, damage of vegetation in the river womb has been noticed in the study area. The natural vegetation as well as the orchards and bamboo grooves go into the river gorge owing to bank erosion. Loss of land property is the main issue of the study area and 37.6% respondents opined about land loss for river bank erosion.

Table 7.31 Negative impact of erosion on environment

Union	**Negative impact of erosion on environment**							
	Damage of vegetation		Loss of land property		Wide river valley		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	19	22.9	34	40.9	30	36.1	83	100
Saulmari	38	23.8	64	40.0	58	36.2	160	100
Bidyananda	25	25.0	41	41.0	34	34.0	100	100
Khuniagachh	61	30.5	71	35.5	68	34.0	200	100
Kolkonda	55	30.4	64	35.4	62	34.2	181	100
Sindurna	28	32.5	30	34.9	28	32.6	86	100
Belka	59	29.8	74	37.4	65	32.8	198	100
All	285	28.2	378	37.6	345	34.2	1008	100

Source: Field survey, 2017 (Percentages are based on responses)

7.4.3 Impact of sedimentation on environment

Sediment accumulation in river bed and bank has been observed by the respondents of the study area. The respondents distinguished the positive and negative impacts of sedimentation on environment. Table 7.32 represents the positive impact of sedimentation on environment. The farmers of the study area replied that though sand deposition causes agricultural production loss, silt accumulation is the blessings for soil productivity and if flood water brings silt, it causes high yield in crop production. Among the replies highest percentage (34.3%) has been noticed in silt increases soil fertility. Likewise, sediment creates opportunity of dwelling places for the river victims. If the land owners do not get back his property, after land accretion, he can easily reside in the *khas* land. Therefore, 25.4% respondent argued that sedimentation increases dwelling place. Moreover, as a braided river, Teesta produces *char* through sedimentation process. Stable-unstable, small-big, old-new etc. different types of *char*s are found in the Teesta basin. The community of the study area use the *char* lands for various purposes such as cattle grazing, paddy drying etc. In addition, they also collect animal fodder from the *char* lands. About 17.4% and 22.9% respondents replied about the positive impact of sedimentation is it forms char and good for cattle grazing respectively.

Table 7.32 Positive impact of sedimentation on environment

Union	**Positive impact of sedimentation on environment**									
	Char formation		Increases dwelling place		Silt increases soil fertility		Good for cattle grazing		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	9	12.7	14	19.7	34	47.9	14	19.7	71	100
Saulmari	30	17.3	40	23.1	62	35.8	41	23.7	173	100
Bidyananda	26	20.5	34	26.8	41	32.3	26	20.5	127	100
Khuniagachh	41	17.4	61	25.8	71	30.1	63	26.7	236	100
Kolkonda	45	25.3	47	26.4	64	36.0	22	12.4	178	100
Sindurna	24	27.3	20	22.7	30	34.1	14	15.9	88	100
Belka	17	7.4	64	27.8	76	33.0	73	31.7	230	100
All	192	17.4	280	25.4	378	34.3	253	22.9	1103	100

Source: Field survey, 2017 (Percentages are based on responses)

As mentioned earlier, sedimentation has many positive sides but it also impacts negatively on environment. Highest percentage of negative impact of sedimentation on environment has been depicted 30.8% in sand decreases soil fertility which governs the agricultural sector. Another high responsive negative impact of sedimentation is increase in elevation of river bed. The Teesta brings a lot of sediments in each flood due to its alluvial characteristics and downstream locations. Therefore, about 29.4% respondents replied that elevated river bed causes flood. The third highest (28.2%) negative impact of sedimentation on environment has been found sedimentation creates navigation problem owing to sediment accretion in river bed and creation of multithreaded river channel. Sedimentation indirectly increases erosion has been replied by 11.6% of respondents. The people of the study area argued that when sedimentation occurs in one portion of the river, it indicates that the river is eroding in another side for balance and it’s a game of nature. Table 7.32 shows the multiple response analysis of negative impact of sedimentation on environment

Table 7.33 Negative impact of sedimentation on environment

Union	**Negative impact of sedimentation on environment**									
	Elevated river bed causes flood		Indirectly increases erosion		Sand decreases soil fertility		Navigation problem		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	31	28.7	14	13.0	33	30.5	30	27.8	108	100
Saulmari	64	31.1	23	11.2	64	31.1	55	26.6	206	100
Bidyananda	35	26.5	24	18.2	41	31.1	32	24.2	132	100
Khuniagachh	70	29.2	28	11.6	72	30.0	70	29.2	240	100
Kolkonda	64	30.6	21	10.0	64	30.6	60	28.7	209	100
Sindurna	25	27.8	12	13.3	26	28.9	27	30.0	90	100
Belka	68	29.6	19	8.7	74	32.1	69	30.0	230	100
All	357	29.4	141	11.6	374	30.8	343	28.2	1215	100

Source: Field survey, 2017 (Percentages are based on responses)

7.4.4 Impact of channel shifting on environment

Channel shifting of Teesta river produces various morphological features in the study area. The present study gives insight into the impact of channel shifting on environment. Table 7.34 indicates 100% presence of braided stream channel morphological feature patterns such as zigzag channel pattern (26.3%), active river channel (26.3%), abandoned channel and back swamp (26.3%) in the study unions. One study union (Belka) has not been observed oxbow lake. Therefore oxbow lake represents 21.0% of replies from the respondents. Thus, the study finds out that channel shifting impact on environment produces variety of landforms in the study area. The landforms produced by the channel shifting mechanism of Teesta river increases the beauty of nature and becomes source of different economic activities of the riparian community.

Table 7.34 Impact of channel shifting on environment

Union	Impact of channel shifting on environment									
	Zigzag channel		Active channel		Abandoned channel and back swamp		Oxbow lake		Total	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	25.0	34	25.0	34	25.0	34	25.0	136	100
Saulmari	64	25.0	64	25.0	64	25.0	64	25.0	256	100
Bidyananda	41	25.0	41	25.0	41	25.0	41	25.0	164	100
Khuniagachh	72	25.0	72	25.0	72	25.0	72	25.0	288	100
Kolkonda	64	25.0	64	25.0	64	25.0	64	25.0	256	100
Sindurna	30	25.0	30	25.0	30	25.0	30	25.0	120	100
Belka	76	25.0	76	25.0	76	25.0	0	0	228	100
All	381	26.3	381	26.3	381	26.3	305	21.0	1448	100

Source: Field survey, 2017 (Percentages are based on responses)

7.5 Case study on river morphology change impact

The case studies conducted in the research, states the countless miseries of the respondents. The case studies of river morphology change impacts are as follows:

Case study 1

Balijan was born in Mid channel bar of Teesta. She is 45 years old. She is a housemaid and lives in Kolkonda union. Her husband went to Dhaka (the capital city of Bangladesh) for livelihood. They have .25 hectare of land and the land is now in the river gorge. Her total family member is 5. She is very poor and most of the time her family members become starved. Balijan lives in the *khas* land and have one room in her house for shelter. She witnessed 10 times erosion of Teesta from her childhood. Seven times her homestead has gone in the Teesta river womb. Her child died in turbulent water flow during flood in Teesta. She has been ruined through poultry, livestock, and household goods damage for river morphology change. She witnessed .40 hectare of land collapsed in the river within one week in his union. About 475 household has been damaged in her village within 26 days. She told with grief that if any house collapses for fire, there must be the debris of the house and one can rebuild house in the burnt land again but river morphology change causes total destruction of people’s life.

Case study 2

58 years old Nasir Mollah lives in Bidyananda union of Kurigram district. He had 1.21 hectare of land. He lost his .40 hectare of land in 2016 and the rest .81 hectare of land in 2017 for morphological change occurred in Teesta river. He was a farmer and agricultural land loss bought enormous sufferings to his life. He told every year flood attacks in his union but the big flood causes much damage to property. He witnessed 12 times erosion in his life. He had 50 bamboo clumps, already 36 bamboo clump has lost in the river. He has a betel nut garden in .20 hectare of land. But the garden is now in the bank of the river. Today it will collapse in the river womb. His house is also in the threat of bank erosion. Now he doesn’t know how he will manage his livelihood and where will take shelter. About 50-60 houses in his village has already broken down in the river in the ongoing river morphology change. He described .28 hectare of land has been destroyed within one week in his village in August 2017 flood. Nasir Mollah expressed his experiences regarding river morphology change. He lost his house seven times in the river gorge. He told that I went to pray in the mosque and after 20 minutes when came back to home, there is no existence of my house. It already collapsed in the Teesta. It is a mad river. It roars during flood and bank erosion. We don’t get time to cut down ripen paddy and it destroys in the river. Our life and fate totally depends upon the Teesta river.

Chapter Eight
Adaptation Strategies of the respondents

The people of the study area try to cope with the changing river morphology. Morphological change in the Teesta basin made the community to perform different indigenous practices to adapt with the changing environment. They use various techniques during flood, erosion and sedimentation including early crop cutting, house platform raising, boiling water, keep the livestock in high land, stop cooking and eat dry food, stay in relatives house etc.

8.1 Indigenous precaution technique before morphological change

The people of the study area have to face recurrent river morphology change. Therefore, they gained various indigenous knowledge and techniques for adaptation, before, during and after river morphology change.

8.1.1 Type of indigenous precaution techniques adopted by the respondents

The community of Teesta basin tries to save life as well as property through indigenous precaution techniques to cope with river morphology change. Anticipation of flood and river bank erosion, data dissemination, abandoning the homestead land is the

Table 8.1 Indigenous precautionary techniques

Union	**Indigenous precautionary techniques**											
	Anticipation of erosion		Disseminate the massage of erosion		Abandoning the homestead land		Tree plantation around house		Protect shelter with bamboo stack		**Total**	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	24.6	32	23.2	33	23.9	29	21.0	10	7.2	138	100
Saulmari	64	25.5	61	24.3	62	24.7	56	22.3	8	3.2	251	100
Bidyananda	41	23.3	41	23.3	41	23.3	40	22.7	13	7.4	176	100
Khuniagachh	72	23.8	72	23.8	72	23.8	71	23.4	16	5.2	303	100
Kolkonda	64	24.0	64	24.0	64	24.0	62	23.3	12	4.5	266	100
Sindurna	30	25.0	28	23.3	28	23.3	26	21.7	8	6.7	120	100
Belka	76	25.4	71	23.7	72	24.0	69	23.1	11	3.6	299	100
All	381	24.5	369	23.7	372	23.9	353	22.7	78	5.0	1553	100

Source: Field survey, 2017 (N.B. Percentages are based on responses)

8.1.2 Precaution technique for homestead management

Homestead management becomes part and parcel of the community of the study area due to flood occurrences in every monsoon. Therefore, indigenous precaution technique for homestead management has been given special attention by the community of Teesta basin. Table 8.2 represents the precaution technique for homestead management owing to flood. The study result represents highest percentage on house platform raising (43.2%) in the study area. It also designates making house with corrugated iron sheet (34.8%) is an important precaution technique for homestead management. The study investigates that people make house with corrugated iron sheet to protect homestead building materials from damage by flood water and salvaging capacity of the material. About 21.9% respondents make house in relatively high land. In the study area ridges are used as high lands to make house. The respondents expressed their opinion that making house in relatively high land is a very old precaution technique to protect homestead from flood in the study area.

Table 8.2 Precaution technique for homestead management

Union	**Homestead management for flood**							
	House platform raising		Making house with corrugated iron sheet		Making house in relatively high land		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	43.6	26	33.3	18	23.1	78	100
Saulmari	62	48.4	40	31.3	26	20.3	128	100
Bidyananda	41	39.0	35	33.3	29	27.6	105	100
Khuniagachh	72	41.4	60	34.5	42	24.1	174	100
Kolkonda	64	43.5	49	33.3	34	23.1	147	100
Sindurna	29	43.3	23	34.3	15	22.4	67	100
Belka	71	43.3	68	41.5	25	15.2	164	100
All	373	43.2	301	34.8	189	21.9	863	100

Source: Field survey, 2017(N.B. Percentages are based on responses)

8.1.3 Precaution practice for loss reduction of poultry

The people of the study area keep poultry in house for adaptation. They take precautionary techniques to save poultry for loss reduction owing to river morphology change. When flood and river bank erosion occur, the community of the study area tries to keep the poultry in high lands and relatively safe place. They use earthen mounds, embankments and roads to protect the poultry from flood water. Table 8.3 shows 49.5% respondents keep the poultry in high and relatively safe land. Sometimes the people keep the poultry in neighbors and relative’s house which is not affected by flood and river bank erosion. This kind of precaution technique helps the people to keep away their poultry from economic loss due to river morphology change. About 41.3% respondents sell poultry before river morphology change to recover financial damage. The people who do not get any safe place for poultry keeping and may not able to sell the poultry, eat the domestic fowl to recover the monetary cost. Among the respondents 9.2% consume the poultry as a technique of loss reduction.

Table 8.3 Precaution practice for loss reduction of poultry

Union	**Loss reduction initiative for poultry**							
	Keep in high and safe land		Sell the poultry		Eat the poultry		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	48.6	30	42.9	6	8.6	70	100
Saulmari	64	46.4	50	36.2	24	17.4	138	100
Bidyananda	40	56.3	31	43.7	0	0	71	100
Khuniagachh	71	48.3	62	42.2	14	9.5	147	100
Kolkonda	64	47.8	59	44.0	11	8.2	134	100
Sindurna	30	52.6	23	40.4	4	7.0	57	100
Belka	76	51.4	61	41.2	11	7.4	148	100
All	379	49.5	316	41.3	70	9.2	765	100

Source: Field survey, 2017(N.B. Percentages are based on responses)

8.1.4 Precaution practice for crop and seed

Sudden river morphology change is responsible for huge damage to harvest mature paddy from field. Therefore, Early crop harvesting is adopted by the people of the study area as precaution technique due to river morphology change. Table 8.4 indicates the responses regarding precaution practice for crop harvest of the respondents. Around 74.2% respondents follow early crop harvesting technique as a precautionary practice for food grains regarding river morphology change incidence. About 25.8% respondents sell the crop before harvest to minimize economic loss. The respondents argued that after hearing the forecast of flood they either sell the crop in field before harvest or engage in early crop cutting. But the situation becomes worst when flash flood occurs. In the flash flood event the farmers ruins and they have no option to save their crops.

Table 8.4 Precaution practice for crop harvest

Union	**Precaution practice for crop harvest**					
	Early crop cutting		Sell the crop in field without harvest		Total	
	N	%	N	%	N	%
Purba chatnai	23	67.4	11	32.4	34	100
Saulmari	45	70.3	19	29.7	64	100
Bidyananda	33	80.5	8	19.5	41	100
Khuniagachh	58	80.6	14	19.4	72	100
Kolkonda	56	87.5	8	12.5	64	100
Sindurna	20	66.7	10	33.3	30	100
Belka	48	63.2	28	36.8	76	100
All	283	74.2	98	25.8	381	100

Source: Field Survey 2017

Due to river morphology change, every year huge amount of agricultural production do not come into the light of economic values. Harvested crop washes away, crops become rotten, ripen crops goes into the river womb for river morphology change. Sometimes, the farmers keep huge amount of harvested paddy in the yard shaded with polythene. Precaution practice for harvested crop and seed includes store the crop in crop storage, mud pot, *machan*[31] and under polythene shed. Table 8.5 describes the precaution practice for crop and seed storage regarding river morphology change in the study area. Approximately 8.6% respondent replied keep crop and seed in crop storage, 3.9 % answered store seed and crop in mud pot, and 19.6% answered store crops under polythene shed. Most of the respondents opined (67.7%) about store crop and seed in *machan* which is regarded as a best precaution technique to save crops and seeds.

Table 8.5 Respondents precaution practice for crop and seed storage

Union	**precaution practice for crop and seed storage**									
	Keep in crop storage		stock in machan		store in mud pot		store under polythene shed		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	3	8.8	22	64.7	1	2.9	8	23.5	34	100
Saulmari	4	6.3	47	73.4	3	4.7	10	15.6	64	100
Bidyananda	7	17.1	27	65.9	2	4.8	5	12.2	41	100
Khuniagachh	6	8.3	48	66.7	4	5.6	14	19.4	72	100
Kolkonda	5	7.8	45	70.3	3	4.7	11	17.2	64	100
Sindurna	1	3.0	22	73.3	1	3.3	6	20.0	30	100
Belka	7	9.2	47	61.8	4	5.3	18	23.7	76	100
All	33	8.6	258	67.7	15	3.9	75	19.6	381	100

Source: Field survey, 2017

8.1.5 Precaution technique for protection of lives

In flooding period rescue of life is very difficult, especially in the *char* lands. People try to protect lives with a small boat in the ferocious Teesta river. In severe flooding condition, the households become drowned and people ascend into the top of roof and thus save life. When the community of Teesta river basin pretends that catastrophic river bank erosion is coming then, they send women/children in relative's house and take accommodation in neighbor's house. Likewise, the respondents also explained that they try to stay in safe and higher place such as earthen mound, *machan*, top of corrugated iron sheet, road and embankment. Moreover, during erosion, the community keeps distance from river to save life. Table 8.6 displays respondent's precaution technique for protection of lives. Highest implemented precautionary technique has been identified in the study is to stay in safe and higher place and keep distance from river (83.7%). Response about keep women/ children and other family members in relative's/neighbor's house has been demarcated by 8.9% of respondents. Other precautionary techniques adopted by the respondents are taking family members in boat which represents 7.3%. of responses.

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[31] *Machan* is a traditional bamboo made platform used in rural Bangladesh to protect lives and household goods from flood water. The height of *machan* is usually 2-5 feet.

Table 8.6 Precaution technique for protection of lives

Union	**Protection of lives**							
	Taking family members in boat		Stay in higher place and keep distance from river		Keep family members in relatives/ neighbor's house		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	3	8.8	28	82.4	3	8.8	34	100
Saulmari	4	6.3	59	92.1	1	1.6	64	100
Bidyananda	2	4.8	30	73.1	9	22.0	41	100
Khuniagachh	5	6.9	60	83.3	7	9.7	72	100
Kolkonda	5	7.8	57	89.1	2	3.1	64	100
Sindurna	2	6.7	26	86.6	2	6.7	30	100
Belka	7	9.2	59	77.6	10	13.2	76	100
All	28	7.3	319	83.7	34	8.9	381	100

Source: Field survey, 2017

8.1.6 Precaution technique for fuel collection and protection

Fuel collection and preservation helps the Teesta riparian community to cope with cooking during river morphology change. In the dry season, the people of the study area collect fuel such as dried branches of trees, dried leaves, straw and fuel wood for their survival. They also collect cow dung for making cow dung cake as fuel. Among the respondents, 57.3% preserve the collected fuel in *machan*. The *machan* which is used for fuel preservation is established in the yard and shaded with corrugated iron sheet. The people who build *machan* outside the yard for fuel protection, cover the fuel with polythene and tie the fuel with rope. About 42.7% respondents dry cow dung to use as fuel (Table 8.7). The cow dung has been processed in two ways. One way is to make cow dung cake and stuck the cake in wall for drying. Another process for cow dung preservation is applying the cow dung on a stick and let it dry in the sun. The fuel collection and preservation technique supports the community to cope with cooking condition and also benefits them to reduce their expenditure.

Table 8.7 Precaution technique for fuel collection and protection

Union	Precaution technique for fuel					
	Preserve collected fuel in machan		Dry cow dung for preservation		Total	
	N	%	N	%	N	%
Purba chatnai	18	52.9	16	47.0	34	100
Saulmari	35	54.6	29	45.3	64	100
Bidyananda	24	58.5	17	41.5	41	100
Khuniagachh	48	66.6	24	33.3	72	100
Kolkonda	41	64.1	23	35.9	64	100
Sindurna	13	43.3	17	56.7	30	100
Belka	39	51.3	37	48.7	76	100
All	218	57.3	163	42.7	381	100

Source: Field Survey 2017

8.1.7 Precaution method for agricultural production

To adapt with changing river morphology the community of the study area proceeds to different precaution method for agricultural production. As a flood prone community they try to cultivate flood resisting variety (22.3%) and 1.8% of respondents replied that no initiatives has been taken as precaution method for agricultural production (Table 8.8). Among the respondents, 75.9% replied that they cultivate crops suitable for *char* lands, because sedimentation effect on agricultural production. The respondents answered about rice, maize, tobacco, nut, pumpkin, chili, jute etc. cultivation in the accreted land. The respondents also explained that they have to choose crops suitable for *char* lands of repeated accretion.

Table 8.8 Precaution method for agricultural production

Union	**Precaution method for agricultural production**							
	Cultivate flood resisting variety		Cultivate crops suitable for char lands		No initiatives has been taken		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	10	29.4	23	67.6	1	2.9	34	100
Saulmari	11	17.1	50	78.1	3	4.7	64	100
Bidyananda	12	29.3	29	70.7	0	0	41	100
Khuniagachh	15	20.8	57	79..2	0	0	72	100
Kolkonda	14	21.9	50	78.1	0	0	64	100
Sindurna	10	33.3	19	63.3	1	3.3	30	100
Belka	13	17.1	61	80.3	2	2.6	76	100
All	85	22.3	289	75.9	7	1.8	381	100

Source: Field survey, 2017

8.2 Adaptation with flood

Due to the recurrent flood strike in the Teesta floodplain, the riparian community adopts different coping techniques with their own perception and knowledge. The people of Teesta basin have both physical and mental strength to adapt with flooding condition but economic strength of the people fall down due to livelihood and property loss for river morphology change. The adaptation of the respondents for flooding condition depends upon the intensity, duration and height of water of flood inundation. Dearth of food is acute in the affected community during and after flood. During flood the Teesta river basin community tries to adapt with food, shelter, health and education but after flood the main challenge is to manage livelihood for income earning. Since, flood along with river bank erosion make the study area people unemployed. Therefore, the victim try to looking for job and migrate for earning sources. Moreover, livelihood intensification and diversification also helps them to adapt with the adverse condition.

8.2.1 Adaptation with food during flood

The present study explores the fact that adoption of various food consumption strategies makes the Teesta riparian community to survive in the flooding condition. Eating behavior change is such a kind of strategy which is highly accepted (51.2%) by the community for adaptation with food for flood. Decrease in the number and amount of meal, reduction of food item, eat dry food item etc. are the some common strategies of eating behavior change among the respondents of Teesta basin. Table 8.9 represents union wise adaptation to food during flood in the study area. The study also explores another important adaptation strategy among the respondents is starvation. About (39.9%) of respondent survives with starvation during flood. On the other hand, 8.9% respondents expressed their opinion regarding relative’s delivery of food during flood.

Table 8.9 Adaptation strategies for food during flood in the study unions

Union	**Adaptation during flood (food)**						**Total**	
	Eating behavior change		**Relatives provide food**		**Starvation**			
	N	%	N	%	N	%	N	%
Purba chatnai	13	38.2	3	8.8	18	52.9	34	100
Saulmari	35	54.6	6	9.3	23	35.9	64	100
Bidyananda	22	53.6	3	7.3	16	39.0	41	100
Khuniagachh	32	44.4	5	6.9	35	48.6	72	100
Kolkonda	33	51.5	4	6.25	27	42.1	64	100
Sindurna	16	53.3	4	13.3	10	33.3	30	100
Belka	44	57.8	9	11.8	23	30.2	76	100
Total	195	51.2	34	8.9	152	39.9	381	100

Source: Field survey, 2017

8.2.2 Condition of food sufficiency and number of meal during lean period

The study investigated that most of the people (91.1%) of the study area suffers for food insufficiency in flooding period. Apart from that, the respondents accused that due to the riverine disaster impact on them they do not get proper food and nutrition all around the year. Table 8.10 displays about 8.9% responses on sufficient food consumption through three times daily food intake. On the contrary, the people who eat insufficient food are able to eat once daily, twice daily and become starved for adaptation. Among the respondents highest percentage (95.8%) of food insufficiency has been observed at Khuniagachh union. Insufficient food consumption and skipping meal is vastly practiced in the community of Teesta basin to adapt with food for river morphology change.

Table 8.10 Respondent's condition of food sufficiency

Union	**Respondent's condition of food sufficiency**					
	Yes (sufficient)		No (insufficient)		Total	
	N	%	N	%	N	%
Purba chatnai	2	5.1	32	94.9	34	100
Saulmari	4	6.2	60	94.8	64	100
Bidyananda	4	9.8	37	90.2	41	100
Khuniagachh	3	4.2	69	95.8	72	100
Kolkonda	7	10.9	57	89.1	64	100
Sindurna	6	20.0	24	80.0	30	100
Belka	8	10.5	68	89.5	76	100
All	34	8.9	347	91.1	381	100

Source: Field Survey, 2017

Adaptation with flood and river morphology change includes skipping meal and become starved for survival. Among the respondents of Teesta basin 39.8% (N=152) took starvation and 60.1% (N=229) survives with once daily, twice daily and three times daily food consumption for adaptation with food. Among the respondents 74.7% take meal once daily and 10.5% receives food twice daily. The respondents argued that they try to skip meal to reduce expenditure of food. The people who eat two times daily, tries to eat their first meal at 10-11 am and consume the second meal in the evening. Most of the people who survives with once daily food consumption, takes only lunch. Among the respondents only 14.8% eat food three times daily and the study investigates that only the solvent farmers take sufficient food but the others either skip meal or become starved. The study shows that p value of respondent's number of meal is significant (Table 8.11).

Table 8.11 Respondent’s number of meal

Union	Respondent’s number of meal							
	Once daily		Twice daily		Three times daily		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	11	68.8	3	18.8	2	12.6	16	100
Saulmari	30	73.2	6	14.6	5	12.2	41	100
Bidyananda	20	80.0	1	4.0	4	16.0	25	100
Khuniagachh	27	71.1	9	23.7	2	5.3	38	100
Kolkonda	27	75.0	1	2.8	8	22.2	36	100
Sindurna	14	66.7	1	4.8	6	28.6	21	100
Belka	42	80.8	3	5.8	7	13.5	52	100
All	171	74.7	24	10.5	34	14.8	229	100
Likelihood ratio	Likelihood ratio=19.850, df=12, p=.070							

Source: Field Survey, 2017

8.2.3 Respondent’s adaptation through dry food items

The community of Teesta basin depends on dry food items during flood. The dry food item includes husked rice, puffed rice, *gur*[32], chapatti, cookies, bread etc. Table 8.12 displays about 70.6% respondents of the study area highly accepted dry foods such as husked rice, puffed rice and *gur*. Among the respondents 16.3% rely on chapatti and sugar. Again, 13.1% respondents replied regarding dependency on cookies and bread during flood. The study result highlights that among the study union’s, husked rice, puffed rice and *gur* are used vastly (84.7%) in Khunigachh union; chapatti and sugar are consumed highly (41.2%) in Purba chatnai union. On the other hand, cookies and bread are mostly (33.3%) used in Sindurna union during flood for adaptation. Thus, the study unveils that the traditional dry food items play significant role in adaptation with flood in the Teesta Basin.

Table 8.12 Adaptation through dry food during flood

Union	Adaptation through dry food during flood							
	Husked rice, puffed rice and gur		Chapatti and sugar		Cookies and bread		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	17	50.0	14	41.2	3	8.8	34	100
Saulmari	52	81.2	9	14.1	3	4.7	64	100
Bidyananda	34	82.9	4	9.8	3	7.3	41	100
Khuniagachh	61	84.7	6	8.3	5	6.9	72	100
Kolkonda	43	67.2	11	17.2	10	15.6	64	100
Sindurna	16	53.3	4	13.3	10	33.3	30	100
Belka	46	60.5	14	18.4	16	21.0	76	100
All	269	70.6	62	16.3	50	13.1	381	100

Source: Field Survey, 2017

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[32] *Gur* is dark brown molasses obtained from sugarcane and frequently used in rural Bangladesh as desert item in breakfast.

8.2.4 Condition of cooking during flood

Flood destroys cooking environment and the community of the study area use indigenous cooking technique as well as stop cooking for their survival. They use portable oven (*chula*[33]) during flood. *Chula* is the only source of cooking in Teesta river basin community but it sinks in flood water. Therefore, every family of the study area prepares mud made portable oven Appendix8 (pic. 7. m) before flood. During flood the community of Teesta basin keeps the portable oven on *machan*/table/chair or cot to protect it from flood water and cook their meal in inundation. This indigenous strategy helps them survive in flood. The table indicates that 39.9% respondent stop cooking during flood due to starvation and problem of cooking place (Table 8.13). Moreover, among the study unions Khuniagachh displays highest percentage (47.2%) regarding stop cooking. On the other hand, cook in *machan* and cook in neighbor's house / relatives provide food has been replied by 25.2% and 17.0% of respondents respectively. Relatives play vital role during flood by supplying food to the flood affected families. The study union Khuniagachh shows highest percentage (26.3%) on cook in neighbor's house / relatives provides food than the other unions. Besides, cook standing in flood water/cook in embankment/ cook in school/flood shelter has been depicted by (17.8%) of respondents. When dry place is not available then the flood affected people tries to cook standing in flood water. Likewise, the people also cook in the places which are relatively safe from flood water such as embankment/ school and flood shelter.

Table 8.13 Condition of cooking during flood

Union	Condition of cooking during flood									
	Cook in machan		Cook in neighbor's house/ relatives provide food		Stop cooking		Cook standing in flood water/ embankment/ road/ flood shelter/school		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	12	35.3	4	11.7	18	52.9	0	0	34	100
Saulmari	25	39.1	13	20.3	23	35.9	3	4.6	64	100
Bidyananda	12	29.3	5	12.1	16	39.0	8	19.5	41	100
Khuniagachh	15	20.8	19	26.3	34	47.2	4	5.5	72	100
Kolkonda	18	28.1	11	17.1	28	43.8	7	10.9	64	100
Sindurna	3	10.0	4	13.3	9	30.0	14	46.6	30	100
Belka	11	14.5	9	11.8	24	31.6	32	42.1	76	100
All	96	25.2	65	17.0	152	39.9	68	17.8	381	100

Source: Field Survey, 2017

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[33] *Chula* means traditional mud made oven used for cooking. Two types of chula is available in Bangladesh one is stacked in mud and another is portable which is placed in a bowl or pot.

8.2.5 Item of meal

Field investigation result shows that the people of the study area choose their meal which is available and cheap. They cook rice and eat the rice with pulse, smashed food item (*vorta*[34]), cooked vegetables etc. The people of the study area try to eat such kinds of food items which are not expensive. The strategy of cheap food item consumption makes the community survive in the brutal river morphology change incident. Expensive food items are excluded by the extreme poor people of Teesta basin (Elahi and Ara, 2008).

The respondents also replied that they eat *panta vat*[35] with onion, chili and salt, which is not expensive. The community of Teesta basin also opined that when they do not collect rice; try to cope with hunger through *kaun* which is a supplementary food item of the survivors. Table 8.14 represents about 45.4% respondent depends upon Rice, pulse and smashed food items during flood. Among the respondents 19.2% and 10.0% take rice- vegetables, and rice-fish as item of meal respectively. The people who have no ability to buy pulse, vegetables and fish; take meal with rice, salt, onion and chili (25.3%). The respondents replied that when onion and chili is not available in house then they eat only rice and salt. The likelihood ratio of item of meal of the respondents shows p value is significant (p=.001).

Table 8.14 Item of meal of the respondents during flood

Union	**Item of meal of the respondents**									
	Rice, pulse and smashed food items		**Rice, salt, onion and chili**		**Rice and vegetables**		**Rice and fish**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	9	56.2	4	25.0	1	6.2	2	12.5	16	100
Saulmari	21	51.2	8	19.5	4	9.8	8	19.5	41	100
Bidyananda	11	44.0	7	28.0	7	28.0	0	0	25	100
Khuniagachh	17	44.7	4	10.5	14	36.8	3	7.9	38	100
Kolkonda	10	27.8	13	36.1	12	33.3	1	2.8	36	100
Sindurna	8	38.1	6	28.6	3	14.3	4	19.0	21	100
Belka	28	53.8	16	30.8	3	5.8	5	9.6	52	100
All	104	45.4	58	25.3	44	19.2	23	10.0	229	100
Likelihood ratio =43.814, df=18, p=.001										

Source: Field Survey, 2017

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[34] *Vorta* is a popular food making technique of boiled smashed potato/ vegetables/dried fish etc. along with onion, chili mustard oil and salt.

[35] *Panta vat* means soup like traditional Bangladeshi dish made with rice and water. The rice is cooked and water is added to it in night but it is eaten in the next morning or afternoon.

8.2.6 Correlation among condition of cooking, coping with food during flood, number and item of meal

The present study identifies significant positive correlation between condition of cooking during flood and adaptation with food (.221*), condition of cooking and number of meal during flood (.216*), adaptation n with food and number of meal (.237*), number of meal and item of meal (.319*). But it is evident from the study that there exists no correlation between condition of cooking in the period of flood and item of meal, as most of the respondents has to face inundation and stop their cooking. Moreover, adaptation with food in flooding condition and item of meal also shows no correlation owing to adoption of starvation strategy. Spearman rank correlation is significant at 0.01 level. Table 8.15 indicates that, there exists positive correlation among condition of cooking, adaptation during flood (food), number of meal and item of meal.

Table 8.15 Correlation for condition of cooking, adaptation during flood (food), number of meal and item of meal

	condition of cooking during flood	**Adaptation during flood (food)**	**number of meal during lean period**	**items of meal**
condition of cooking during flood	1.000	.221**	.216**	.003
Adaptation during flood (food)		1.000	.237**	.035
number of meal during lean period			1.000	.319**
items of meal				1.000

**. Correlation is significant at the 0.01 level (2-tailed).

8.2.7 Adaptation with Shelter during flood

During flood the victim suffers for inundation of shelter. The adaptation strategy regarding shelter of the community varies with locational variation. Such as the people of main land (*kaim*[36]) mostly take shelter in embankment, road, flood shelter and schools but the people of the mid channel bars (*char*) take shelter in *machan* and corrugated iron sheet. The people also face problem of keeping of domestic animal in inundation and the animals are also found in the dry high lands in *kaim*. On the other hand, livestock's and domestic fowls are observed to live in *machan* and top of corrugated iron sheet during flood inundation in the *chars*. The shelter of the flood victim depends upon according to the height and duration of flood water. When height of inundation is 1-3 feet and the extent of flood is 2-5 days then the victim do not leave their own shelter but when flood height is more than 3 feet and inundation stays long time then people search alternative accommodation for adaptation (*Sultana*

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[36] *Kaim* is a local term refers to main land which has no connection with river island or char.

et al., 2018). Table 8.16 designates that the Teesta basin community people highly depends on embankments/roads during flood (44.1%) for their shelter. They take shelter on machan (24.4%), live in school/flood shelter (22.0%) which characterizes the second and third highest percentage respectively. The respondents also seek accommodation in relative's house/ live in top of corrugated iron sheet (9.4%) during flood. The table also designates that there exists significant differences (p=.000) regarding the respondents adaptation with Shelter during flood.

Table 8.16 Adaptation with Shelter during flood

Union	**Adaptation with Shelter during flood**									
	Machan		Embankment/ road		School/flood shelter		Relatives house/ top of corrugated iron sheet		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	12	35.3	16	47.1	2	5.9	4	11.8	34	100
Saulmari	14	21.9	29	45.3	8	12.5	13	20.3	64	100
Bidyananda	7	17.1	21	51.2	4	9.8	9	22.0	41	100
Khuniagachh	22	30.6	37	51.4	10	13.9	3	4.2	72	100
Kolkonda	15	23.4	24	37.7	22	34.4	3	4.7	64	100
Sindurna	6	20.0	13	43.3	9	30.0	2	6.7	30	100
Belka	17	22.4	28	36.8	29	38.2	2	2.6	76	100
All	93	24.4	168	44.1	84	22.0	36	9.4	381	100
Likelihood ratio=55.041, df=18, p=.000										

Source: Field Survey, 2017

8.2.8 Adaptation with drinking water

Inundation of tube well causes scarcity of safe drinking water in the study area. Moreover, contamination of drainage waste is another obstacle to get safe drinking water during flood. Due to the problem of dry cooking place most of the people of the study area do not able to drink boil water. Therefore, they adopted the strategy of safe drinking water collection from neighbor's house. The people who have the ability to replace tube well in higher place have taken the initiative for safe drinking water. The study identifies that 17.8% respondents drink boil water, 5.2% use water purifying tablet and 4.2% respond regarding replacement of tube well in earthen mounds (Table 8.17). The study observed that drinking water collection becomes a great problem in inundation. Though community clash arises during drinking water collection, most of the respondents (72.7%) take pure water from neighbor's house in the flooding situation. Because it is the convenient way to collect drinking water rather than drinking boil water, use water purifying tablet and place tube well in higher place.

Table 8.17 Respondents adaptation with drinking water during flood

Union	Adaptation with drinking water									
	Drink boil water		Use water purifying tablet		Take pure water from neighbors house		Tube well placed in higher place		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	6	17.6	4	11.8	22	64.7	2	5.9	34	100
Saulmari	17	26.6	3	4.7	43	67.2	1	1.6	64	100
Bidyananda	3	7.3	4	9.8	34	82.9	0	0	41	100
Khuniagachh	12	16.7	0	0	57	79.2	3	4.2	72	100
Kolkonda	12	18.8	4	6.2	44	68.8	4	6.2	64	100
Sindurna	4	13.3	0	0	24	80.0	2	6.7	30	100
Belka	14	18.4	5	6.6	53	69.7	4	5.3	76	100
All	68	17.8	20	5.2	277	72.7	16	4.2	381	100

Source: Field Survey, 2017

8.2.9 Adaptation with education

Every year the children of the study area lose their spirit of education due to inundation. Extended flood causes school closed for weeks to months which hampers educational environment. Moreover, schools are converted as flood shelters during flood and the family of the students disrupts after flood occurrences. Therefore, to adapt with the condition, the students stop school going, dropout occurs and some of the students goes to school for relief. Table 8.18 displays highest percentage (64.4%) on stop going to school for adaptation with education during flood. The study finds out that 24.4% drop out occurs in the study area after flood. The respondents mentioned that drop out is a survival strategy with flood to engage the school going children in work. The study also depicts there exists significant differences (p=.006) in adaptation with education for flood in the study unions.

Table 8.18 Adaptation with education for flood

Union	Adaptation with education for flood							
	Drop out		Stop school going		Go to school for relief materials		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	11	32.4	19	55.9	4	11.8	34	100
Saulmari	17	26.6	37	57.8	10	15.6	64	100
Bidyananda	13	31.7	21	51.2	7	17.1	41	100
Khuniagachh	22	30.6	38	52.8	12	16.7	72	100
Kolkonda	8	2.5	50	78.1	6	9.4	64	100
Sindurna	4	13.3	25	83.3	1	3.3	30	100
Belka	18	23.7	56	73.7	2	2.6	76	100
All	93	24.4	246	64.6	42	11.0	381	100.0
Chi square	χ^2 value= 27.529, df=12, p=.006							

Source: Field survey, 2017

8.2.10 Medicine facilities during flood

Most common disease of the study area during flood is skin infection, respiratory and water borne disease. The study areas are remote and far from hospital. People could not go to doctor for treatment and they have no opportunity to get medicine free of cost from upazilla health complex. Therefore, they depend on buying medicine without any concern with doctor. Table 8.19 shows that 60.4% respondents buy medicine from nearby drug shop during inundation to get rid from disease. The study explores that buying medicine from pharmacy is a coping strategy of the respondents to decrease the transportation cost and the charge of doctor's visit. The study result shows p value is significant (.000) for medicine facilities during flood. Among the respondents 10.8% answered that they rely on relief medicine and about 3.1% mentioned about keeping additional drug in house to cope with flood disease. During field survey, the respondents replied regarding dependency on herbal medicine (25.7%) for remedy from flood induced disease. They take *tulsi*[37], *thankuni*[38], *sorpogondha* [39], *kacha kola*[40] as herbal medicine for cough, fever, and diarrheal disease during flood. Besides, they apply coconut oil, mustard oil, turmeric on infected skin for flood inundation.

Table 8.19 Medicine facilities during flood

Union	Medicine facilities during flood									
	Keep extra medicine in house		Buy medicine from pharmacy		Depend on relief medicine		Depend on herbal medicine		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	0	0	17	50.0	6	17.6	11	32.4	34	100
Saulmari	2	3.1	32	50.0	6	9.4	24	37.5	64	100
Bidyananda	0	0	22	53.7	8	19.5	11	26.8	41	100
Khuniagachh	2	2.8	41	56.9	4	5.6	25	34.7	72	100
Kolkonda	2	3.1	39	60.9	14	21.9	9	14.1	64	100
Sindurna	2	6.7	21	70.0	1	3.3	6	20.0	30	100
Belka	4	5.3	58	76.3	2	2.6	12	15.8	76	100
All	12	3.1	230	60.4	41	10.8	98	25.7	381	100
Likelihood ratio = 46.121, df=12, p=.000										

Source: Field survey, 2017

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[37] *Tulsi* (*Ocicum basilicum)* is a tropical herb found in Africa and South East Asia. The leaf of tulsi is used as herbal medicine of cough in the Indian subcontinent.

[38] *Thankuni (Centella asiatica)*is a common plant of south, South East Asia and used for treatment of fever, inflammation and wound pain.

[39] Sorpogondha (*Rauwolfia serpentine)* is known as perennial shrub in the South Asia with its herbal value of curing snake bites and insomnia.

[40] *Kacha Kola* (*Musa acuminata*) means green and unripen variety of banana used to cure diarrheal disease.

8.2.11 Flood defense by local community for adaptation

Without community support for flood defense it is impossible for the victim to survive in a flooded environment. The community of Teesta basin accepted various strategies such as road cutting to make the flood water passage, create earthen barricade, sand bag assembling in the way of flood water. The study result shows highest percentage (37.3%) on artificial levee construction. Making barrier by sand bag stacking represents 32.0% as community defensive method for flood. Making obstacle through tree cutting in road/ release flood water through road cutting also has been adopted by 20.2% of respondents. Among the respondents 10.5% replied about community based awareness for flood adaptation. Table 8.20 shows union wise flood defense by local community for adaptation in the flooding condition. Union wise highest percentages have been observed in make barrier through sand bag stacking (55.8%) at Purba chatnai union, artificial levee construction by mud (51.5%) at Saulmari union, barricade through tree cutting/ release flood water through road cutting (25.0%) at Kolkonda union and community based awareness (23.5%) at Purba chatnai union.

Table 8.20 Flood defense by local community for adaptation

Union	**Flood defense by local community**									
	Make barrier through sand bag stacking		**Artificial levee construction through mud**		**Barricade through tree cutting/ release water through road cutting**		**Community based awareness**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	19	55.8	0	0	7	20.5	8	23.5	34	100
Saulmari	11	17.1	33	51.5	12	18.7	8	12.5	64	100
Bidyananda	9	21.9	17	41.4	12	29.2	3	7.3	41	100
Khuniagachh	21	29.1	32	44.4	14	19.4	5	20.8	72	100
Kolkonda	24	37.5	19	29.6	16	25.0	5	7.8	64	100
Sindurna	9	30.0	13	43.3	4	13.3	4	13.3	30	100
Belka	29	38.1	28	36.8	12	15.8	7	9.2	76	100
All	122	32.0	142	37.3	77	20.2	40	10.5	381	100

Source: Field Survey, 2017

8.3 Adaptation with erosion

The people of the study area have to adapt with erosion for food, shelter and livelihood also. River morphology change during erosion makes the victim shelter less and they cope with the situation through build house in char, live in embankments and live in relative’s house for survival. The Teesta river basin community accepted various strategies for food related adaptation such as reducing meal, reducing food item, starvation, wild food harvest etc. They also take initiatives for bank erosion prevention including sand bag filling in the bank, reserve block filling in the erosive bank, tree plantation, community based awareness etc. to save life and property.

8.3.1 Eating habit change for erosion impact minimization

During and after erosion occurrences the Teesta riparian community become unemployed which instigate them reduce food item and reduce meal. They also take step to starvation to adapt with erosion. Joblessness and poverty are the main constrains for starvation of the river bank erosion victims (Elahi and Ara, 2008). The respondents of the study area mentioned that they change their eating behavior through reduction of food item, reduction of meal and starvation to minimize the erosion impacts. Table 8.21 depicts the adaptive measure taken by the respondents for food in the incident of erosion. Among the respondents 39.9% had starved and 8.9% reduced food item to survive in the condition of river bank erosion. The respondents mentioned that skipping meal is a common tendency to cope with river bank erosion. The study result shows 51.2% respondents reduced meal and consume food once or twice daily for their survival. The Chi square test result for eating habit change due to erosion impact minimization indicates p value is significant (.000).

Table 8.21 Eating habit change for erosion impact minimization

Union	**Eating habit change**							
	Reduce food item		**Starvation**		**Reduce meal**		**Total**	
	N	%	N	%	N	%	N	%
Purba chatnai	2	5.9	7	20.6	25	73.5	34	100
Saulmari	2	3.1	17	26.6	45	70.3	64	100
Bidyananda	4	9.8	11	26.8	26	63.4	41	100
Khuniagachh	5	6.9	36	50.0	31	43.1	72	100
Kolkonda	6	9.4	26	40.6	32	50.0	64	100
Sindurna	6	20.0	15	50.0	9	30.0	30	100
Belka	9	11.8	40	52.6	27	35.5	76	100
All	34	8.9	152	39.9	195	51.2	381	100
Chi-square	χ^2 value=37.777, df=12, P=.000							

Source: Field survey, 2017

8.3.2 Indigenous practices for food regarding erosion adaptation

Wild food harvesting is a common indigenous practice for food related adaptation of the local community to combat with erosion. It is also an impact minimization strategy of the respondents. The children and the women of the study area collect food items such as arum, drum stick, vegetable fern, *mocha*[41], *thor*[42] etc. During FGDs the respondents answered about adoption of inexpensive food item consumption for coping with erosion. Mutton, chicken, beef etc. expensive food items are avoided and relatively cheap food items are accepted by the Teesta river bank erosion victim (Sultana, *et al.*, 2018). Inexpensive food items such as *khud*[43], *jau vat*[44], wild vegetables etc. are taken as meal for adaptation with erosion. The people of the study area initiated indigenous food making and preservation technique such as, *shutki*[45], *pelka-solka*[46], *sidol*[47], *kumrar bori*[48] etc. to combat with erosion. They catch fish from the river and dry the fish in sun to eat in the lean period. The respondents replied that indigenous food preservation technique gives them foremost strength to survive in the crucial moment when they have no money to buy food. Homestead gardening is also adopted by the respondents. Moreover, the vegetables like pumpkin, gourd, potato etc. are stored in house to eat. Indigenous food making, food preservation, eating habit change, inexpensive food consumption, wild vegetable collection, homestead gardening are excepted by the Teesta riparian community to adapt with erosion induced river morphology change. The victim of river morphology change follows buy less and consume less technique (if they need 1 kg of rice per meal they buy only half kg) to survive in the brutal environment. Table 8.22 displays the indigenous practices for food related adaptation.

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[41] *Mocha* refers to the maroon color cone of banana.

[42] *Thor* means inner portion of banana tree stem used as vegetable.

Table 8.22 Indigenous practices for food related adaptation

Food items	**Indigenous practices for food related adaptation**
Rice	Buy less than real need; do not eat with full stomach
Pulse	Buy rarely; do not buy for high price.
Fish	Buy rarely, catch from river.
Egg	Eat if domestic fowl lay egg.
Meat	Eat half kg broiler chicken in a month, eat chicken when relatives come to the house, eat beef in the occasion of *Eid*[49], eat mutton once or twice time in life.
Vegetable	Collect wild vegetable, homestead gardening, agriculture.

Source: Focus Group Discussion, 2017

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[43] *Khud* means broken rice which is used as animal fodder and also consumed by the poor/ultra-poor as inexpensive staple food.

[44] *Jau vat* is cooked with huge water accompanied by small amount of rice.

[45] *Shutki* is traditional preserved food item made with dried edible fishes and vegetables.

[46] *Pelka-solka* is an indigenous food of Teesta basin made through mixed vegetables (arum, jute leaf, drum stick leaf)along with baking soda, garlic, chili and salt.

[47] *Sidol* is a kind of preserved food made mainly with arum and dried fish powder along with spices which is very popular in the northern Bangladesh.

[48] *Kumrar bori* is prepared with mashed pulse and gourd and dried in the sun for preservation.

[49] *Eid* is the main festival of the Muslim religious community.

8.3.3 Adaptation with shelter during erosion

The people of the study area fall into most shocking condition when they become homeless during erosion. People take different initiatives regarding shelter management to combat with river bank erosion. Adaptation with shelter during erosion is a burning issue in the study area during and after erosion took place. Therefore, the river victim tries to rebuild house in the embankments and char lands. Likewise, some of the respondents argued that the period when the people of Teesta basin restructure their houses, the family members take shelter in relatives and neighbor's house. Maximum respondents (55.6%) of the study area build house in embankments to take shelter owing to homestead destruction after erosion. When the community of Teesta basin lost their homestead land in the river they also build house in the *char* lands which is recognized as *khas* lands because they have no ability to buy land. Therefore, 35.4% of respondents replied regarding build house in the char lands. About 5.5% and 3.4% respondents provided their opinion on living in relative's house and living in neighbor's house respectively.

Table 8.23 Adaptive measures taken by respondent for shelter during erosion

Union	**Adaptive measures taken for shelter during erosion**									
	Build house in embankment		**Build house in char lands**		**Living in relatives house**		**Living in neighbor's house**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	25	73.5	6	17.6	2	5.9	1	2.9	34	100
Saulmari	38	59.3	25	39.0	1	1.0	0	0	64	100
Bidyananda	14	34.1	18	43.9	5	12.2	4	9.6	41	100
Khuniagachh	42	58.3	23	31.9	5	6.9	2	2.8	72	100
Kolkonda	40	62.5	22	34.4	2	3.1	0	0	64	100
Sindurna	13	43.3	15	50.0	1	3.3	1	3.3	30	100
Belka	40	52.6	26	34.2	5	6.6	5	6.6	76	100
All	212	55.6	135	35.4	21	5.5	13	3.4	381	100
Likelihood ratio=44.565, df=18, P=.000										

Source: Field survey, 2017

8.3.4 Adaptation with drinking water for erosion

Community support during erosion gives strength to the victim during river bank erosion. The tube well of the affected people goes in the river womb and they can survive in the condition through collection of drinking water from neighbors and relatives house. Among the respondents 69.6% assemble their drinking water from neighbor's house and 30.4% people collect drinking water from relative's house. Among the study unions Purba chatnai shows highest percentage (73.5%) on collection of drinking water from relative's tube well and Kolkonda union shows highest percentage (89.1) on accumulation of drinking water from neighbor's house. Table 8.24 designates significant (P=.000) variation on adaptation with drinking water for erosion in the study unions.

Table 8.24 Adaptation with drinking water for erosion

Union	**Adaptation with drinking water for erosion**					
	From relatives tube well		**From neighbors tube well**		**Total**	
	N	%	N	%	N	%
Purba chatnai	25	73.5	9	26.5	34	100
Saulmari	44	68.7	20	31.3	64	100
Bidyananda	8	19.5	33	80.5	41	100
Khuniagacch	15	20.8	57	79.2	72	100
Kolkonda	7	10.9	57	89.1	64	100
Sindurna	6	20.0	24	80.0	30	100
Belka	11	14.5	65	85.5	76	100
All	116	30.4	265	69.6	381	100
Chi-square	χ^2 value=1.590, df=6, P=.000					

Source: Field Survey 2017

8.3.5 Erosion protection initiatives by local community for adaptation

The protection measures taken by the local community for bank erosion has been regarded as very effective way to save life and property in Teesta basin. Sand bag filling in the bank is mostly accepted (55.9%) preventive method to control bank erosion in the study area. Reserve concrete block/ boulder filling in the bank also recognized in Teesta basin to control bank erosion. About 24.4% respondents answered regarding their concrete block filling initiatives during erosion. Community based awareness initiatives also remarkable in the study area. Announcement of erosion strike in mosque helps to save life and property during erosion. Among the respondents 19.7% replied about community based awareness initiatives by local community for adaptation regarding erosion. Table 8.25 shows different protection initiatives implemented by the local community for erosion adaptation. The table also designates the significance (P=.000) of chi-square test in the study area regarding erosion protection initiatives by local community. The study result indicates that sand bag filling in the bank is highly adopted by the community of Khuniagachh union on the other hand reserve block/ boulder filling is highly accepted by the people of Kolkonda union. Moreover, community based awareness is high among the people of Purba chatnai union. Therefore, the study result shows that there is variation of erosion protection initiatives by the local community of Teesta river basin to combat the disaster.

Table 8.25 Erosion protection initiatives by local community for adaptation

Union	Erosion protection initiatives by local community							
	Sand bag filling in the bank		Reserve block/boulder filling		Community based awareness		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	7	20.6	16	47.1	11	32.4	34	100
Saulmari	42	65.6	12	18.8	10	15.6	64	100
Bidyananda	25	61.0	7	17.1	9	22.0	41	100
Khuniagachh	50	69.4	12	16.7	10	13.9	72	100
Kolkonda	24	37.5	31	48.4	9	14.1	64	100
Sindurna	18	60.0	6	20.0	6	20.0	30	100
Belka	47	61.8	9	11.8	20	26.3	76	100
All	213	55.9	93	24.4	75	19.7	381	100
Chi-square test	χ^2 value= 53.986, df=12, P=.000							

Source: Field survey, 2017

8.4 Adaptation with sedimentation and Channel shifting

The people of the study area have to cope with sediment accretion in river bed and bank. They also take initiatives to cope with changing river morphology in drought conditions. The respondents opined that during the spring, *poschia*[50] occurs. people are affected by the accreted sands of Teesta river. Sandy accretion generate dust and dust storm occurs during *hurka*[51] (norwester). To adapt with *hurka* and *poschia* people try to stay in house by closing the door and window but their yards are occupied by sandy sediments of Teesta river. Moreover, the people of the study area try to cope with river channel shifting through initiating new income sources such as collection of water borne food and fishing in the oxbow lakes and back swamps.

8.4.1 Respondents strategies to cope with sediment accretion

The study area possesses unique characteristics of *char* land formation through sediment accumulation in the riverine environment. The continuous sediment accretion impacts on the lifestyle of the respondents. As a result they take attempt to adapt with sedimentation process. When a *char* land form, the people of the study area use the *char* as cattle grazing field. They take initiative to improve the soil condition through tree plantation and after few years start cultivation in chars. Moreover, the people of the study area mentioned that if sand accretion occurs in char land; it is impossible to cultivate the land but if luck fevers and the lands are covered with *meead*[52] after flood; then people starts to cultivate the *char* lands. Likewise, after the completion of *char* formation process, the river basin community shifts their house in *char* as an erosion victim. Table 8.26 denotes different initiatives taken by the local community to cope with sedimentation. Among the respondents 52.7% initiate cultivation in *char* after sediment accretion. From the table it is clear that initiating cultivation in *char* is highly accepted by the study unions to cope with sediment accretion. About 25.5% respondents initiate pasture livestock in the newly accreted *char* land. Tree plantation in *char* land and shift house in *char* has been taken by 11.2% and 10.5% of respondents to survive in the sedimentation process of Teesta river basin. The study result indicates that tree plantation in the *char* lands are highly (23.5%) noticed in Purba chatnai union, livestock pasture is highest (59.4%) in Kolkonda union and shift house in char is highest in Bidyananda union. The likelihood ratio of the respondents strategies to cope with sediment accretion shows P value is significant (p=.000).

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[50] *Poschia* means hot wind and dust blow in the spring. The dust is generated from sand of Teesta river sediments.

[51] *Hurka* is a local term similar to norwester in the Teesta basin. During norwester the homesteads of Teesta basin is occupied by sands blown from Teesta river bed.

[52] *Meead* is a term used by the Teesta river basin community which refers soil that contains silt alluvium.

Table 8.26 Respondents strategies to cope with sediment accretion

Union	**Respondents strategies to cope with sediment accretion**									
	Tree plantation in char		**Initiating cultivation in char**		**Livestock pasture**		**Shift house in char**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	8	23.5	21	61.7	2	5.9	3	8.8	34	100
Saulmari	9	14.1	49	76.6	0	0	6	9.4	64	100
Bidyananda	0	0.0	31	75.6	0	0	10	24.4	41	100
Khuniagachh	10	13.8	39	54.2	19	26.4	4	5.6	72	100
Kolkonda	7	10.9	13	20.3	38	59.4	6	9.4	64	100
Sindurna	4	13.3	8	26.7	15	50.0	3	10.0	30	100
Belka	5	6.6	40	52.6	23	30.3	8	10.5	76	100
All	43	11.2	201	52.7	97	25.5	40	10.5	381	100
Likelihood ratio= 148.571, df=18, P=.000										

Source: Field survey, 2017

8.4.2 Strategies to adaptation with river channel shifting

Though river channel shifting causes homestead destruction and economic loss, the people of the study area try to adjust the damage through finding new income earning sources in the shifted channel. The oxbow lakes and back swamps are used as fishing grounds and aquatic vegetable/water borne food collection. Different water borne food such as water chestnut, *kolmi*[53], *shaluk*[54], is available in the oxbow lakes and back swamps of Teesta river. People collect this water borne food for consumption and also sell in the local market. Likewise, the abandoned channels are used as paddy and other crop cultivation fields. The new abandoned channels are not used for cultivation because the lands are easily affected by flood water. The abandoned channels which are chocked with sediments are suitable for cultivation. Table 8.27 denotes the respondent's strategies to adaptation with river channel shifting. Among the respondents 41.2% replied regarding adaptation through water borne food collectionafter river channel shifting. Fishing in oxbow lakes/back swamps has been adopted by 35.7% of respondents. The study also reveals that 23.1% of respondents initiate cultivation in the abandoned channels after river channel shifting. The chi-square test result of strategies to adaptation with river channel shifting shows p value is significant (p=.000) in the study unions.

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[53] *Kolmi (Ipomea aquatic)* is an aquatic vegetable grows plenty in swamps and wetlands.

[54] *Shaluk (Nymphaea Nouchali)*refers the shoot of water lily that is cooked as vegetable.

Table 8.27 Strategies to adaptation with river channel shifting

Union	**Strategies to adaptation with river channel shifting**							
	Fishing in oxbow lakes/back swamps		**water borne food collection**		**Cultivation in abandoned channel**		**Total**	
	N	%	N	%	N	%	N	%
Purba chatnai	10	29.4	17	50.0	7	20.6	34	100
Saulmari	14	21.8	30	46.9	20	31.2	64	100
Bidyananda	24	58.5	9	22.0	8	19.5	41	100
Khuniagachh	40	55.6	22	30.6	10	13.9	72	100
Kolkonda	17	26.5	26	40.6	21	32.8	64	100
Sindurna	10	33.3	11	36.7	9	30.0	30	100
Belka	21	27.6	42	55.3	13	17.1	76	100
All	136	35.7	157	41.2	88	23.1	381	100
Chi-square	χ^2 value=40.295, df=12, P=.000							

Source: Field survey, 2017

8.5 Economic adaptation with river morphology change

The opinion of the respondent's regarding river morphology change impact unveils the destruction of their economic condition for such an event. The people of the study area survive in the horrible situation through mental strength. Moreover, technical supports from GOB and different NGO's help them to battle against river morphology change. Adaptation strategies taken by the local community regarding economic condition includes income diversification, income intensification, borrow money and goods, sell land, sell productive assets, savings, relief materials collection etc.

8.5.1 Strategy of earning and expenditure to adapt with changing river morphology

The community of Teesta river basin takes plan and policy regarding their earnings and expenditure for adaptation with river morphology change. During FGDs respondents talked about the effectiveness of strategies intended for earning and expenditure helps them to cope in the adverse condition for river morphology change incidence. Table 8.28 shows the multiple responses analysis regarding respondent's strategy of earning and expenditure to adapt with the adversities. Field investigation result shows 36.1% responses for reduction of expenditure as a very effective adaptive strategy of the respondents. Another way of adaptation through changing river morphology is change in occupation which represents 34.9%. The third type of strategy taken by the respondents is migration for occupation which is replied by 28.9% of respondents.

Table 8.27 Strategy of earning and expenditure to adapt with the adversities

Union	Strategy of earning and expenditure							
	Reduction of expenditure		Change in occupation		Migration for occupation		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	35.4	34	35.4	28	29.2	96	100
Saulmari	64	35.1	63	34.6	55	30.2	182	100
Bidyananda	41	37.6	37	33.9	31	28.4	109	100
Khuniagachh	72	39.5	68	37.4	42	23.1	182	100
Kolkonda	64	35.3	62	34.2	55	30.3	181	100
Sindurna	30	34.5	29	33.3	28	32.2	87	100
Belka	76	35.0	75	34.6	66	30.4	217	100
All	381	36.1	368	34.9	305	28.9	1054	100

Source: Field survey, 2017(N.B. Percentages are based on responses)

8.5.2 Livelihood strategy for adaptation

Respondents livelihood is at high risk for agricultural land loss and standing crop damage. To survive with river morphology change the people of the study area take livelihood diversification, income intensification and agricultural intensification as adaptive measures. Table 8.29 exemplifies the multiple response analysis of the respondent's livelihood strategy. Among the respondents 34.5% replied about livelihood diversification. Income intensification is highly accepted strategy of the respondents 34.8%. Agricultural intensification is also an established strategy in the study area for adaption with river morphology which represents 30.7% of responses. The respondents answered about their use of agricultural land as double and triple cropped area for agricultural intensification which is a very effective sign of combat with river morphology change in the study area.

Table 8.29 Livelihood strategy of the respondents

Union	Table 8.29 Livelihood strategy of the respondents							
	Livelihood diversification		Income intensification		Agricultural intensification		Total	
	f	%	*f*	%	*f*	%	*f*	%
Purba chatnai	34	34.7	34	34.7	30	30.6	98	100
Saulmari	64	34.4	64	34.4	58	31.1	186	100
Bidyananda	41	35.3	41	35.3	34	29.3	116	100
Khuniagachh	71	34.6	72	35.1	62	30.2	205	100
Kolkonda	62	32.8	64	33.8	63	33.3	189	100
Sindurna	29	34.9	30	36.1	24	28.9	83	100
Belka	76	35.0	76	35.0	65	30.0	217	100
All	377	34.5	381	34.8	336	30.7	1094	100

Source: Field survey, 2017(N.B. Percentages are based on responses)

8.5.3 Livelihood groups and livelihood diversity

Livelihood diversification and income intensification helps the study area people to combat with the adversity. Household head and the female household member are engaged in diversified livelihood activities for income intensification. Moreover, children of the households also engaged in income earning sources to cope up with the adverse condition. The livelihood sectors/groups and their occupation diversity of the studied unions are shown in Table 8.30. According to the field survey 2017 and FGD's the farmers are not only engaged in farming but also they involve in other sectors of agriculture such as cattle rearing, fishing, and pond aquaculture. Occupational diversity of the wage labor in nonfarm is much wide-ranging than the wage labor in farm. Due to joblessness for river morphology alteration the landless, marginal and even the small farmers involve in wage labor in farm and non-farming sectors.

Table 8.30 Livelihood sectors/groups and livelihood diversity

Livelihood sectors/groups	Livelihood diversity
Farmer	Own farming, Share cropping, cattle rearing, fishing, pond aquaculture.
Wage labor farm	Seed sawing, weed picking, paddy harvesting, paddy husking
Wage labor nonfarm	Rickshaw/van puller, food for work, cash for work, stone collection, stone crush, sand mining, mechanic, traditional cigarette making, carpenter, mason, house maid, packet making, textile mill worker, brick field worker, wood worker.
Petty business	Hawker, tobacco, nut, rice, potato, poultry, fish and cow trader, cow dung selling, wastage plastic and iron product collection business, cow slaughter.
Grocer	Dry food item grocer, egg, tea, betel leaf grocer, household product grocer.
Service	Village police, land surveyor, sweeper, spiritual person

Source: Focus Group Discussion, 2017

8.5.4 Borrowing money for adaptation

Most of the people of the study area borrow money from various sources to survive in the vulnerable condition for river morphology change. About 53.8% respondents of the study area borrow money from money lenders which represents highest percentage of way of borrowing money for adaptation (Table 8.31). Borrowing from intra households and relatives also plays important role for adaptation in the study area which represents second highest percentage (24.1%). The people of the study area arrange local clubs for borrow money. Among the respondents 16.7% borrow money from these clubs. About 5.2% respondents who are solvent, replied about hate borrowing or do not borrow. Moreover, the hard core poor who have no ability to pay interest replied that they do not borrow. The respondents talked about high interest rate of borrowing money from money leaders, borrow club and intra household. The respondents try to borrow money from the mentioned sources due to easy access of money in river morphology change event though they have to pay high interest rate. Thus, the study represents 94.8% respondents borrow money from different sources and the others do not borrow or hate borrowing or no ability to borrow and pay interest. The study result also indicates significant differences (P=.000) among the study unions regarding respondents way of borrowing money for adaptation.

Table 8.31 Respondents way of borrowing money for adaptation

Union	Borrowing money for adaptation									
	From intra households and relatives		From money lenders		From money borrowing clubs		Hate borrowing/ no ability to borrow and pay interest		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	20	58.8	11	32.4	3	8.8	0	0	34	100
Saulmari	18	28.1	35	54.6	8	12.5	3	4.6	64	100
Bidyananda	13	31.7	22	53.7	3	7.3	3	7.3	41	100
Khuniagachh	20	27.8	39	54.2	7	9.7	6	8.3	72	100
Kolkonda	7	10.9	22	34.3	29	45.3	6	9.3	64	100
Sindurna	7	23.3	15	50.0	8	26.7	0	0	30	100
Belka	7	9.2	61	80.3	6	7.9	2	2.6	76	100
All	92	24.1	205	53.8	64	16.7	20	5.2	381	100
Likelihood ratio= 90.657, df=18, P=.000										

Source: Field Survey, 2017

8.5.5 Borrowing food products

Unavailability of necessary food during river morphology change involves the study area people to borrow food products. The respondents talked about borrowing food products from the mentioned sectors (Table 8.32) pay their necessity of food for survival. The study result indicates highest percentage of borrowing food products from neighbor’s house (70.1%). The respondents mentioned that they borrow mainly rice and vegetables from neighbor’s house. Respondents answer about borrowing food products such as rice, oil, egg, pulses etc. from grocers shop represents 19.2%. The respondents also opined about borrow from relatives (6.8%) for adaptation with changing river morphology. Among the respondents 3.9% responded about not to borrow food products.

Table 8.32 Borrowing food products for adaptation

Union	**Borrowing food products**									
	From neighbors house		**From relatives**		**From shop**		**Do not borrow food products**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	26	76.5	2	5.6	5	14.7	1	2.9	34	100
Saulmari	44	68.7	3	4.6	16	25.0	1	1.5	64	100
Bidyananda	32	78.0	2	4.9	7	17.1	0	0	41	100
Khuniagachh	49	68.1	8	11.1	13	18.1	2	2.8	72	100
Kolkonda	45	70.3	5	7.8	10	15.6	4	6.2	64	100
Sindurna	19	63.3	1	3.3	6	20.0	4	13.3	30	100
Belka	52	68.4	5	6.6	16	21.1	3	3.9	76	100
All	267	70.1	26	6.8	73	19.2	15	3.9	381	100

Source: Field Survey, 2017

8.5.6 Selling asset for adaptation with river morphology change

The people of Teesta river basin reduce their economic loss through asset selling. They sell crop and livestock to get money during river morphology change. The respondents replied that when they cannot shift house building material then sell the materials which provide them money to cope with the changing environment. Sometimes they provoked to sell land before erosion to decrease economic loss. But most of the cases they fail to sell land or sell the land in very low price at last. Table 8.33 represents 68.2% respondent sell crop and livestock for adaptation. Among the respondents 16% replied for selling land, 9.2% for selling house building materials and 6.6% opined about nothing to sell and get money. Thus, the study finds out 93.4% respondents rely on selling of asset for adaptation with river morphology change. The study result finds out that there exists variation (P=.001) in asset selling in the study unions. Among the study unions crop and livestock selling has been observed highest percentage (78.1%) in Kolkonda union, house building material selling is highest (17.1%) in Bidyananda union and land selling is highest (30.3%) in Belka union. Therefore, the study result indicates that among the entire asset selling types, crop and livestock selling is mostly adopted by the respondents to cope with river morphology change in terms of asset selling conditions.

Table 8.33 Selling of asset for adaptation with river morphology change

Union	Selling asset for adaptation									
	Crop and livestock		House building materials		Land		Nothing to sell		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	25	73.5	3	8.8	5	14.7	1	2.9	34	100
Saulmari	49	76.5	10	15.6	5	7.8	0	0	64	100
Bidyananda	26	63.4	7	17.1	4	9.8	4	9.8	41	100
Khuniagachh	53	73.6	6	8.3	8	11.1	5	6.9	72	100
Kolkonda	50	78.1	2	3.1	8	12.5	4	6.2	64	100
Sindurna	15	50.0	2	6.7	8	26.7	5	16.7	30	100
Belka	42	55.3	5	6.6	23	30.3	6	7.9	76	100
All	260	68.2	35	9.2	61	16.0	25	6.6	381	100
Likelihood ratio=43.565, df=18, P=.001										

Source: Field survey, 2017

8.5.7 Relief facilities to cope with river morphology change

Relief distribution has been considered as an effective initiative from government and NGOs for adaptation of the victim. Most of the victims are eager to get relief facilities during river morphology change but all of them do not get the opportunity. The people in the mid channel bar get very limited access to relief materials during flooding period. The respondents accused that relief facilities has been provided only on the relatives of local muscleman and sometimes relief materials are stolen by the local government authority. Table 8.34 shows the condition of relief facilities in the study area. Among the respondents 74.3% get relief and 25.7% do not get relief. Food items get priority for relief facilities because scarcity of food becomes acute during river morphology change. Among the respondents 37.0% replied about food item (rice, pulse, oil, drinking water, dry foods, sugar, salt) distribution during river morphology change. About 23.4% answered for getting medicine and different products as relief materials to cope with the adversities. The respondents told that the relief medicine such as oral tablet, oral saline, water purifying tablet etc. help them to cure from different diseases during river morphology change. They also opined about different essential products for example candle, match, kerosene oil, etc. are also provided as relief goods. Among the respondents 13.9% replied about housing and agricultural products (corrugated iron sheet, seed, fertilizer etc.) as relief materials which support them to combat with the river induced disaster. The respondents argued about the disparities regarding distribution of relief materials. Among the respondents 25.7% accused that relief materials has not been provided.

Table 8.34 Relief facilities for adaptation in the study area

Union	**Relief facilities in the study area**									
	Food		**Medicine and different products**		**Housing and agricultural products**		**Relief facilities has not been provided**		**Total**	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	14	41.1	10	29.4	3	8.8	7	20.5	34	100
Saulmari	26	40.6	15	23.4	11	17.2	12	18.8	64	100
Bidyananda	13	31.7	11	26.8	7	17.0	10	24.3	41	100
Khuniagachh	36	50.0	9	12.5	10	13.9	17	23.6	72	100
Kolkonda	22	34.4	15	23.4	7	10.9	20	31.2	64	100
Sindurna	10	33.3	7	23.3	5	16.6	8	26.6	30	100
Belka	20	26.3	22	28.9	10	13.2	24	31.6	76	100
All	141	37.0	89	23.4	53	13.9	98	25.7	381	100

Source: Field survey, 2017

8.5.8 Social safety net services

The government of Bangladesh has different social protection programs for the poor communities. The fund for climate change, school feeding program, community based health care, poverty reduction and livelihood security, *char* development and settlement, climate victims rehabilitation, VGD (Vulnerable Group Development), VGF (Vulnerable Group Feeding), FFW (Food For Work), WFM (Work For Money) are some of the programs of government for the people of the economically back ward area. The Government of Bangladesh allocated 42.7 crore BDT money for poverty reduction of northern area, 50 crore BDT for disaster and climate resilient and 3.50 crore BDT for *Char* livelihood program (GOB, 2017) but most of the people of the study area are not getting the social safety net services. Table 8.35 presents the condition of social safety net services in the study area. The table indicates that the people of the study area are deprived from the social safety net services. During FGDs the respondents claimed that social safety net services has been provided in the relatives of local muscleman and also stolen by them. Among the social safety net services school feeding program shows highest percentage (32.8%) and work For money shows second highest percentage (16%) in the study area. The condition of receiving social safety net services like VGD/VGF facility shows very shocking picture among the Teesta river basin community. Amongst the respondents only (1%) receives VGD/VGF facilities. The study also illustrates 3.1% of respondent gets old age/widow/disability allowance. Almost half (47%) of the respondents of the study area do not get social safety net services which would be very effective way for the riverine community to adapt with river morphology change.

Table 8.35 Condition of social safety net services in the study area

Union	**Social safety net services**											
	VGD/VGF facilities		**Old age/ widow/ disability allowance**		**School feeding program**		**Work For money**		**Safety net services has not been provided**		**Total**	
	N	%	N	%	N	%	N	%	N	%	N	%
Purba chatnai	0	0	0	0	24	70.6	4	11.8	6	17.6	34	100
Saulmari	0	0	0	0	36	56.9	11	16.9	17	26.2	64	100
Bidyananda	0	0	3	7.3	22	53.7	6	14.6	10	24.4	41	100
Khuniagachh	2	2.7	1	1.3	27	37.5	7	9.7	35	48.6	72	100
Kolkonda	0	0	2	3.1	16	25.0	14	21.9	32	50.0	64	100
Sindurna	1	3.3	0	0	0	0	6	20.0	23	76.7	30	100
Belka	1	1.3	6	7.9	0	0	13	17.1	56	73.7	76	100
All	4	1.0	12	3.1	125	32.8	61	16.0	179	47.0	381	100

Source: Field survey, 2017

8.6 GOB and NGO initiatives to prevent river morphology change disaster

The Government of Bangladesh (GOB) has taken anti erosion and flood defense measures to control river morphology change. Different plans and programs of Government also have been implemented in the study area to help the vulnerable people of Teesta basin. NGOs (Non-Government Organization) took different initiatives for the survival of the community. GOB and NGO activities to mitigate people’s vulnerability have been also investigated in the present study to explore the institutional supports behind the respondent’s adaptation.

8.6.1 NGO activities regarding river induced disaster mitigation

The vulnerable people of Teesta river basin tries to cope with changing river morphology by different NGO activities. House platform raise, cattle/ plant/seed distribution, pumpkin cultivation in *char* land, cash money distribution, livestock distribution, fish cultivation in cage are some effective initiatives from different NGO's to cope with the changing river morphology and thus poverty alleviation in the study area. Among the respondents 59.6% replied about NGO activities regarding river induced disaster mitigation and 40.4% replied that they have not noticed/get help from NGOs for adaptation with river morphology change.

The NGOs mainly acts for micro financing in the study area. The respondents blamed that the NGOs give aid to those victim who are the members of their NGOs for micro finance program. However, a number of national and foreign NGOs initiate various programs for the river victims such as *Char* Livelihood Program (CLP) and *Char* rehabilitation program (CRP) to cope with changing river morphology. Different NGOs like RDRS (Rangpur Dinajpur Rural Services), BRAC (Bangladesh Rural Advancement Committee), OXFAM (Oxford Committee for Famine Relief), USAID (United States Agency for International Development), GUK (Gono Unnayan Kendro), POPY (Peoples Oriented Program Implementation), JSKS (Jhanjira Shomaj Kollan Songhtha), PKSF (Palli Karma Sahayak Foundation), SHARP (Self Help And Rehabilitation Program) etc. acts during and after river morphology change in the study area for disaster mitigation.

The important NGO activities regarding adaptation of the respondents includes house platform raise, livestock and feed distribution, initiating pumpkin cultivation in *char* land etc. Table 8.36 represents that the respondents of Sindurna union has not taken any adaptation related help from the NGO's. Moreover, 40.4% of respondents of the study unions mentioned that they have not given adaptation related help by the NGO's. The study result also shows that about 16.5% answered for their house platform raising which represents highest percentage regarding NGO initiatives for adaptation. The second and third highest percentage regarding NGO activities has been observed in pumpkin cultivation in char land (15.2%) and livestock and feed distribution (12.5%) in the study unions. The other NGO activities are fish cultivation in cage as well as sanitary latrine and tube well distribution which is replied by 6.5% and 6.8% of respondents respectively. Floating vegetable cultivation has been noticed only in Belka union and replied by 1.8% of respondents. Therefore, the study result highlights that the NGOs has lots of activities for adaptation with changing river morphology but their initiatives are limited in few areas and most of the victims are not the beneficiaries.

Table 8.36 NGO activities regarding adaptation of the respondents

Union	**NGO activities regarding adaptation**															
	House platform raise		**Pumpkin cultivation in char**		**Livestock and feed distribution**		**Fish cultivation in cage**		**Sanitary latrine and tube well distribution**		**Floating vegetable cultivation**		**Adaptation related help has not given by NGO's**		**Total**	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Purba chatnai	8	23.5	0	0	6	17.6	0	0	0	0	0	0	20	58.8	34	100
Saulmari	13	20.3	11	17.1	5	7.8	16	25.0	0	0	0	0	19	29.6	64	100
Bidyananda	0	0	0	0	7	17.0	0	0	14	34.1	0	0	20	48.8	41	100
Khuniagachh	18	25.0	15	20.8	17	23.6	0	0	0	0	0	0	22	30.5	72	100
Kolkonda	10	15.6	24	37.5	0	0	0	0	12	18.7	0	0	18	28.1	64	100
Sindurna	0	0	0	0	0	0	0	0	0	0	0	0	30	100	30	100
Belka	14	18.4	8	10.5	13	17.1	9	11.8	0	0	7	9.2	25	32.8	76	100
All	63	16.5	58	15.2	48	12.5	25	6.5	26	6.8	7	1.8	154	40.4	381	100

Source: Field survey, 2017

8.6.2 Government initiatives to build awareness for river morphology change

Awareness building in river basin community substantially reduces the impact and vulnerability of river morphology change. The respondents of the present study were asked about initiatives from government to build awareness to mass people for river morphology change issues. Table 8.37 shows among the respondents 68% opined about no government initiatives have taken to build awareness for river morphology change. The study result shows limited opportunities have been taken regarding education and training (2.9%) and afforestation (3.6%) in the study unions. Among the respondents 25.5% were warned from local government/army which shows highest percentage regarding government initiatives to build awareness for river morphology change. The study result also depicts that among the study unions, Purba chatnai union has been highly (70.0%) warned by local government/army.

Table 8.37 Government initiatives to build awareness

Union	Government initiatives									
	Warning from local Govt./army		Education and training		Afforestation		No initiatives has taken		Total	
	N	%	N	%	N	%	N	%	N	%
Purba chatnai	24	70.6	0	0	0	0	10	29.4	34	100
Saulmari	8	12.5	4	6.2	7	10.9	45	30.3	64	100
Bidyananda	9	21.9	1	2.4	2	4.8	29	70.7	41	100
Khuniagachh	17	23.6	1	1.3	3	4.1	51	70.8	72	100
Kolkonda	20	31.2	2	3.1	0	0	42	65.6	64	100
Sindurna	6	20.0	2	6.6	0	0	22	73.3	30	100
Belka	13	17.1	1	1.3	2	2.6	60	78.9	76	100
All	97	25.5	11	2.9	14	3.6	259	68.0	381	100

Source: Field survey, 2017

8.6.3 Preventive measures for erosion control from government

Different preventive measures have been taken from Government in the study area to control river bank erosion but the measures are not sufficient. Concrete block and geo bag filling has been noticed in those unions which have been accompanied by bank erosion at present. Among the studied unions geo bag filling shows highest percentage at Khuniagachh union (81.9%) and concrete block filling shows highest percentage at Bidyananda union (46.3%). Protection through groin (55.9%) and boulder (44.1%) has been noticed only at Purba Chatnai union. Therefore, this union has been faced low erosion at present. The respondents opined that groin construction in Purba chatni union and unplanned sluice gate opening in Teesta barrage during monsoon causes erosion to the downstream locations. About 45.1% respondents answered regarding no erosion control initiative has been taken in their union. Among the preventive measures for erosion, geo bag filling shows highest percentage (32.8%) and concrete block filling represents second highest percentage (13.1%) in the study area (Table 8.38). Among the study unions, Saulmari and Belka show 100% no initiatives regarding erosion because these two unions have been facing no erosion at present. The likelihood ratio regarding preventive measures for erosion control from government in the study unions represents p value is significant (.000).

Table 8.38 Preventive measures for erosion control from government

Union	**Preventive measures for erosion control from government**											
	Groin/ Spur		**Geo bag filling**		**Concrete block filling**		**Boulder protection**		**No initiatives has been taken**		**Total**	
	N	%	N	%	N	%	N	%	N	%	N	%
Purba chatnai	19	55.9	0	0	0	0	15	44.1	0	0	34	100
Saulmari	0	0	0	0	0	0	0	0	64	100	64	100
Bidyananda	0	0	22	53.7	19	46.3	0	0	0	0	41	100
Khuniagachh	0	0	59	81.9	13	18.1	0	0	0	0	72	100
Kolkonda	0	0	31	48.4	18	28.1	0	0	15	23.4	64	100
Sindurna	0	0	13	43.3	0	0	0	0	17	56.7	30	100
Belka	0	0	0	0	0	0	0	0	76	100	76	100
All	19	5.0	125	32.8	50	13.1	15	3.9	172	45.1	381	100
Likelihood ratio= 619.793,df=24, p=.000												

Source: Field survey, 2017

8.6.4 Government initiative for flood management

Embankment is the only flood control method implemented in the study area. Among the studied unions 22% respondents replied about earthen embankment for flood defense in their union and 29.9% answered about embankment constructed with concrete block. 48% respondents replied about their living without flood defense. They opined that embankment has not been constructed in their area and some of them answered that embankment has been broken in previous flood. Table 8.39 indicates Bidyananda union has no (100%) flood control actions from government. Khuniagachh union has 45.8% earthen embankment but the union have no embankment with concrete block. The study result also shows that Saulmari, Kolkonda, Sindurna and Belka union has both earthen and concrete embankment but the whole union is not protected with embankment. Therefore, 48.4% of Saulmari, 42.1% of of Kolkonda, 43.3% of Sindurna and 42.1% of respondents of Belka union opined that no initiatives has been taken for flood control actions from government in their union. The study result shows significant differences (p=.000) in terms of flood control actions from government in the study unions.

Table 8.39 Flood control actions from government

Union	Flood control actions from Government							
	Earthen embankment		Embankment with concrete block		No actions has been taken		Total	
	N	%	N	%	N	%	N	%
Purba chatnai	0	0	34	100	0	0	34	100
Saulmari	10	15.6	23	35.9	31	48.4	64	100
Bidyananda	0	0	0	0	41	100	41	100
Khuniagachh	33	45.8	0	0	39	54.2	72	100
Kolkonda	18	28.1	19	29.6	27	42.1	64	100
Sindurna	7	23.3	10	33.3	13	43.3	30	100
Belka	16	21.1	28	36.8	32	42.1	76	100
All	84	22.0	114	29.9	183	48.0	381	100
Likelihood ratio=205.406,df=12, p=.000								

Source: Field survey, 2017

8.6.5 Defensive methods for sedimentation from government

The people of the study area blamed that no initiatives regarding sedimentation control yet have been implemented in the study area. The respondents highly argued for dredging in the Teesta river. All the respondents of the studied union mentioned that every flood brings huge sediments in Teesta river bed but government has not been concerned about dredging in the river. Therefore, no defensive methods for sedimentation from government have been observed in the study area.

8.6.6 Respondent’s expectation from Government

The people of the study area expect government help to cope with the river induced disaster. Relief materials help to survive during river morphology change but the respondents argued that it is not the permanent solution. They can survive only few days with the relief goods. Moreover, relief facilities do not reach to all the victims and to the real victims. The acute problem arises for joblessness due to river morphology change. Therefore, the respondents debated for no relief but employment opportunities (46.7%) from the government should be the best option for them. About 27.0% of respondent’s expectation from government is to take more protection initiatives in the bank to save their livelihood and property. Among the respondents 12.3% replied about their expectation from government is rehabilitation of the river displaces. About 8.1% and 5.8% of respondent’s expectation from government to provide low interest bank loan and infrastructural development respectively (Table 8.40).

Table 8.40 Respondent's expectation from Government

Union	Respondent's expectation from Government										Total	
	More protection initiatives in bank		No relief but Employment opportunities		Rehabilitate the displaces		Low interest bank loan		Development of infrastructure			
	N	%	N	%	N	%	N	%	N	%	N	%
Purba chatnai	0	0	22	64.7	3	8.8	9	26.5	0	0	34	100
Saulmari	21	32.8	26	40.6	7	10.9	4	6.3	6	9.4	64	100
Bidyananda	13	31.7	24	58.5	4	9.8	0	0	0	0	41	100
Khuniagachh	28	38.9	27	37.5	4	5.6	6	8.3	7	9.7	72	100
Kolkonda	18	28.1	25	39.0	8	12.5	9	14.1	4	6.3	64	100
Sindurna	8	26.7	16	53.3	4	13.3	0	0	2	6.7	30	100
Belka	15	19.7	38	50.0	17	22.4	3	3.9	3	3.9	76	100
All	103	27.0	178	46.7	47	12.3	31	8.1	22	5.8	381	100

Source: Field survey, 2017

8.7 Case studies on adaptation with river morphology change

Case study 1

Nobia banu lives in Khuniagchh union. She is a 62 years old widow woman. She lives in the balcony of union land office. During day time she stays here and there. She uses the balcony after office time and cook meal only at night. She keeps her material of daily use in other people's house. She looks very skinny and weak. She gathers and sells dried leaves of trees to earn livelihood. Her earning source hampers in the rainy season and flooding condition. She takes meal one time and most of the days become starved. She has one *shari*[55] to wear. She lost her everything in Teesta river. Once upon a time she had a family of nine members. Her husband had .30 hectare of land. But the land lost in the morphological change of Teesta river. Her house damaged 6 times in the river. She with her husband tried heart and soul to manage livelihood. After their land and livelihood loss, they took one meal of only one kg flour with nine family members. Nobia banu described that after the situation, she was so poor to manage fuel wood for cooking and used *kantha*[56] as fuel for food cooking. River morphology change forced her children to migrate in different town for earning. She didn't meet her children long time. She collects different wild vegetables for cooking. She can't remember the last time when she eat beef and mutton. She has lots of disease but never goes to doctor. She told that a bird have a nest but I'm so unlucky that I have no shelter to stay, no cloth to wear and no food to eat. The violent Teesta ruined my life.

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[55] *Shari* is the traditional dress of Bangladeshi woman with length of 6 yards.

[56] *Kantha* means ordinary rural blanket made with old clothes and *sharies* and stitched with threads.

Case study 2

Abbas Ali (50 years old) was a solvent farmer with .40 hectare of land. Now he is land less and lives in a rented house at Purba Chatnai union. 7 years ago he came into this union and build house in the present location to stay with his family. But the ongoing flood destructed his house again and his shelter lost in the river bed. Now he is living in the flood shelter with his family. Eight times he shifted his house due to river morphology change. Now he is a boat man with 6 family members. His 3 children goes to school. This year he will stop education of his children and engage them in work to manage livelihood. Moreover, he will borrow money after the flood to reconstruct house. Abbas Ali and his family members took starvation as an adaptive measure to cope with the changing river morphology. His family members catch fish in the rainy season and make *shutki* (dried fish) which they eat in the lean period. His wife cooks broken rice to reduce expenditure of rice. His each child wear only one shirt and one pant and works as agricultural day labor. He has no ability to buy sufficient food, cloth and medicine for his family but tries to cope with the adverse condition with different adaptive measures.

8.8 Respondents suggestion for better preventive measures

To minimize the impact of river morphology change the respondents gave various suggestions for better preventive measures. The respondents mentioned that dredging is essential for channelization of the river because the river is chocked with sediments

Table 8.41 Respondents suggestion for better preventive measures

Union	**Respondents suggestion for better preventive measures**									
	Embankment construction		**Dredging; both bank revetments with road construction and tree plantation**		**Awareness, education & training**		**Up to date warning system**		**Total**	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Purba chatnai	22	23.7	34	36.6	15	16.1	22	23.7	93	100
Saulmari	41	24.1	61	35.9	20	11.8	48	28.2	170	100
Bidyananda	36	30.5	40	33.9	11	9.3	31	26.3	118	100
Khuniagachh	70	28.0	72	28.8	45	18.0	63	25.2	250	100
Kolkonda	56	29.2	63	32.8	19	9.9	54	28.1	192	100
Sindurna	16	17.8	30	33.3	21	23.3	23	25.6	90	100
Belka	39	19.4	74	36.8	19	9.5	69	34.3	201	100
All	280	25.1	374	33.6	150	13.5	310	27.8	1114	100

Source: Field survey, 2017

and it lost the water holding capacity. Therefore, every year the community has to face several times flood and erosion. But according to the respondents, only dredging is not the solution. Moreover, the respondents opined that dredging as well as both bank revetments with road construction in the bank and tree plantation will be the best preventive measure to protect the Teesta river bank dwellers from river morphology change. Likewise, the study result shows highest percentage on dredging, both bank revetment with road construction and tree plantation in the bank which represents 33.6%. Up to date warning system has been emphasized by 27.8% of respondents that may help the community to save life and property (Table 8.41). About 25.1% respondents suggest embankment construction and 13.5% suggests awareness, education and training will be effective for better preventive measure. Among the study unions, Bidyananda shows highest percentage (30.5%) on embankment construction because the union is not protected with embankments, on the other hand, Belka union shows highest percentage (36.8%) on dredging with both bank revetments. Hence, the study result indicates prevention through dredging, bank revetment and up to date warning system development will be the best option for the Teesta riparian community.

Chapter Nine
Findings, Recommendations and Conclusion

9.1 Findings

Fluvial geomorphological hazards are the fate of Bangladesh due to its location, physiography and climate. River morphology change is the cause which has effects on the social, economic, cultural and environmental condition of Teesta basin and increases vulnerability of local people. The study tries to analyze the morphological changes occurred in the Teesta basin, impact of the changes and the adaptation strategies of the community people to combat with such changes. People's perception about flood, river bank erosion, sedimentation, channel shifting, and causes of river morphology change have been also discussed in the previous chapters. This chapter includes the findings, recommendations and concluding remarks of the present research.

9.1.1 Findings about river morphology change

Morphological change is an ever happening phenomenon in Teesta river through erosion and deposition of each flood. Channel shifting is also dominant in the study area. The study result unveils that during 1975-2017 the left bank of Teesta river is more erosion prone (70.43 sq.km) than the right bank (39.97 sq.km) (Table 5.1**)**. On the other hand, during 1975-2017 the left bank of Teesta river is less deposition prone (33.48 sq.km) than the right bank deposition (132.03 sq.km) (Table 5.2**)**.

The Teesta river morphology has repeatedly changed through bank line shifting and channel migration during the study decades (Map 5.7). The study finds out that among the study periods the river shows highest width (7.46 km) in segment C in 1975 and lowest width (0.62 km) in segment G in 1997. District wise erosion and deposition indicates that Lalmonirhat is highest erosive district (31.72 sq.km) and Rangpur is highest deposited district (66.48 sq.km) among the districts of Teesta basin during 1975-2017 (Table 5.9). The study finds out that among the seven study union's highest erosion (11.23 sq.km) and highest deposition (5.35 sq.km) has been detected at Khuniagachh union of Lalmonirhat district during the 42 years study period (Table 5.17).

9.1.2 Findings on geomorphological features

Diversified landscapes have been developed in Teesta river basin. The geomorphological features produced by the Teesta river have been demarcated in the present research. The identified stream channel types of the Teesta river are Active Channel (AC), Abandoned Channel (ABC), Meandering stream Channel (MSC) and Braided Stream Channel (BSC) (Appendix 7. Pic.1). Back Swamp (BS), Flood Basin (FB) and Oxbow lakes (OXL) are prominent morphological features in the river basin (Appendix 7). Pot Hole, river Terrace and Ridges are also identified during field survey which is used for different livelihood purposes. The other identified depositional landforms produced by the Teesta are Natural

Levee (NL), Bar (Char), Flood plain (FP), Alluvial Fan (Teesta Mega Fan), etc. The Teesta river form different types of Bar. The study identified Old Channel Bar (OCB), Old Lateral Bar (OLB), Old Pointed Bar (OPB), Mid Channel Bar (MCB), Recent Pointed Bar (RPB), Recent Lateral Bar (RLB) Recent Alternate Bar (RAB) in the Teesta river.

9.1.3 Findings on respondents profile and perception about morphological change

Mainly illiterate population with male dominated households

The study result shows that the study area occupies male dominated households. About 95.5% respondents are male and they are household heads (Table 6.2). The study investigates that most of the people (69%) of the study area are illiterate (Table 6.4). The study identifies illiteracy causes the people of the study area vulnerable to river morphology change in terms of their life and livelihood.

Absent household member for river morphology change

Due to river morphology change, the earning family members of the respondents were absent in their house. Field investigation about absent household member of the respondents for river morphology change identifies that 49.5%, 34.1%, 11.5% and 1.6% respondents have 1, 2, 3, 4 number of absent household member respectively (Table 6.6). 94.2% respondents replied about cause of absence is river morphology change (Table 6.7). Therefore, the study result unveils that river morphology change instigates the working population of the study area to go outside of their community for searching a new job after livelihood distruction.

Change in occupation

The study finds out that 10.8% respondents are unemployed at present owing to river morphology change (Table 6.9). The unemployed population opined about their new job search after the hazardous event and they must have to change occupation for survival. Currently most of the people of the study area are engaged in wage labor in farm (34.4%) and wage labor in non-farm activities (22.8%) and only 9.7% respondents are involved in own farming but earlier 3.9% were wage labor in farm as well as 2.8% were non-farm wage labor and 87.1% respondents were involved in own farming(Table 6.8). Thus, the present study investigates that, change in occupation occurs mainly in farming to wage laboring sector. The study explores the fact that agricultural land loss for river morphology change instigates the Teesta riparian community to change their occupation and turn into wage labor.

Dependency on secondary occupation

The present study identified that secondary occupation pays dominant role in the socio-economic condition of the respondents. After the destruction of main occupation for river morphology change the people of Teesta basin rely on secondary occupation. Among the secondary occupations wage labor farm (36.4%) and wage labor non-farm (34.3%) has significant influence on victim's livelihoods ((Table 6.11)

Change in farmer type

Substantial changes have been observed in present and past farmer type. The study result indicates that before most of the respondents of the study area were marginal farmer (80.1%) but at present it decreased in 17.8% (Table 6.13). The study also finds out that landlessness has been increased from 6.3% to 81.6% due to river morphology change. Among the respondents 96.6% replied about the cause of occupation/socio-economic alteration is river morphology change (Table 6.14).

Tree and bamboo clump as important household asset

The study observed that trees are important household asset but river morphology change and recurrent shifting of house causes monetary loss of trees. The study result indicates that about 47.5% respondents have no ownership of trees due to destruction of trees in the river womb owing to river morphology change (Table 6.15). The respondents argued that though they get loss of trees/bamboo clumps due to river morphology change, the people of the study area become aware about tree plantation in house and consider tree and bamboo as necessary household asset. There is also a remarkable feature regarding tree ownership is that about 52.5% respondents have trees in and around house but most of the case the trees are small in size which has no monetary value. The study observed most of the houses have bamboo clump to cope with changing river morphology. 64.7% households has bamboo clump because bamboo helps to rebuild house in a new destination (Table 6.16).

Community without Savings

The study investigates that the community of Teesta basin have insufficient money to fulfill their basic needs. Moreover, savings of money after expenditure is beyond their means. The study explores about 89.5% respondents of the study area have no savings (Table 6.17). The respondents argued that river morphology change diminishes the socio-economic condition of the community. Therefore, they have no money for savings.

Build house with salvageable and durable materials

The study result highlights that most of the houses (93.2%) are *kancha* in type (Table 6.18). House building materials are mostly corrugated iron sheet 86.8% (as roof materials) (Table 6.19) and 80.7% wall materials are also found corrugated iron sheet in the study area (Table 6.20). Respondents answer regarding causes of making house mainly with corrugated iron sheet was the materials are easy to remove during river morphology change (80.7%) (Table 6.22). The community of Teesta basin constructs their house with corrugated iron sheet due to its salvageable capacity. Moreover, it is also remarked from the study that the community also use corrugated iron sheet for its durability.

Hamper in drinking water collection and toilet facilities

The present study observed that river morphology change obstructs drinking water collection and toilet facilities of Teesta riparian community. About 12.8% respondents collect drinking water from neighbor’s tube well because they experienced tube well destruction in the river womb in the previous floods. Likewise, 17.9% respondents opined about their tube well departed in the river womb in 2017 (Table 6.23). The respondents opined that drinking water collection from neighbor’s house causes different social problem. The study also investigates about 17.8% respondents toilet destroyed in the river womb in the ongoing river morphology change and most of the toilet (74.3%) of the respondents is *kancha* in type (6.24). The study investigates the cause behind *kancha* toilet type. The respondents mentioned that they make low cost *kancha* toilet due to recurrent river morphology. change causes toilet destruction

Closest distance of homestead from river

Field data regarding the distance of residence of the respondents denotes that the community of Teesta basin predominantly lives very close to the river though they know the severity of river morphology change. About 39.6% respondents live in the bank of Teesta (Table 6.25). Furthermore, 30.7% people lives within 100 meter distance from the river. This implies that the community of the study area lives closest distances from Teesta river and become the victim of riverine disaster.

Homestead shifting

Homestead shifting is a major finding of the study. About 98.7% respondents replied regarding their homestead shifting due to river morphology change (Section 6.4.3). The time of staying at present house answered by the respondents is less than one year 12.6%, 1-4 year 29.1% (Table 6.26). Therefore, the study observed that river morphology change causes homestead shifting and unstable lifestyle of the riverine people.

Relocation of house close to source region

The study result shows that homestead relocation is a common tendency towards river morphology change and people tries to live closest to their previous house. 51.7% respondent’s place of displacement is another location of the union that they presently live (Table 6.27). The study investigates that the victim of river morphology change do not leave their source region due to the hope of eroded land accretion and reconstruct house in another location of the same union and the nearby union or village that they previously lived.

Frequent flood occurrences

Outcomes on flood types in the study area explore that Monsoon flood occurs mainly (54%) in the study area but flash flood also a major flood type (46%) in Teesta basin (Table 6.28). The frequency of flood is also high in the study area. About 82.2%

respondents opined regarding flood occurrence in every year in the study area (Table 6.29). The study explores that flood occurs more than one times in each year. The study result indicates that 67.2% respondents replied about two times flood occurrences and 25.2% informed three times flood occurrences in the study area in each year (Table 6.30). The average depth of inundation in the flooding condition is 3-4 feet according to 76.6% of respondents in the study area (Table 6.31). Hence, the study result explores the fact that flood occurs almost every year with 2-3 times flood attack in every single year. The study finds out that the frequency, intensity of flood in each year, types of flood and depth of flooding has close relation to frequent river morphology change in the study area.

High intensity of erosion occurrence

The study examined the condition of river bank erosion in the study unions according to the respondent's opinion in the recent floods and finds out that the condition of erosion is worst in Bidyananda and Khuniagachh union at present (Table 6.32). The study depicts that the intensity of erosion is high in the study area. Every year erosion hits in the Teesta basin. The findings of the study indicates that depending on flood frequency erosion occurs several times in each year (63.3%) (Table 6.33). The study result shows that severe erosion occurs (57.5%) in the months of *Ashar-Sravan* (mid june-mid August) (Table 6.34).

Findings on degradation and aggradation activities of Teesta

Findings regarding degradation activities of Teesta river explores almost same responses in the study unions (Table 6.35). Thus, the study identifies that degradation activities such as channel shifting, erosion, bank failure and river valley widening occurs continuously in the study area. Multiple response analysis of aggradation activities of Teesta river indicates highest percentage (26.1%) on char formation. Other aggradation activities for example natural levee, under water shoal and sediment transport anomalies are also remarkable in Teesta basin (Table 6.36).

High sediment deposition

High sediment accumulation and thus multithreaded river channel pattern has been observed in the study area during field survey. The study result also explores about 44.6% of respondent's responses regarding high intensity of sediment deposition in the study area (Table 6.37). Recent sediment deposition detected by the respondents has been observed at Khuniagachh, Purba chatni and Kolkonda union.

High to very high level of channel shifting

The study result identifies frequent channel shifting in the study area. The community of Teesta basin observed the situation of channel shifting from their childhood and illustrated the picture of ever-changing channel pattern of Teesta river. Hence, the study identifies 39.4% replies regarding recently house gone under the river womb and now the river is nearest to house has been answered by 37.0% of respondents (Table 6.38). Again, the respondents mentioned that few years ago river was 1-2 km far from house and in childhood, the river was near to house but now it is far from house. The response of the community designates the shifting behavior of Teesta river. The findings of the study reveals high to very high level of channel shifting (46.5%) in the study area (Table 6.39).

Elevated river bed causes flood

The study identified three causes of flood in Teesta basin are: heavy rainfall, high volume of upstream discharge and elevated river bed for sedimentation. Among the different causes of flood, highest percentage (46.7%) has been depicted in river bed rise for sediment deposition in the study area (Table 6.43). Thus, the study result represents that due to high concentration of sediment deposition, the Teesta river bed is elevated than before and it is the foremost cause of flood in the study area.

Flood, non-cohesive bank material and human activity causes bank erosion

The study explores the fact that flood, non-cohesive bank material and human activity causes river bank erosion in the study area. Multiple response analysis regarding causes of river bank erosion indicates highest percentage on flood (36.7%) because, erosion occurs after the recession of flood water. Moreover, weak soil condition or non-cohesive bank material is also responsible for river bank erosion which has been replied by 33.1% of respondents (Table 6.44). A lot of development activities have been occurred in the upstream and downstream locations of Teesta river. Therefore, the study also identifies that human activities are also responsible for river bank erosion in the study area.

Flood, river bank erosion and human activity causes sedimentation

Findings’ regarding causes of sedimentation in the study area portrays that flood and upstream sediment flow is the main cause of sedimentation in the study area but river bank erosion and human activities area also responsible for sedimentation. Human activities such as embankment and bridge construction, river revetment and eroded bank materials are liable to sedimentation. The study result depicts 37.3% of responses regarding the cause of sedimentation is flood and upstream sediment flow which shows highest percentage of the observation (Table 6.45).

Sediment deposition and erosion causes channel shifting

The study identified that sediment deposition is the main cause behind channel shifting in the Teesta river. The study result also unveils another important cause of channel shifting is river bank erosion. About 43.6% respondents opined regarding sedimentation and 35.7% respondents replied about erosion causes channel shifting (Table 6.46).

9.1.4 Findings regarding impacts of morphological change

House reconstruction and repair for river morphology change

The study finds out the respondents repair/reconstruct their house every year due to river morphology change. In the study area, the affected people repair house owing to damage of homestead for flood. Likewise, the community reconstruct house in another location after river bank erosion. Field observation of the study investigates that the community ruins after river morphology change, they have no money to rebuild/ reconstruct house then they get loan from money lenders with high interest for housing. House reconstruction/repair cost has been detected highest percentage (42.2%) on the amount of Less than 30000 BDT for river morphology change (Table 7.1). Thus, the community of the study area has to face the impacts of river morphology change in their homestead rebuilding and shelter management.

Standing crop loss

Findings of the study reveal that standing crop loss is a regular incident in Teesta basin for flash flood. Food crops (mainly paddy and pulses), cash crops (mainly jute and tobacco) and vegetables wash away within a moment due to sudden river morphology change. The amount of standing crop loss varies within different types of farmer. The study result shows that about 51.3% respondents lost their standing crops of more than 1000 kg which shows highest percentage of standing crop loss owing to river morphology change (Table 7.2).

Livestock damage

The study investigates that more or less every family of the study area have livestock such as cow, goat and sheep. Moreover, horses are also remarkable domestic animal for transportation of goods. Death of livestock in flood water, falling down of animals in river gorge during erosion and death for illness owing to inundation causes livestock damage in the study area. The study result shows highest percentage (75%) regarding loss of livestock’s in the amount of less than 30000 BDT and second highest percentage (18.3%) in the amount of 30000-60000 BDT for river morphology change (Table 7.3).

Loss of poultry

Poultry is considered as most important productive asset in the study area because during river morphology change the community of Teesta basin easily can sell these domestic fowl and get cash money in the time of hardship. But loss of poultry diminishes the hope of getting cash money of the riparian community. The study result portrays the loss of poultry ranging from less than 1000-more than 3000 BDT owing to river morphology change. Highest percentage (64.1%) regarding poultry loss has been observed in economic loss of less than 1000 BDT (Table 7.4). Moreover, about 27.8% respondents’ poultry loss occurred in the amount of 1000-2000 BDT.

Loss of tree, garden and bamboo clump

During field survey it has been observed that household assets such as tree, garden and bamboo clump etc. damage occurs during river bank collapse in the study area. The study investigates the loss of tree; garden and bamboo clump into the river gorge causes enormous economic damages of the community of Teesta basin. The study finds out about 74.5% of respondents replied regarding less that 30000 BDT economic loss in tree, garden and bamboo clump loss (Table 7.5).

Change in income and livelihood

The study explores that the most disastrous impact of river morphology change in the community of Teesta basin is change in income and livelihood. Due to the destruction of livelihood after river morphology change, substantial change has been found in respondent's income. At present 10.8% respondents are unemployed due to 2017 flood. Significant changes has been found in the income group of less than 5000 BDT, 5000-10000 BDT and more than 10000 BDT(Table 7.7 and Table 7.8). The study finds out that lower income group is increasing and higher income group is decreasing in the study area due to river morphology change.

Migration for job search

The study finds out that occupational migration occurs in the study area. Both temporary and seasonal migration occurs for income generation but when it is quiet impossible for the victim to cope with changing river morphology, then permanent migration occurs. Among the migration types seasonal migration show highest percentage (53.1%) (Table 7.9).

Change in land holding size and increasing trend of landlessness

Remarkable changes have been found in the size of land holding in the study area owing to river morphology alteration. Before the recent changes in river morphology, most of the respondents (80.1%) holds 0.02-0.20 hectare of farm land but now the same land holding size holds only 17.8 % of respondents. The study result depicts that landlessness increased due to river morphology change (at present 81.6% and before 6.3%) (Table 7.10 and Table 7.11). Hence, the study unveils change in land holding size and increasing trend of landlessness in the study area.

Destruction of economy for land loss

The economic conditions of the respondents have been ruined due to land loss in the river gorge. The findings of the study depicts that the agro-based economy of the study area is hampered for loss of land. The study result shows that the victim land owners of river morphology change get loss of money ranging from less than 300000 BDT to more than 600000 BDT and most of the respondents (47%) had the economic loss of less than 300000 BDT for land loss. (Table 7.12).

Land loss is higher than land regain

The study finds out the fact that land loss is easier but regaining the accreted land is a hardest process. The result of the study regarding eroded land accretion shows only 19.2% respondents land accreted after erosion. (Table 7.14) and the amount of accreted land is highest(46.6%) in the amount of 0.02-0.20 hectare. The study finds out that land loss is higher than land regain in the study area and the amount of accreted land is very little than the land loss of the respondents.

Ownership problem of accreted land

Observation from the field, it has been remarked that land accretion causes ownership problem and social conflicts. The study finds out that among the accreted land owners about 75.3% have not get the legal ownership of the accreted land (Table 7.16). Therefore, the study explores that due to ownership conflicts the real owner of the lands do not get back their land after accretion.

Sand cover in the accreted land

Reemergence of eroded land gives birth of a lot of issues. The study result indicates that though land emergence brings the hope of land regain to the farmer but sand coverage in the land diminishes the chance of cultivation instantly. The study result shows about 38.9% of people do not cultivate the accreted land due to sand cover in the accreted land (Table 7.18).

Findings of the gap between erosion and accretion of land

Frequent sediment deposition and land accretion occurs in Teesta basin but most of the victim does not get back the land again for various socio-cultural and environmental conditions. If the eroded land accreted after 20 years later it becomes *khas* land according to the rule of the Government of Bangladesh. Some people sell the land before erosion to cope with river morphology change, so they do not get back the land after accretion. Ownership problem and land grabbing are recognized issues in the char lands of Teesta basin. The study finds that after receiving the lawful ownership of land, the land owners do not cultivate the land due to unstable condition of char and sand deposition for recurrent flood. Therefore, from satellite image processing and field investigation it has been examined that erosion and accretion causes river morphology change. The people of the study area battle against river morphology change. Though, accretion and char formation occurs, very few of the land property holders get back the lost property and cultivate the land again. Sometimes, it needs one generation to another generation to get back the land. Thus, the study highlights that it is easy to lose the land for river morphology change but difficult to regain the accreted land and cultivate it. As a consequence of morphological change in Teesta river, the people of the study area face '*Monga*' and they are known as '*Mofij*'.

Several times homestead displacement and damage of house

Frequent river bank erosion causes several times homestead displacement in the study area. Highest displacement (48.6%) for river bank erosion has been depicted in 7-9 times among the respondents (Table 7.19**)**. The study result also shows the people of Teesta basin lost their house more than 9 times due to river morphology change but they don’t lose the hope of lives in a brutal environment. The study depicts erosion causes homestead displacement as well as partial damage of house occurs owing to flood incidence. Recurrent flood impacts on household damage and 53% respondents replied about7-9 times damages of their house for inundation (Table 7.20).

Damage in household and agricultural commodity

The present study tries to explore the cost of agricultural and household commodity damage. The study investigates that materials of daily use, furniture, kitchen kits, fertilizer, pesticides, insecticides and seed of different crops have been damaged due to river morphology change. The result of the study shows highest percentage (37%) in more than 20000 BDT economic losses in household goods damage (Table 7.21). Moreover, agricultural commodity damage has been observed ranging from less than 5000-more than 10000 BDT (Table 7.22). Thus, the study investigates huge economic losses in household and agricultural goods in the study area.

Inadequate food consumption

The study investigated that morphological change in Teesta basin impacts on daily food consumption of the community. About 79.3% respondents consume food two times daily (Table 7.23). The ultra-poor people manage hardly one time food for their survival. This reveals the condition of inadequate food consumption in the study area. The study finds out that only the solvent people have the adequacy of food and they take their meal three times daily.

Discontinue education in secondary school

The study identifies that the students try to go in primary school but after the completion of primary education they do not go to school for secondary education because parents engage the children in work for livelihood. Therefore, the victim of river morphology change intensifies their income through engaging the school going children in laborious job for extra earnings. The study result regarding the condition of school going represents that at present 72.2% of children stopped going to secondary school after river morphology change (Table 7.24). Moreover, the study finds out that inaccessible zigzag channel pattern and remoteness of char hampers education of the children of Teesta basin.

Flood and erosion impacts on health

The community of Teesta basin has to face different health related problems in flood and erosion. In flooding condition people are affected by diarrhea, respiratory disease, skin infection and also with snake bite. The study observed highest percentage (38.5%) on diarrheal disease in the study area due to flood (Table 7.25). The people of the study area are poor and they spend very little amount of money for treatment and they rely on village doctor. The study result for sanitation problem due to flood inundation includes toilet goes under water, toilet is covered by sand and toilet waste floats on water (Table 7.26). The study identified unhygienic conditions such as spread odor, cooking problem, floor damage, increase of insect, earthworm, frog and snake in house in flooding situation. Field investigation explores that the top most unhygienic condition for flood inundation is cooking problem (39%) (Table7.27). The effect of erosion on human health designates that 36.7% of respondent face weakness for starvation (Table 7.28).

Flood impacts on environment

The study tries to explore both the constructive and destructive influences of floods on environment. The positive influence of flood on environment implies highest percentage on it fertile agricultural land (47%) (Table 7.29). The study detects negative impact of flood on environment which point toward highest percentage on it erodes river bank extremely (33.1%) (Table 7.30).

Impact of erosion on environment

The study examined that erosion has no positive impacts. Field investigation result regarding negative impact of erosion on environment suggests loss of land (37.6%) which shows highest percentage of the observation (Table 7.31). The study also depicts wide river valley and damage of vegetation are also the negative impacts of erosion on environment.

Sedimentation impacts on environment

Sedimentation is such a kind of fluvial process that impacts on environment. The study result of sedimentation impacts on environment conveys various optimistic views such as increase in soil fertility, char formation, increase in dwelling place, good for cattle grazing etc. The findings of the study depicts highest percentage on silt increases soil fertility (34.3%) (Table 7.32) regarding the positive impact of sedimentation on environment. The result of negative impact of sedimentation on environment indicates high responses (30.8%) on sand decreases soil (Table 7.33).

Impact of channel shifting on environment

The study identifies various landform feature formation as a result of channel shifting of Teesta river. The study result shows presence of zigzag channel, wide river valley, abandoned channel and back swamp in all the study unions which are the ultimate impact of channel shifting on environment. The study also explores that except Belka union, all the other union possess oxbow lakes (Table 7.34).

9.1.5 Findings on adaptation strategies

The people of Teesta basin tries to adapt with changing river morphology through taking different adaptive measures. They took adapptation strategies for food, shelter, education, cultivation, occupation and economic condition.

Use of indigenous precautionary techniques

Adoption of indigenous precautionary technique supports the Teesta riparian community to survive with river morphology change. Among the precaution techniques anticipation of river bank erosion shows highest percentage (24.5%). The study also identified other precaution practices such as abandoning the homestead land, dissemination of the massage of erosion, tree plantation around house and protection of shelter with bamboo stack (Table 8.1).

Adopt precaution technique for homestead management

The study explored that the people of Teesta basin take different precautionary techniques to protect homestead from river morphology change. The Indigenous homestead management technique includes house platform raising, making house with corrugated iron sheet and making house in relatively high land. House making with corrugated iron sheet helps the people shift house building materials during erosion and house platform raising as well as making house in relatively high land benefits the people during flood. The study identifies highest percentage (43.2%) on house platform raising technique for homestead management (Table 8.2).

Taking precaution initiative for poultry

Poultry keeping is an adaptive strategy of the Teesta riparian community. As precautionary initiative, people keep the poultry in safe land, sell the poultry and sometimes eat the domestic fowl to recover the monetary loss. The study investigates that the most accepted (49.5%) precaution technique for poultry is keeping the poultry in high land (Table 8.3).

Precaution practice for crop harvest and seed storage

The study identified two precaution practices for crop protection from river morphology change such as early crop cutting and selling the crops in field without harvest. About 74.2% farmers of Teesta basin cut their crops before harvest season after hearing of upcoming flood incidence (Table 8.4). The study also analyzed the precaution techniques regarding crop and seed storage which detected highest percentage on storing crop and seed in *machan* (67.7%) (Table 8.5).

Use high and safe place for protection of lives

Findings of the study explores that people take shelter in high and safe place to protect lives during flood and erosion. About 83.7% people stay in earthen mound, *machan*, top of corrugated iron sheet, embankment, road and keep distance from river which is the best adopted practice to save life (Table 8.6). The study identifies that during flood people searches dry and high place. Likewise, during erosion the community looks for relatively safe place which is distant from the river to protect lives.

Fuel collection and preservation for adaptation

The study finds out that the community of Teesta basin tries to manage fuel from nature. Highest adopted precaution practice for fuel preservation is use of *machan* for protection of fuel (57.3%). The study identified another recognizable technique for fuel preservation is dried cow dung (42.7%) (Table 8.7).

Cultivate crops suitable for char lands

The study finds out that the people of the study area cultivate the crops which are suitable for char lands (75.9%) (Table 8.8). The respondents cultivate nut, watermelon, pumpkin etc. in the newly accreted land but after the improvement of soil condition they cultivate rice, maize, wheat, jute, tobacco, potato and different vegetables. Such kind of adaptation technique gives assistances to the community.

Eating habit change and starvation

The people of the study area adapt through eating habit change, starvation and food supply by relatives during flood. Starvation shows highest percentge at Khuniagachh union (48.6%) (Table 8.9). The study finds out that eating habit change is mostly accepted (51.2%) flood adaptation technique for food in the study unions. Moreover, starvation is also widely practiced (39.9%) for adaptation with food.

Reduce number of meal and insufficient food consumption

The study finds out that the respondents reduce number of meal and item of meal to adapt with river morphology change. Insufficient food consumption is a common tendency of the community of Teesta basin towards adaptation with riverine disaster. The study result shows 91.1% replies on food insufficiency for livelihood damage due to river morphology change (Table 8.10). The respondents reduce number of meal through once daily food consumption (74.7%) and twice daily food consumption (10.5%) for adaptation (Table 8.11). The study explores that river morphology change affected community minimize their expenditure through reducing per day meal.

Dependency on dry food

The study investigates during flood most accepted adaptation technique for food is dependency on dry foodstuff in the study area. People tries to store dry food items such as husked rice, puffed rice, *gur* etc. in house before the severity of flood increases. and highest percentage has been depicted adaptation with these dry food items (70.6%) during flood (Table 8.12).

Stop cooking and apply indigenous cooking techniques during flood

The study result depicts that application of indigenous cooking techniques during flood gives assistance to the community to cope with flood. Condition of cooking highlights that 39.9% respondents stop cooking and 25.2% cook in machan to adapt with flooding condition (Table 8.13). Indigenous cooking technique includes use of portable oven made with mud, cook in neighbor's house as well as cook standing in flood water. People try to cook in different places such as in embankment, school, road, flood shelter during flood.

Consume inexpensive item for meal

The present research explores that inexpensive food item plays dominant role for adaptation with changing river morphology. During flood most of the people (45.4%) take rice and mashed food items (*vorta*) as item of meal to manage the situation (Table 8.14). They choose the items which have comparatively low price and low fuel consumption in flooding condition. The study finds that the extreme poor who have no ability to eat pulse, vegetables and fish, take meal with rice-onion chili and salt (25.3%).

Wild food harvest and indigenous food making technique adoption

In the situation of erosion occurances people also changes their eating habit and took starvation as an adaptive technique like flood adptation. A very effective technique adopted by the Teesta river basin community is wild food harvest. During erosion occurrences and the condition of hardship the people of the study area collect different aquatic and wild food for their survival. They make *sutki* with dried fish and use *sutki* to make *vorta* and cooking in the lean period. *Pelka-sholka, kumrar bori* and *sidol* are very well accepted indigenous food making techniques that help the study area people to cope with river morphology change. The study also explored the strtegy of buy food items less than real need and do not eat with full stomach for adaptation (Table 8.22).

Take shelter in high land and safe place

The study result shows most of the people (44.1%) use embankment as their shelter(Table 8.16). During flood inundation *machan* are also well accepted adaptation technique for own shelter (24.4%). Thus, the study identifies that people tries to take shelter in higher places (embankments, machan, road) during flood but during erosion the people of the study area tries to save their house building materials and build house in relatively safe places like embankment (55.6%) which has been protected from erosion (Table 8.23).

Take pure water from neighbor's house

Most of the respondents (72.7%) take pure water from neighbor's house to adapt with drinking water and 17.8% respondents drink boil water (Table 8.17). In the time of erosion tube well goes under the river womb. Therefore, people suffer for pure drinking water and solve the problem through collecting water from neighbor's house (69.6%) and from relative's house (30.4%) (Table 8.24). Thus the study finds out community help plays vital role for adaptation with drinking water during river morphology change.

Stop school going during flood

Long duration flood causes school closed for several weeks to months which hamper in education. School activities are interrupted during flood and the institutions are used as flood shelters. Moreover, after flood dropout occurs to cope with socio-economic loss reduction. About 64.6% respondents stop school going for flood water inundation (Table 8.18). Dropout from school (24.4%) has been noticed after flood for destruction of livelihood.

Dependency on pharmacy and herbal medicine rather than physician

The study finds out that the community of Teesta basin depends on pharmacy and herbal medicine during inundation. In flooding period 60.4% respondents buy medicine from pharmacy without any concern from doctor, because they have no ability to pay doctor and 25.7% rely on herbal medicine (Table 8.19) to cope with illness. The herbal medicine includes *tulsi*, *thankuni,* turmeric, coconut oil etc. People also depend upon relief medicine for different water born disease like diarrhea, skin infection, cough etc. to survive with flooding condition. Few conscious people keep extra medicine in house for adaption with medicine.

Community based indigenous flood defense technique

The people of Teesta basin adopted different indigenous techniques to cope with flooding conditions. The study finds out that making barrier through sand bag pilling, artificial levee construction by mud, making barrier through tree cutting, release flood water through road cutting and community based awareness are the indigenous flood defense techniques implemented by the local community. Among the indigenous techniques making barrier through artificial levee construction shows highest percentage (37.3%) for flood defense (Table 8.20).

Community based erosion protection initiative adoption

To cope with river morphology change the people of Teesta basin initiated different community based erosion protection techniques. The community based erosion protection technique includes sand bag filling in the bank, reserve block or boulder filling, community based awareness and tree plantation. The study finds out the most accepted erosion protection technique adopted in the study area is sand bag filling (55.9%) in the bank (Table 8.25). Announcement of warning regarding flood and erosion has been initiated in local masjid. These type of community based awareness helps people to save life and property.

Indigenous coping mechanism for sedimentation

Indigenous coping mechanism assistances the local people adapt with sedimentation. Sedimentation brings new hope to the erosion victims. When new *char* develops in Teesta river the people of the study area tries to improve the soil quality through tree plantation. The people who are affected by homestead damage, took shelter in the newly accreted land. They also pasture livestock in the *char* lands because there grows plenty of grass in the newly accreted lands. The study identifies that the most effective technique to cope with sedimentation is initiating cultivation in the *char* land (52.2%) (Table 8.26).

Strategies to adaptation with river channel shifting

Field investigation result indicates that the people of the study area take initiatives to adapt with river channel shifting which includes mainly the livelihood activities. The study finds out the adaptation strategies for river channel shifting are water borne food collection from the shifted channel, fishing in oxbow lakes/back swamps and initiating cultivation in the abandoned channels after river channel shifting Table (8.27).

Change in earning and expenditure to manage livelihood

River morphology change ruins the socio-economic condition of the community of Teesta basin. Therefore, the people of the study area changes their earning and expenditure strategies through reduction of expenditure, change in occupation and migration for occupation. Reduction of expenditure is a highly adopted technique for adaptation with changing river morphology (Table 8.28). The identified livelihood strategies are livelihood diversification, income intensification and agricultural intensification (Table 8.29).

Livelihood groups and livelihood diversity

Diversified livelihood groups have been noticed in the study area for income generation. The study finds out six livelihood groups in the study area such as farmer, wage labor farm, wage labor non-farm, petty business, grocer, service etc. (Table 8.30). The people of the six identified livelihood groups are engaged

Borrowing tendency for adaptation

Both money and food product borrowing after river morphology change is a very common tendency of the respondents for adaptation. Among the sources of borrow money for adaptation highest percentage (53.8%) has been depicted in the source of money receiving from money lenders though the borrower have to pay high interest (Table 8.31). The study also finds other sources of borrowing money such as from intra households, from relatives and from local clubs which are initiated to lend money to the river victims. Most of the respondents borrow food products from neighbor’s house (70.1%) for coping (Table 8.32).

Provision of precaution for loss reduction through asset selling

Selling livestock’s, crops, house building materials and lands play significant role for the survival of the river morphology change victims. The finding of the study shows highest percentage (68.2%) on crop and livestock selling (Table 8.33).

Relief facilities for adaptation

Relief facilities play vital role for adaptation during river morphology change. Among the respondents 74.3% get relief materials and 25.7% do not get relief materials for adaptation. There exist various issues regarding relief facilities supply to the victim people. The study result indicates food items play dominant role (37%) as relief materials (Table 8.34).

Limited access to social safety net services for adaptation

The government of Bangladesh initiated various social safety net services such as VGD/VGF, old age, widow and disability allowance, cash for work etc. But the study finds out that among the respondents 47% do not get social safety net services. Without school feeding program (32.8%) and work for money (16%) the condition of other social safety net services are very vulnerable (Table 8.35).

NGO activities for community resilience

The study result depicts 59.6% responses about NGO activities in the study area to improve the community resilience regarding river morphology change induced disaster mitigation. The study identified the livelihood and rehabilitation program of the NGOs in the study unions to improve the community resilience includes house platform raise, pumpkin cultivation, livestock and feed distribution, fish cultivation in cage etc. (Table 8.36).

Loose awareness initiatives and defense from government for river management

Though flood and river bank erosion is acute in Teesta river, awareness from government is negligible in the study area. 68% respondents replied regarding no initiatives has been taken for awareness from government (Table 8.37). Among the erosion control measures geo bag filling is prominent (32.8%) in the study area (Table 8.38) which indicates more defensive methods should be implemented for erosion control. The study finds out that 48% area of the study unions has not been protected with embankment for flood control (Table 8.39). Among the study unions Bidyananda union is vulnerable to flooding because the union is not protected with embankment. Field study result also identifies 100% responses regarding no initiatives for sedimentation control in the study area.

Expectation of employment opportunities and river bank protection

The study finds out that the people of the study area expect job opportunity (46.7%) from government to combat with river morphology change. 27% respondents expect more protection initiatives in the river bank (Table 8.40).

Suggestion for bank revetment and dredging

The people of the study area suggested embankment construction, dredging, both bank revetments, awareness, education, training, warning will help them to survive in the Teesta basin. The study result unveils the most suggested preventive measure is dredging; both bank revetments with road construction and tree plantation which shows 33.6% responses (Table 8.41).

9.2 Recommendations of the study

The study result portrays the morphological changes of Teesta river basin, impact of such changes and adaptation strategies of the affected community. Therefore, the present study depicts the recommendations in three different segments such as recommendations for impact minimization through river management; recommendations for planning, decision making and cooperation and recommendations for adaptation.

9.2.1 Recommendations for impact minimization through river management

Based on the study results the following recommendations for river management may be considered:

Construction and maintenance of embankments

The present study recommends constructing new embankments with low inclination and several layers and maintenance of existing embankments in the study area. The earthen embankments and roads of the study area should be raised above flood danger level and constructed with cohesive soil texture.

Dredging and re-excavation of existing wetlands

A feasibility study should be conducted in the study area where actual dredging and channel improvement is needed. Not only dredging but also maintenance of dredging will help the river a sustainable basin management. The study strongly suggests dredging in the Teesta river bed as well as in the small stream channels connected with Teesta to control the flooding situations. Moreover, the small stream channel dredging is economically feasible for Bangladesh. The existing wetlands of Teesta basin are silted up and chocked with aquatic vegetation. Therefore, re-excavation of existing wetlands in the study area will hold flood water to maintain river morphology.

Construction of flood shelter

Inadequate flood shelter has been observed in the study area. Therefore, the study suggests that the schools, colleges and community health care centers of the study area should construct such a way that it may be used as flood shelters.

Flood monitoring with more gauging stations

Only two water discharge and sediment gauging station has been established in the Teesta Basin. The study recommends establishment of more water gauging stations in Teesta basin with improved technical and manpower supports.

Lead time flood Forecasting and erosion prediction

Real time flood forecasting will be effective way to the local community for their survival in the pre, during and post flood situations. Satellite image processing, data collection, analysis with led time and real time forecast will be very effective way for flood management. To get more accuracy in flood forecasting, Bangladesh should collect water level, discharge and rainfall data from the co-riparian countries of GBM basin in the pre-monsoon and monsoon period with 48-72 hours lead time and from more upstream stations than present. Rather than empirical method, numerical models such as MIKE 21c model are very useful for river bank erosion prediction. Bangladesh Water development Board should take initiatives to use the numerical models for erosion prediction and disseminate the massage to the mass people.

Doppler radar station set up and warning

There is a radar station of BMD (Bangladesh Meteorological Department) at Rangpur. The hydrological data of Indian Teesta river catchment should be collected from radar signal to achieve lead time forecast. Moreover, a Doppler radar station set up in the Teesta catchment will also enhance the capability of BWDB, BMD and FFWC as well for warning.

Flood insurance, flood proofing and Flood fighting

Flood insurance would help the river basin community to sustain their livelihood and also defend them from borrowing tendency. Therefore, the study advocates for flood insurance. But until the floodplain zonation has not been completed it is quiet impossible to access risk of the affected people for flood insurance (Faisal *et al*., 2000). To enhance the coping capacity of the affected community the government should give emphasis on flood proofing through raising awareness, education and training about river morphology change.

Likewise, prevention may help to manage the flooding situation. Traditionally people fight with flood water through constructing barrier with sand bags, lie down trees into flowing flood water and earth wall construction. The study proposes to practice these traditional flood fighting methods to manage flooding situations. In case of heavily flood inundation areas pumping station should be established to pump out the flood water. To identify the flood vulnerable areas and set up of pumping stations, floodplain zonation is also essential.

Research on River morphology and conduct seminar/conference for river

Extensive research on fluvial geomorphology and hydrology should be carried out to find out the issues, challenges and management aspects of the concerned sector. Research grants should be initiated to attract the country wide researchers to conduct research on river and hydrological issues. Publish report, Journal articles and prepare database on flood, erosion, sedimentation and river channel shifting which will help the future researchers.

Seminar/ Workshop/ symposium/ conference about river, fluvial geomorphology, fluvial disaster impact and adaptation will enhance skill and capability of the professionals that will help on planning and decision making in the concerned sector. Hence, the existing study recommends organizing local, regional, national and international level seminar/ conference on river.

Afforestation

Stream bank stabilization with vegetation cover would be best practice for Bangladesh than the structural measures. The rooting system of trees acts as anti-erosion agent. Moreover, afforestation is also effective to control surface run off. Vegetation cover along the bank line will help in compactness of soil and prevent quick crack down of river banks.

National River Morphology Change Cell

To identify the areas of river morphology change, a monitoring cell is critically needed. The present study proposes a National River Morphology Change Cell (NRMCC). The government of Bangladesh should establish a National River Morphology Change Cell through GIS and Remote Sensing based technological supports along with skilled manpower. Figure 9.1 illustrates the proposed activity of NRMCC.

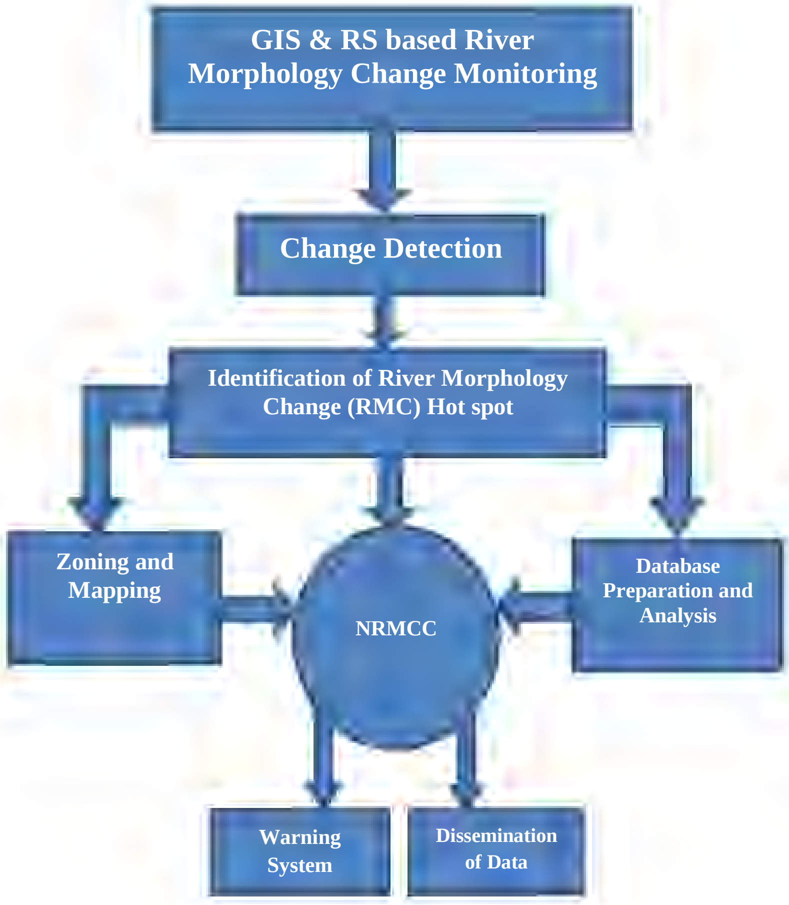
GIS & RS based River Morphology Change Monitoring
Change Detection
Identification of River Morphology Change (RMC) Hot spot
Zoning and Mapping
NRMCC
Database Preparation and Analysis
Warning System
Dissemination of Data

Figure 9.1 Proposed activity of NRMCC

9.2.2 Recommendations for planning, decision making and cooperation

Planning and decision making needs special attentions to reduce the vulnerability of river morphology change and maintain a sustainable river basin. The recommendation of the present study for planning and decision making includes:

Review the existing river management plan

The Government of Bangladesh (GOB) has taken the National Water policy (NWP) in the year 1999. The National Water Management Plan (NWMP) has been developed in 2002 to achieve long term (strategies for 25 years) goal oriented with water resources. The existing river management plan needs review with proper technical and institutional supports, environmental impact assessment, socioeconomic aspects of river basin community and the physical characteristics of floodplains. Government should develop a master plan for river training and improve a strategic plan to protect the erosive river banks.

Floodplain and land use zoning

Floodplain zoning will protect the floodplain ecology and drainage basin. Though floodplain zoning and land use zoning/ planning has not paid much attention from the planners of the country but this nonstructural measure is highly recognized in the developed countries (Faisal *et al*., 2000). The study highly recommends floodplain and land use zonation for not to save only the riverine community but also protect the riverine environment. River capture by the land grabber's is an important issue for floodplain zoning. To ensure a sustainable floodplain zoning it is crucial to take into consideration not to build structure in abandoned channel and its floodplains. Development activities in the paleo channels should be restricted because extreme flooding may recapture the river channel (Ramkumar, 2009).

Field level structural organization of Disaster Management Bureau

Field visit and questionnaire survey from different organizational personals it has been investigated that during river morphological disaster the management activities was conducted through the Disaster Management Bureau (DMB) with the support of District commissioner, Upazilla Nirbahi Officer (UNO), Upazilla Parishad Chairman and Union Parishad Chairman. Thus, the study suggests establishing field level Disaster Management Organization in the disaster prone Unions, Upazillas and Districts.

Strengthening the activity of Joint River Commission

The study suggests to strengthening the activity of Joint River Commission (JRC) to maintain the morphology of the Teesta river and the other rivers as well. The JRC should actively work to solve the Teesta water dispute and give efforts to the Teesta water treaty.

Cooperation with co-riparian countries and regional-global collaboration

Deteriorating environment of Ganga-Brahmaputra-Meghna basin can be improved through collaboration with co-riparian countries. Establish an organization of same river basin sharing countries to mitigate trans-boundary river issues and conflicts (Ahmed, 2007).

Bangladesh has to enhance the regional and global collaboration for trans-boundary water issues and the river linking projects of the upstream countries. To ensure the sustainable water resource and river basin management, Bangladesh needs to improve networking with Global water partnership (GWP) and World Water Council (WWC) with the countries mission and vision of development in the water resource sector.

Coordination among the experts

River morphology change issues, challenges, impacts and adaptation needs attention from the experts of various fields related to river and water. The mass media have to collect and broadcast the information. The policy makers have to implement the expert's opinion. Thus, coordination among the experts of different fields, mass media and policy makers would help to establish a sustainable river basin. Figure 9.2 shows the coordination among the experts of different fields.

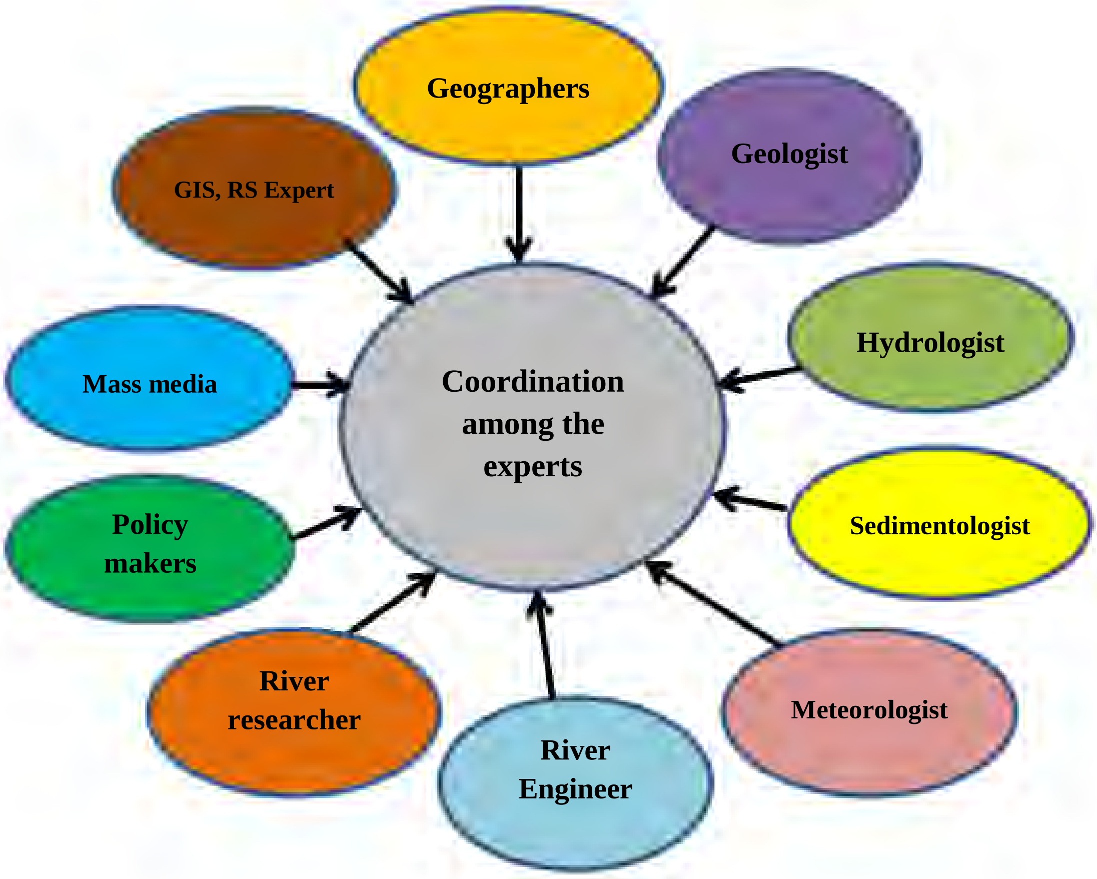
Geographers
Geologist
GIS, RS Expert
Hydrologist
Mass media
Coordination among the experts
Sedimentologist
Policy makers
River researcher
Meteorologist
River Engineer

Figure 9.2 Coordination among experts of different sectors to reduce vulnerability of river morphology change

Integration among the water related sectors

Cooperation among the planning, monitoring, forecasting, warning and management system should be developed for flood and river bank erosion vulnerability reduction to maintain sustainable river morphology. Integrated Water Resources Management (IWRM) should get priority. The present study recommends building Bangladesh Integrated River Basin Organization (BIRBO). The institution should be established and supported by all the Government and non-government organizations aimed at the development of hydrological and morphological issues and challenges. The present study suggests institutional supports from Flood Forecasting and Warning Centre (FFWC), Bangladesh Water Development Board (BWDB), Water Resources Planning Organization (WARPO), Centre for Environmental and Geographic Information Services (CEGIS), Space research and Remote Sensing Organization (SPARSO), Institute of River Research (IRR), Joint Rivers Commission (JRC) and Institute of Water Modeling (IWM), to establish Bangladesh Integrated River Basin Organization (BIRBO) (Figure 9.3).

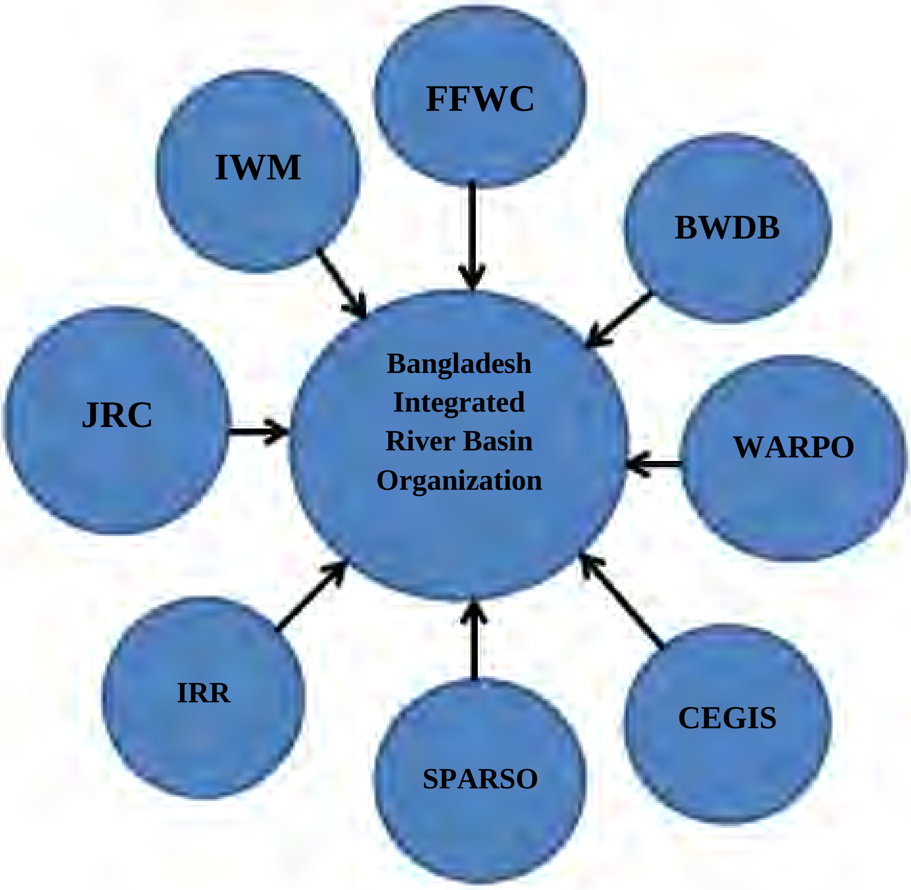

Figure 9.3 Institutional Supports for Bangladesh Integrated River Basin Organization (Modified concept from Ahmed and Galib, 2007)

9.2.3 Recommendation for Adaptation

Both institutional and non-institutional support is essential for adaptation with changing river morphology. Though the Government of Bangladesh and NGOs play role to disaster recovery in the affected community, the present study suggests more Government and NGO initiatives during and post river morphology change incidence for building peoples resilience towards adaptation. The present study recommends the following adaptation strategies.

Public participatory approach and Social consciousness for adaptation

Public participatory approach is required in the study area and the mass people should get priority. Community level team building is very much crucial for river morphology change disaster mitigation such as relief distribution team, rescue team, Warning team and Advisory team with local learned and elderly people. Social consciousness will substantially help the community to adapt in a changing riverine environment. Observation from the field reveals that warning of disaster in the mosques play significant role in adaptation with disaster. Motivational activities of students to contribute society with their humanitarian work may support the community to combat against disaster. Organizing different age groups for voluntary works such as road repairing; salvaging household materials; helping woman, children and elderly people during disaster will also enhance the coping capacity of the river victim.

Recommendation for rescue and relief distribution

The study suggests a well-trained rescue team of armed force should be ready in the emergency period. The force must be well equipped and helicopter is essential for rescue from remote char because the river become violent for high volume of water discharge in the monsoon. The local rescue team will work with the armed force. Moreover, the study observed inequalities in relief distribution. Hence, the study recommends identification of vulnerable family (destitute and hard core poor) to distribute relief with priority basis. The study also suggests distribute relief in the remote areas and pursue relief to all the victims rather than repeat distribution of relief as well as not to distribute relief to the relatives of local leaders.

Rehabilitation

The study advocates allocation of the asroyan (accommodation) and guccho gram (clustered village) shelter of Government to the real homeless hardcore poor. will reduce the vulnerability of the river victims.

Health adaptation

Temporary medical camp will help the affected people from water borne disease. Shelter and relief camps must be fortified with medical facilities. For emergency management, paramedical training should be given to a pre-organized social group. Veterinary doctors should play their contribution to protect the domestic animals. Adequate sanitation facilities in the shelter and relief camp should be maintained. Hence, the study suggests sufficient treatment and sanitation facilities in the flood shelters. Moreover, the study also recommends replacing tube well and making sanitary latrine in higher place (above floodplain) for health adaptation.

Agricultural adaptation

The study recommends government initiatives to provide agricultural commodity to the farmers. Likewise, access to low interest bank loan to the agrarian society should be very effective to combat with river morphology change. Motivate the farmers to grow deep water Aman or mixed broadcast Aus cultivation to protect crops from flood waters. Long Aman seedling transplantation technique will be very helpful after flood water recession. The farmers should Store seed for their survival. Therefore, the study suggests farmers training on crop and seed preservation and protection from flood water which will enhance their agricultural adaptation with changing river morphology.

Employment opportunities

The study recommends provision of employment opportunities for the affected people all around the year to reduce livelihood vulnerability. Government and NGOs should spread out Char Livelihood Development project to ensure employment opportunities to the river victims of Teesta basin. Expansion of cattle farming in the char lands would help the community to enhance their livelihood opportunities. Besides, initiating food for work and cash for work during and aftermath of disaster will compensate the vulnerability of the community.

Social safety nets

The government of Bangladesh has initiated different social protection services for poor community and environmental victims. But the actual victims are far from the social safety services. The present study recommends the following measures to ensure social protection for the deprived people of Teesta basin:

- Introduce the affected people with the programs/ activities/ projects from government to reduce their vulnerability to disaster.
- The widow, old age people and women are the most destitute community of the society and they are more susceptible to riverine disaster. So, they should get priority to gain widow allowance, old age allowance, VGF and VGD cards for adaptation with changing river morphology.
- Swanirvar Training Program of Government should be given to the community of Teesta basin for building resilience towards river morphology change.
- Test Relief (TR) Food and Test Relief (TR) Cash would be very effective way to reduce livelihood damage during and post disaster conditions.
- Open Market Sales (OMS) service of Government Food Security Program should be initiated for the river victims of the study area.

9.3 Conclusion

The Teesta is the heart of the agrarian society of northern Bangladesh. But people's vulnerability to river morphology change is the main problem of the study area. The present research has been carried out through GIS and Remote Sensing techniques to determine the morphological changes in Teesta river basin. On the other hand, the impact and adaptation of the affected people has been investigated through different field survey techniques with the help of multiple set of questionnaires. The findings of the study illustrates the erosional and depositional changes from 1975-2017 in the Teesta river basin. From the evidences of the historical past and the analysis of the study it has been established that the Teesta river gradually shifted its course. Several abandoned channel, back swamp, flood basin, bar, oxbow lake have been remarked in the study area which determines distinct morphological landscapes in the Teesta floodplain. Such research result approves the findings of Islam *et al*., (2014). The study of Chakraborty and Ghosh (2010); Ghosh (2014) also agrees with the geomorphological changes of Teesta river. The Teesta river experiences perennial flood with indicative magnitude and huge sediment load deposited in both the bed and the bank. The present study investigates recurrent flood occurrences in Teesta which has consistency with other studies such as Pal *et al*., (2016) and Rahman *et al*., (2011).

Likewise, this study approves that fluvial geomorphological disaster conveys countless distresses to the people inhabited in Teesta floodplains. Standing crop loss, death of human being, loss of poultry, loss of livestock, destruction of homestead, loss of livelihood, sickness and environmental alteration are the impacts of river morphology change which causes socio-economic loss of the study area. Extensive damages have been occurred in the study area due to recurrent flood and bank erosion of the Teesta. The impacts of flood and river bank erosion is well documented in the previous studies such as Armah *et al*., (2010), Rahman and Khan (2011), Uddin and Basak (2012), Bhuiyan *et al*., (2017). The impact of river morphology change instigates the community of Teesta basin to take different adaptive measures for their survival. The findings of Haque (1988), Hutton and Haque (2003) Paul and Routray (2010) and Islam *et al*., (2014) also confirm the community level flood and river bank erosion adaptation. The Teesta riparian community initiated their own adaptation strategies on livelihood, shelter management, food making and health environment. The study explores the adaptation techniques of the respondents are impact minimization techniques, loss reduction techniques, indigenous survival techniques and change in livelihood strategies. Such kind of adaptation strategy gives substantial strength to the local community to fight against frequent river morphology change in Teesta basin. Moreover, Government and NGO initiatives towards vulnerability reduction also contribute the victim of river morphology change to survive in a harsh environment.

Though, Government initiative helps the community to battle against disaster, the present study observed weak Administration and shortage of manpower in the study area during river induced disaster impacts on the community of Teesta basin. However, the study suggests strong Government support system after river morphology change impacts for community adaptation with disaster and also for infrastructural impact recovery. In addition, the NGOs should extend livelihood development activities not only for their microcredit receiving people but for the river victim of Teesta basin. The Government of Bangladesh should take necessary steps for impact recovery, adaptation as well as river management in the study area. But the Teesta River management is not an easy task for Bangladesh. Because, firstly, the Teesta is a trans-boundary river and Bangladesh possesses its downstream location. Secondly, the Teesta is an active alluvial river, thirdly, high population density and displacement for river bank erosion and channel shifting, fourthly, corruption in the concerned sector and finally the budget constraints are the barriers for Bangladesh in river management. Therefore, public participatory approach with self-financing from solvent stakeholders may be an effective solution for mitigating the river morphology change related issues. Both short term and long term flood and erosion protection actions are required in the study area to combat with river morphology change. Shelter management and relief distribution gets better attention during flooding period. Though, there is an extensive effect of river bank erosion on the victims and in the society, this sector has not paid much attention from the decision makers regarding the relief and rehabilitation program. Thus, the study advocates give emphasis on both flood and river bank erosion for emergency management. It also recommends performing a feasibility study of what type of flood, erosion and sedimentation controlling method is needed where, when and how it should be implemented and maintained.

River morphology change is not an issue of Teesta riparian community but also a major concern for Bangladesh and several factors such as geology, anthropogenic impacts on riparian environment and climate change effects are involved with the issue. Hence, engineers, planners and decision makers face tremendous challenges for frequent morphological changes occurred in river basins. Therefore, this kind of disaster should be mitigated through multidisciplinary approach. Similarly, expertise from different fields, modern technologies, strong planning initiatives, implementation of planning and mitigation measures can save the life and property of the Teesta river basin community. Apart from that, considerations should be taken from economic, socio-cultural, environmental and political aspects to mitigate the disasters associated with river. Flood, sedimentation, riverbank erosion and channel shifting process induced morphological changes of the river cannot be stopped but it can be maintained through appropriate precautionary measures. The study confirms that adoption of more indigenous precautionary measures and indigenous techniques for food, shelter and health adaptation will substantially reduce the impact of river morphology change. It is extremely important to measure the actual length of Teesta river and the best approach to control the river morphology is to use combination of both structural and nonstructural measures. Likewise, the respondents of the study suggested provision of employment opportunity to the river victim and dredging with both bank revetments along with tree plantation will be the best solution for their existence in the riparian environment. The findings of the study suggests implementation of planning, enforce laws and regulations regarding river and water issues, floodplain zonation and mapping, involvement of community people, timely monitoring, forecasting and warning will mitigate river morphology change related issues and save the life and property of the Teesta river basin community of northern

Bangladesh. The outcome of the present study also suggests that synchronization among the river and water related sectors along with planners and decision makers will ensure a sustainable river basin management in Teesta river basin.

9.4 Future research direction

The present study is the starting point of Teesta river morphology change of previous four decades. This research also explores the impacts and adaptation strategies of Teesta riparian community according to the objectives of the study. But the study could not include all the aspects of river morphology change. Moreover, there are so many dimensions of riverine disaster impacts and adaptations such as mental, social, cultural and political. Therefore, the study directs for future research which has not been explored in the present research. Similarly, Teesta river needs greater attention from the researchers to mitigate the geo-political issues. Human intervention and development activities cause distinguished changes in river morphology which is a vast area of research. The findings and limitations of the research exposed the door of future research. The present research triggers the future research in the following dimensions:

- Time series analysis of hydrology of Teesta river to detect river morphology change.
- Bar dynamics and river morphology change.
- Change in planform pattern of the Teesta river.
- Forecast the river dynamics to reduce vulnerability of river morphology change.
- Community resilience towards river morphology change with indigenous and institutional supports.
- Climate change effects on river morphology.

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Appendix-1

Questionnaire On

Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

Questionnaire number:	Name of respondent:	Upazilla:
Date:	District:	Union:

Section A: Personal and Demographic Information

Respondents profile:

1.Age	2.Gender	3.Education	4.Marital Status
	i) Male	i)) Illiterate	i) Married
	i) Female	ii) Can signature	iii) Widow/ Widower
		iii) Primary education	iv) Divorced
		vi) SSC	
		vi) HSC	
		vii) Graduate	

Information of household member:

5.Total H. H member	6.Absent H.H member	7.Cause of absence

Section B: Occupation and Asset Information

8.Current occupation	9.Past occupation	10. Secondary occupation	11. Farming type (current)	12. Farming type (past)	13.Cause of occupation change/Socio economic change

Is there any fruit /wood tree or bamboo clump in your ownership? ?

14. Fruit Tree	15. Wood tree	16. Bamboo clump
i) Yes (Mention the type of trees)	i) Yes (Mention the type of trees)	i) Yes
ii) No	ii) No	ii) No

17. Do you have any savings after your expenditure? i) Yes ii) No

Section C: Socio- Cultural Information

18. What type of house do you live in? i) Kancha ii) Semi-pacca iii) Pacca

What kind of materials do you use to make your house? Please (Tic the information)

19.Roof materials	i) Corrugated iron sheet	ii) Thatch	iii) Concrete	
20.Wall materials	i) Corrugated iron sheet	ii) Jute stick	iii) Thatch	iv) Brick
21.Floor materials	i)Mud	ii)Brick	iii)Plaster	

22. What are the causes for making this type of house?

23. What is the condition of source of drinking water facilities?
24. Mention the condition of toilet facilities?

Section D: Morphological Change in Respondent's view

25. What is the approximate distance of Teesta river from your residence?
26. How long you are staying in this house?
27. Did you relocate from another area? i) Yes ii) No
28. If yes, then what is the reason for relocation? i) River morphology change ii) Personal problem iii) For marriage
29. From where you relocate in this area?
30. What type of flood occurs in your locality? i) Monsoon flood ii) Flash flood
31. What is the frequency of flood?
32. What is the intensity of flood occurrences in each year?
33. What is the average depth of inundation?
34. What is the condition of river erosion in your union in recent floods? i) Low ii) Moderate iii) Worst
35. What is the intensity of river erosion in a year?
36. What is the month of serious erosion occurrences?
37. What kind of degradation activity occurs by river? i) Channel shifting ii) erosion iii) Bank failure iv)River valley widening
38. What kind of aggradation activity occurs by the river? i) Natural levee ii) Char formation iii) Under water shoal iv) Sediment transport anomalies
39. What is the condition of sediment deposition in your union? i) Low ii) Moderate iii) High
40. What is the situation of channel shifting?
41. What is the level of channel shifting? i) Low-moderate ii) Moderate-High iii) High-very high

Section E: Respondent's perception about causes of Morphological change:

42. Why flood occurs frequently in your area?
43. According to your understanding, why river bank erodes?
44. What is the cause of sedimentation, give your opinion?
45. From your experience, what is the cause of river channel shifting?

Section F: Impact of Morphological Change:

a. Impact on economy and agricultural land:

46.House reconstruction/ repair cost (BDT)	47.Quantity of loss of standing crops (kg)	48.Loss of livestock (BDT)	49.Loss of poultry (BDT)	50.Loss of garden/tree (BDT)

Respondent's current income and income before the morphological change

51.Current income (BDT)	52. Income before the change (BDT)

53. What is the condition of migration for income or job search? i) Temporary migration ii) Seasonal migration

Land holding size (In Hector) for morphological change occurrence

54.Before morphological change	55.After morphological change	
	Amount of lost land (Hector)	Economic value of lost land (BDT)

56. Do your eroded land rising again? i) Yes ii) No
57. If answer is yes then what is the amount of gained land (in Hector)?
58. Do you have the lawful ownership of the accreted land? i) Yes ii) No
59. If answer is no then why you didn’t get the lawful ownership of the accreted land?
60. Do you cultivate the land that has been reemerged?

b. Impact on household and agricultural assets:

61. What is the frequency of homestead displacement for river bank erosion in your life time?
62. How many times your house damaged for flood?

What is the situation of asset damage?

63.Type of household asset damage	64.Cost of the damage	65Type of agricultural asset damage	66.Cost of the damage

c. Impact on food, education, health and environment:

67. What is the condition of daily food consumption?
68. What is the condition of education of children?

What is the condition of health for flood?

69. Human health problem	70. Sanitation problem during flood	71. Unhygienic situation for flood water

72. What are the effects of erosion on human health?

What is the impact of flood and erosion on environment?

73.Flood Impacts (Positive)	74.Flood Impacts (Negative)	75.Erosion Impacts (Positive)	76.Erosion Impacts (Negative)

What is the impact of sedimentation on environment?

77. Positive impact of sedimentation on environment	78. Negative impact of sedimentation on environment

79. What is the impact of river channel shifting on environment?

Section G: Adaptation strategies

a. Indigenous precaution technique before morphological change:

80. What type of indigenous precaution technique do you take before river morphology change?
81. What is your precaution technique for homestead management?
82. What is your precaution technique for loss reduction of poultry?

How you protect your crop and seed?

83. Precaution practice for crop	84. Precaution practice for seed

85. How you protect lives?
86. What is your precaution technique for fuel collection and preservation?
87. What type of precautionary technique you adopt for agricultural production?

b. Adaptation with flood:

How you adapt yourself during flood? Please tic the following

88.Food	89.Own Shelter	90.Cattle shelter	91. Drinking water	92.Education

93. During flooding condition what type of dry food you take?
94. What is the condition of cooking during flood?
95. Do you get sufficient food in the hazardous period? I) Yes ii) No
96. What's the number of meal during lean period?
97. What are the items of meal?
98. How can you get medicine during flood?

c. Adaptation with erosion:

99.Food	100.Shelter	101.Drinking water

d. Adaptation with sedimentation and river channel shifting:

102. What is your strategy to cope with sediment accretion?
103. What is your strategy regarding adaptation with river channel shifting?

e. Economic adaptation for river morphology change:

104. What is your strategy of earning and expenditure to adapt with the adversities? i) Reduction of expenditure ii) Change occupation iii) Migration for occupation

105. What is your livelihood strategy? i) Livelihood diversification ii) Income intensification iii) Agricultural intensification

How you adapt your economic condition with the adversities?

106.Borrow money from	107.Borrow food products	108. Type of asset selling	109. Type of received relief	110. Adopted social safety net services

Section H: Government, NGO and community initiatives and respondents suggestions:

111. Do you observe any NGO activities regarding river induced disaster mitigation in your locality? i)Yes ii) No

112. What are the activities of the NGOs for river induced disaster mitigation

113. Are there any initiatives from govt. to build awareness to the mass people for river morphology change related issues in your area? I) Yes ii) No

114. If yes, then what are the initiatives?

115. What type of preventive measures had been taken from the govt. for erosion control?

116. What are the flood control actions from Govt. in your area?

117. What type of defensive methods had been taken from the govt. for sedimentation control?

118. What is the community flood defense technique in your locality?

119. What type of protective/preventive measure has been taken by the local community for erosion control?

120. What type of help do you expect from Government for adaptation with river morphology change issues?

121. Do you have any suggestion for better preventive/ protective measures?

Thanks for your patience

Appendix-2

Questionnaire for FGD
Questionnaire On
Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

FGD No. **Union:** **Date**

A. Morphological Change:

1. What is the condition of Teesta river water in your union?

In dry season:

In monsoon:

2. Give your explanation about the recent morphological change of Teesta river in your union?

3. What was the situation of river morphology? Describe from your past experience

4. How erosion occurs in your area?

5. What kind of erosional landforms are found here?

6. How deposition occurs in your area?

7. What kind of depositional landforms are found here?

8. Describe the channel shifting process of Teesta river.

Impact:

9. What kind of economic changes are found for river morphology change?

Occupation:

Property:

10. What is the impact of morphological change on agriculture?

Land:

Production:

11. Describe the condition of house and infrastructure for such changes.

House:

Infrastructure:

12. How the environment and health is affected?

Health:

Environment:

13. What is the impact of river morphology change on poultry and livestock?

14. What is the impact on food habit?

15. Discuss the Impact of river morphology change on society and culture.

16. What type of precautionary technique you adopt for impact minimization and loss reduction.

17. What is the role of early warning system on impact minimization of river morphology change?

Adaptation:

18. What kind of adaptive measures has been taken during morphological change?
Food habit:

Food making and preservation:

Wild food harvest:

Fuel Collection and Preservation:

Water collection:

Shelter:

Education:

Health/ medicine facilities:

Agriculture:

Livestock and poultry:

Livelihood:

Transportation:

19. What is the \mechanism behind community resilience regarding recurrent river morphology change in your area?

20. What type of support and services do you get from GOB/ NGO for morphological change adaptation?
From GOB:

From NGO:

21. Do you observe any activities of news reporters in your locality during riverine disaster? If answer is yes then what are the activities?

22. Do you think, the existing embankment serve you properly? If answer is no then what should be done?

23. Do you think, human activity is mostly responsible for changing river morphology? If yes then why?

24. What is your opinion about education and training for river morphology change adaptation?

25. What is your expectation from govt. to minimize the impact of morphological disasters?

25. Do you have any suggestion regarding mitigation of river induced disaster?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thanks a lot for your cooperation.

Appendix-3

Questionnaire for Experts from different Fields (KII)
Research title: Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

Questionnaire no. **Date:**

Name:
Designation:
Department/ Working place:
Field of Expertise:

1. How a river changes its morphology?

2. What is the hydrological condition of the Teesta river?

3. What is the present flooding condition of the river?

4. What is the present condition of erosion of the river?

5. What is the sedimentation status of the river?

6. What is the river channel change status of the river?

7. What are the impacts of morphological change on environment?

Flood	Erosion	Sedimentation	Channel shifting

8. What are the impacts of morphological change on human being?

Flood	Erosion	Sedimentation	Channel shifting

9. What are the programs/courses of your department associated with river morphology change?

10. What type of plans, programs and policies will be effective for the betterment of the riverine environment and the community?

11. What is your opinion about awareness, education, Training and warning regarding the issues?

Awareness	Education	Training	Warning

12. What role should be played by the concerned ministry to reduce the negative impacts of the issue?

13. What is your opinion and suggestion about the role of news reporters and mass media for disaster recovery?

14. Do you have any suggestion for preventive and mitigation measures about the issue?

Thank you very much for your kind support.

Appendix-4

Questionnaire for officials of NGOs

Research title: Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

Questionnaire no. **Date:**
Name:
Designation:
Department/ Working place:

1. Is there any activity of your department regarding river morphology change/ impact/adaptation related issues? If answer is yes, then describe the activities.

2. How many employees are involved to implement these activities?

3. How many years you/ your organization working with these issues?

4. Did you face any barrier to implement the programs? If yes, please describe

5. Which aspect of socio-economic problem associated with river morphology change, deals your organization?

6. Do your organization works with livelihood development programs? If yes, what are the programs?

7. Which aspect of environmental problem deals your organization?
8. Do your organization works with health and nutrition issues? If yes, what are the activities?
9. Have there any shelter management programs for the victims of river morphology change in your organization? If yes, what are the activities?

10. Do your organization deals with micro credit for disaster management?
11. Do the organization works for relief distribution during disaster?

12. Is there any awareness building program regarding river morphology change impact minimization from your organization? If yes, what are the initiatives?
13. Do you think, NGOs can contribute in river morphology change impact minimization? If yes, then how?

14. Give your opinion and suggestion regarding the role of NGOs for adaptation with river morphology change.

Thank you very much for your humble support.

Appendix-5

Questionnaire for officials of Government

Research title: Morphological Changes in Teesta River Basin: Impact and Adaptation Strategies in the Northern Bangladesh

Questionnaire no. **Date:**
Name:
Designation:
Department/ Working place:

1. What are the main reasons for river morphology change in Teesta river?
2. What are the disastrous effects of river morphology change?

Effects of flood	Effects of erosion	Effects of sedimentation	Effects of channel change

3. What is the role of your organization to control the river induced disasters?

For flood control	For erosion control	For sedimentation control	For channel shifting control

4. What are the programs/courses of your department associated with river/ water management?

5. What is the amount of money to implement the programs?

6. How many employees are involved to implement these activities?

7. Which programs are initiated in last Five Years plan about river induced issues?

8. What kinds of actions are needed to reduce the impact of river morphology change?

Needed for flood	For erosion	For sedimentation	For river channel shifting

9. What is the present condition of embankment/Groin/Barrage in your administrative unit?

10. Is there any mass people awareness program about this issue? If answer is yes then what are the programs?

11. What is the condition of disaster information and warning?

12. What is your opinion about relief distribution of local Govt.?

13. What kind of support and services are essential in the area for riverine disaster mitigation?

14. What kind of preventive measures will be most effective for Teesta river?

15. Do you think political commitment is essential to mitigate the problem? Please give your opinion.

16. Give a SWOT analysis of your organization to mitigate the river morphology change issues?

Strength	Weakness	Opportunities	Threats

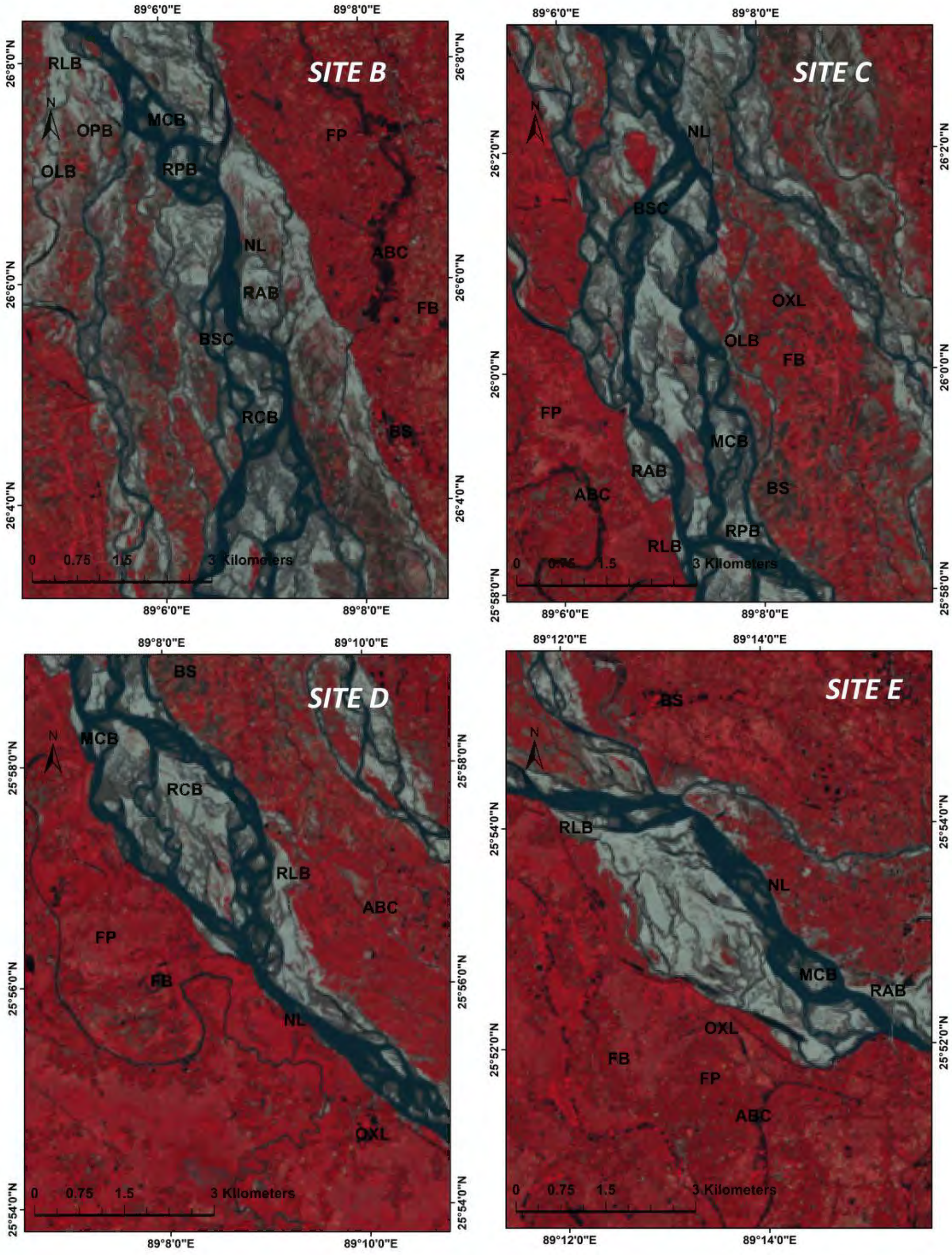
17. Can you please say about the achieved results of your organization?

18. What is your suggestion for plans, policies and programs about impact minimization?

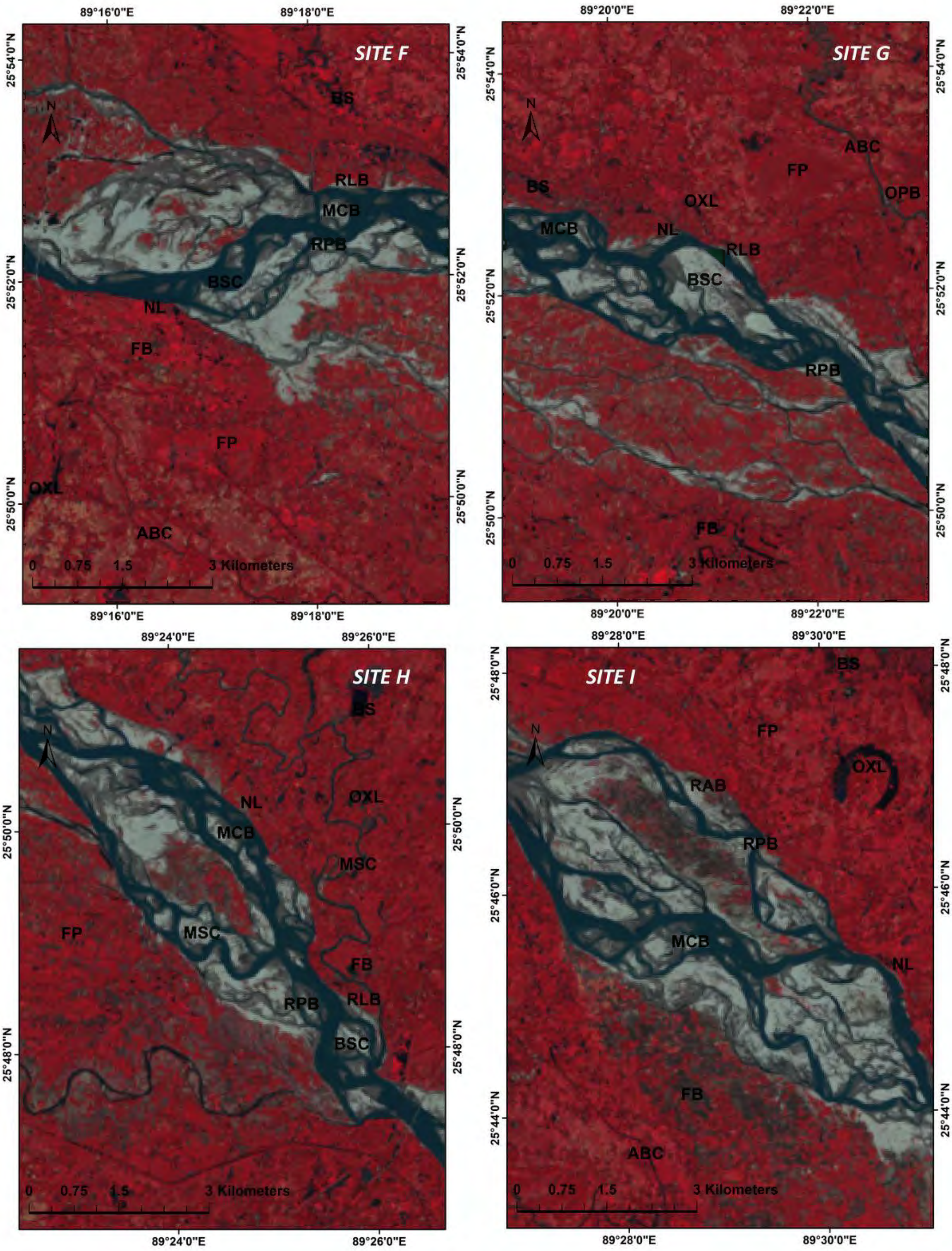
Thank you very much for your humble support.

Appendix-6

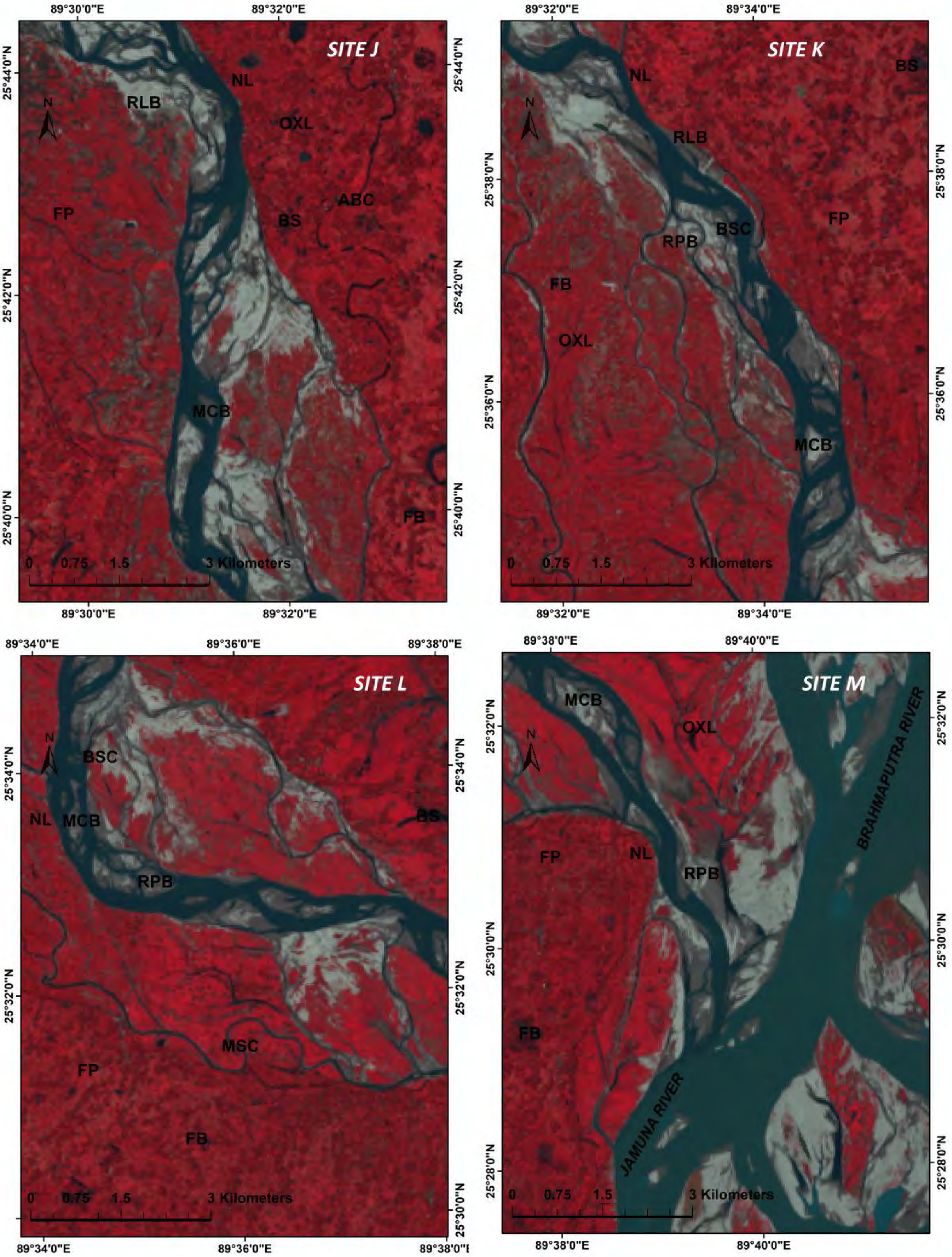
Identification of geomorphological features from satellite image


SITE B
89°6'0"E
89°8'0"E
26°8'0"N
26°6'0"N
26°4'0"N
N
RLB
OPB
MCB
OLB
RPB
FP
NL
ABC
RAB
FB
BSC
RCB
BS
0 0.75 1.5 3 Kilometers
SITE C
89°6'0"E
89°8'0"E
26°2'0"N
26°0'0"N
25°58'0"N
N
NL
BSC
OXL
OLB
FB
FP
MCB
RAB
ABC
BS
RPB
RLB
0 0.75 1.5 3 Kilometers
SITE D
89°8'0"E
89°10'0"E
25°58'0"N
25°56'0"N
25°54'0"N
N
BS
MCB
RCB
RLB
ABC
FP
FB
NL
OXL
0 0.75 1.5 3 Kilometers
SITE E
89°12'0"E
89°14'0"E
25°54'0"N
25°52'0"N
N
BS
RLB
NL
MCB
RAB
OXL
FB
FP
ABC
0 0.75 1.5 3 Kilometers

Caption of Map: AC-Active Channel, BSC-Braided Stream Channel, MSC- Meandering Stream Channel, OCB-Old Channel Bar, OLB- Old Lateral Bar, OPB-Old Point Bar, OXL-Oxbow lake, BS-Back swamp, ABC-Abandoned Channel, FB-Flood Basin, FP-Floodplain MCB-Mid Channel Bar, RPB-Recent Point Bar, RLB-Recent Lateral Bar, NL-Natural Levee, RAB-Recent Alternate Bar.


89°16'0"E
89°18'0"E
25°54'0"N
25°52'0"N
25°50'0"N
SITE F
N
BS
RLB
MCB
RPB
BSC
NL
FB
FP
OXL
ABC
0 0.75 1.5 3 Kilometers
89°20'0"E
89°22'0"E
SITE G
ABC
FP
OPB
BS
OXL
MCB
NL
RLB
BSC
RPB
FB
89°24'0"E
89°26'0"E
25°50'0"N
25°48'0"N
SITE H
BS
NL
OXL
MCB
MSC
FP
MSC
FB
RPB
RLB
BSC
89°28'0"E
89°30'0"E
25°48'0"N
25°46'0"N
25°44'0"N
SITE I
BS
FP
OXL
RAB
RPB
MCB
NL
FB
ABC

Caption of Map: AC-Active Channel, BSC-Braided Stream Channel, MSC- Meandering Stream Channel, OCB-Old Channel Bar, OLB- Old Lateral Bar, OPB-Old Point Bar, OXL-Oxbow lake, BS-Back swamp, ABC-Abandoned Channel, FB-Flood Basin, FP-Floodplain, MCB-Mid Channel Bar, RPB-Recent Point Bar, RLB-Recent Lateral Bar, NL-Natural Levee, RAB-Recent Alternate Bar.


SITE J
89°30'0"E
89°32'0"E
25°44'0"N
25°42'0"N
25°40'0"N
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ABC
FP
BS
MCB
FB
0 0.75 1.5 3 Kilometers
SITE K
89°32'0"E
89°34'0"E
25°38'0"N
25°36'0"N
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BS
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BSC
RPB
FP
FB
OXL
MCB
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SITE L
89°34'0"E
89°36'0"E
89°38'0"E
25°34'0"N
25°32'0"N
25°30'0"N
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BSC
NL
MCB
BS
RPB
MSC
FP
FB
0 0.75 1.5 3 Kilometers
SITE M
89°38'0"E
89°40'0"E
25°32'0"N
25°30'0"N
25°28'0"N
N
MCB
OXL
BRAHMAPUTRA RIVER
FP
NL
RPB
FB
JAMUNA RIVER
0 0.75 1.5 3 Kilometers

Caption of Map: AC-Active Channel, BSC-Braided Stream Channel, MSC- Meandering Stream Channel, OCB-Old Channel Bar, OLB- Old Lateral Bar, OPB-Old Point Bar, OXL-Oxbow lake, BS-Back swamp, ABC-Abandoned Channel, FB-Flood Basin, FP-Floodplain, MCB-Mid Channel Bar, RPB-Recent Point Bar, RLB-Recent Lateral Bar, NL-Natural Levee, RAB-Recent Alternate Bar.

Appendix-7

1. a) Braided stream channel

1. b) Meandering stream channel

1. c) Flood basin

1. d) Natural levee

1. e) Back swamp

1. f) Floodplain

1. g) Mid channel bar

1. h) Sand bar

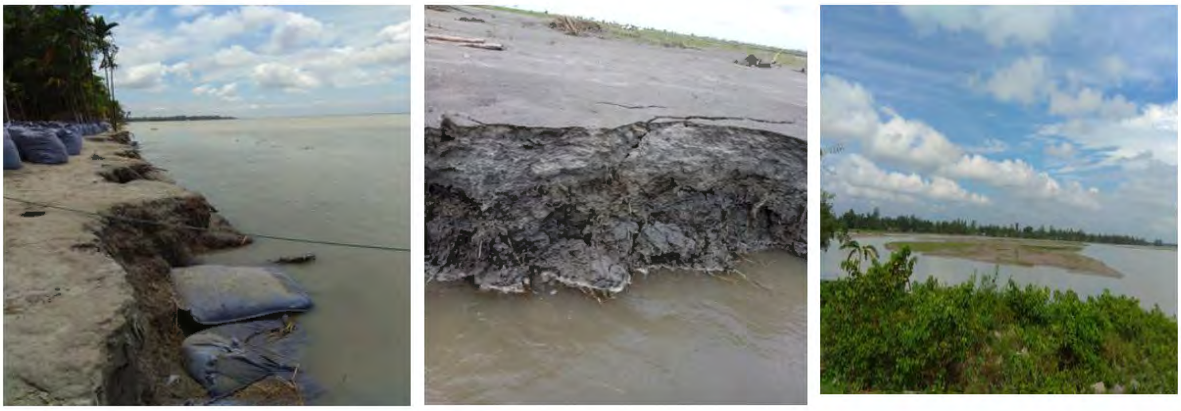
1. i) Point bar

1. j) Pot hole

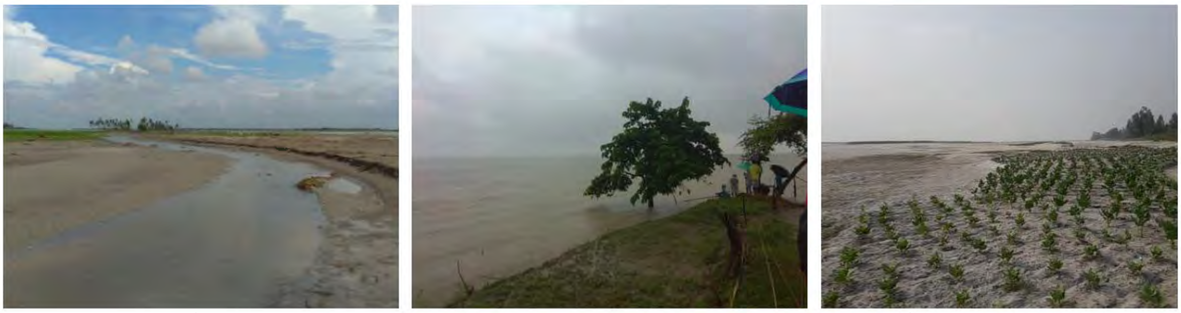
1.k) Ridges

1. l) River terrace

Picture 1. Land form features of Teesta River (a-l)

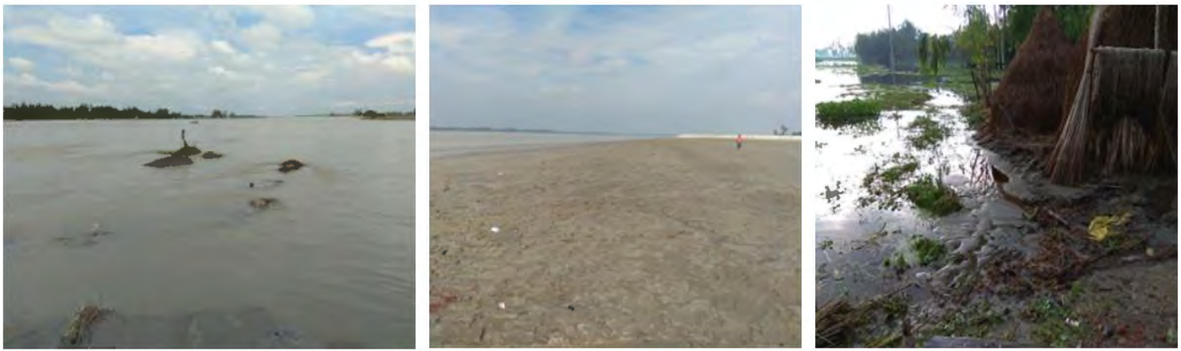


2. a) Bank erosion 2. b) Bar erosion 2. c) Sediment deposition



2. d) Arrival of a new channel 2. e) Flood in Teesta 2. f) Dried river bed

Picture 2. Morphological changes in Teesta river basin after flood 2017 (a-e). 2. (f) River morphology change in summer



3. a) Debris flow 3. b) Clay deposition in river bed 3. c) Sand deposition in the floodplain

Picture 3. Sedimentological aspects of Teesta after flood 2017 (a-c)

4. a) Water level measurement at Dalia point

4. b) Turbulence and vortices during flood

4. c) Teesta river in bankful stage

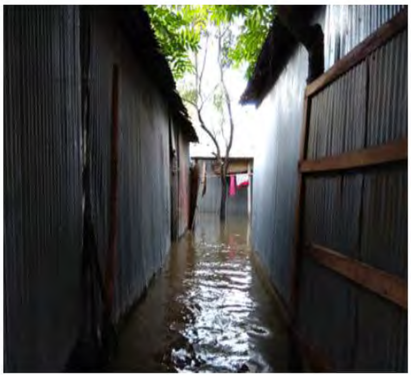
Picture 4. Hydrological aspects of Teesta river (a-c)

5. a) Road construction in the bank of Teesta

5. b)Mohipur bridge in Teesta

5. c)Teesta river revetment

Picture 5 Anthropogenic impacts on Teesta river morphology (a-c)



6. a)Inundation

6. b)Migration

6. c) Transportation problem

6. d) Loss of trees

6. e) Rotten nut

6. f) Rotten paddy

6. g) Sand deposition in paddy field

6. h) Skin disease

6. i) Closed school

6. j) Household destruction

6. k) Drowned household

6. l) Collapsed bridge

6. m) Collapsed road

6. n) Erosion affected business shop

6. o) Biodiversity loss

Picture 6. Impacts of morphological changes in Teesta river basin after flood 2017 (a-o)

7. a) Living in flood shelter

7. b) Adaptation with shelter in school

7. c) Shelter in road

7. d) Shelter in embankment

7. e) House platform raise

7. f) House construction material salvage

7. g) Shifting of household goods

7. h) Shifting of lives and materials

7. i) Multipurpose use of *machan*

7. j) Paddy storage

7. k) Food for relatives

7. l) Dried fish for preservation

7. m) Cooking in portable oven

7. n) Fuel storage in machan

7. o) Fuel preservation

7. p) Temporary sanitation

7. q) Temporary cattle shelter

7. r) Bamboo grove for adaptation

Picture 7 Adaptation strategies for morphological changes in Teesta river basin (a-r).

8. a) Road cutting for release of flood water and fill with hyacinth

8. b) Artificial levee construction to prevent flood water

8. c) Sand bag piling for flood protection

8. d) Erosion protection through sand bag

8. e) Reserve block for emergency management

8. f) Meeting with UP chairman during river morphology change

Picture 8 Community action for adaptation (a-f)

9. a)Bamboo bundling

9. b)Geo bag filling in the bank

9. c)Teesta right bank embankment

9. d) Boulder protection

9 e) Groin in Teesta river

9. f) Briefing from minister during 2017 flood

9. g) Danger flag for warning

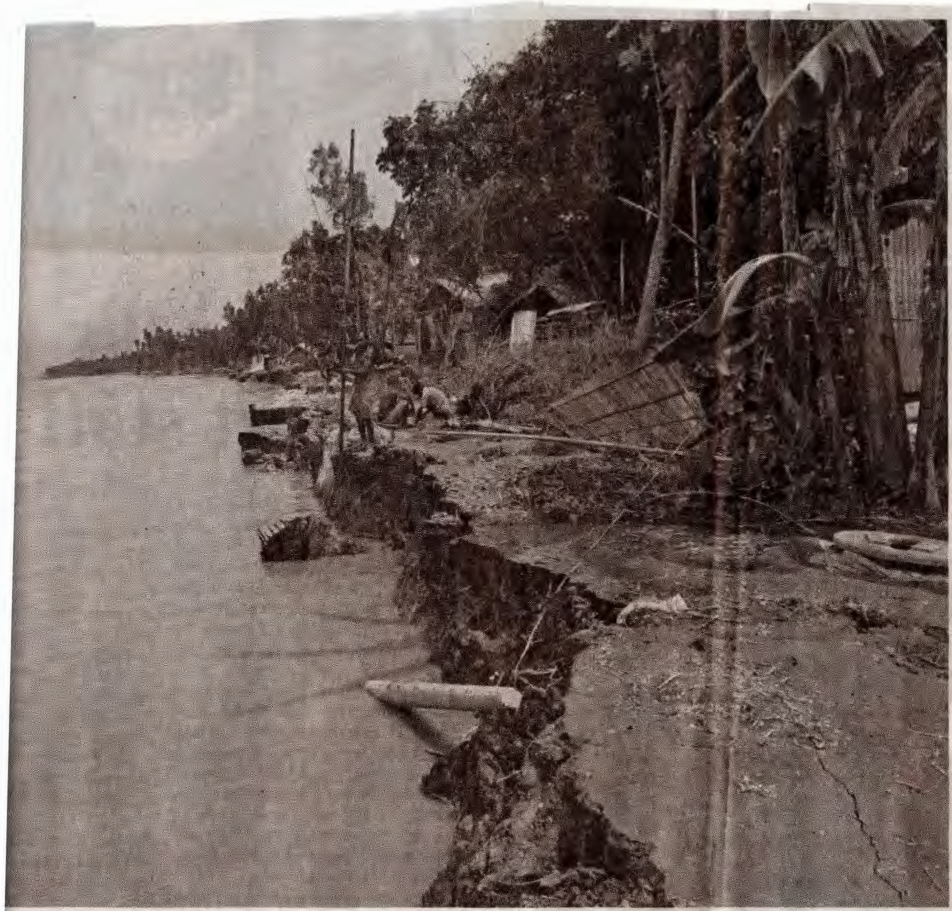
9. h) Clustered village for landless community

9. i) Relief distribution

Picture 9. Adaptation with river morphology change through institutional support (a-i)

Appendix-8

River morphology change, impact, adaptation from newspaper articles



river has taken a serious turn at five villages in Rajarhat upazila of Kurigram during recession of floodwater. The picture
Kha village on July 28.

PHOTO: STAR

Roaring Teesta

Erosion takes serious turn in five villages of Rajarhat upazila

30-7-2017 The Daily St

ABDUL WAHED, *Kurigram* P. 13

Erosion by the Teesta river after recession of floodwater has taken a serious turn in five villages under Rajarhat upazila of the district.

"I am shifting my house to a neighbour's land due to the erosion by the Teesta river. Another erosion victim is also shifting his house to the same land. Now we are facing shortage of food," said Chandi Charan Barmon, 42, an erosion victim of Tayab Kha village of Bidyananda union.

Chandi's daughter Sohagi Rani Roy, an HSC student of Najimkhan School and College, said, "I have not been able to study for about one week, even though my test examination will be held in two months. Now my father cannot bear the expenditure of my education. I am afraid that I might have to suffer break of study without financial support."

Bishnu Chandra Das, 45, a fisherman of Somnarayan village in Najimkhan union, said, "I have become landless as the river Teesta had eroded my land and house. I maintain my family through fishing. I recently bought 13 decimals of land, which is facing threat of erosion."

Abdul Latif, 65, of Tayab Kha village said, "Erosion by the Teesta river washed away my three acres of land this month. Now I have shifted my house to another land. Most parts of Tayab Kha village went into the river this month."

The erosion has already rendered over 200 families homeless this month and eroded hundreds of acres of land in Chatura, Paramaula, Ratee and Tayab Kha villages of Bidyananda union and Somnarayan village of Najimkhan union.

At least 68 families of Somnarayan village were made homeless this month, while over one hundred families are under threat, said Bishnu Chandra Das, 45, a fisherman and erosion victim.

"The upazila administration helped each of the 136 erosion-hit families with cash Tk 2,000 and 30 kg of rice or one maund of wheat in Bidyananda union recently," Bidyananda Union Parishad Chairman Taijul Islam said.

Executive Engineer of Wate Development Board in Kurigram Shafiqul Islam, said, "I visited the erosion spot or July 28. I sent a proposal for preventin erosion of a 700-metre area in Tayab Kh village, but I received only Tk 33 lakh in tw instalments this year. Work is going on in 400-metre area in Tayab Kha village with th allocated money. Bamboo pilings and sand filled bags are washed away by the river du to strong current, making it difficult t protect the place."

"I have sent a request for Tk 83 lakh mor on emergency basis. If I get the allocation, can start the rest of the work. But the prote tion will be on a temporary basis due t rainy season," Shafiqul said.

The Daily Star 9-7-2017 p.1 & 2

A farmer's cattle huddle together on a piece of high ground on his yard in Porerpara village in Kurigram sadar yesterday as villages and farmlands go under water in the district.

PHOTO: ABDUL WAHED

Flood hits the North

Low-lying areas in Sirajganj, Bogra, Kurigram, Gaibandha inundated

Star Report

Low-lying areas of Sirajganj, Bogra, Gaibandha, Kurigram and Jamalpur were inundated yesterday as three major rivers witnessed a rise in water level due to heavy flow and a deluge of rains.

The Indian state of Assam has been experiencing heavy floods for the last few days and its water is overflowing to Bangladesh through the Brahmaputra river, said Sazzad Hossain, executive engineer of Flood Forecasting and Warning Centre (FFWC) of the Water Development Board (WDB).

As a result, water level in the Brahmaputra and the Jamuna witnessed a rise that caused floods in the low-lying areas of the river basins, he told The Daily Star yesterday.

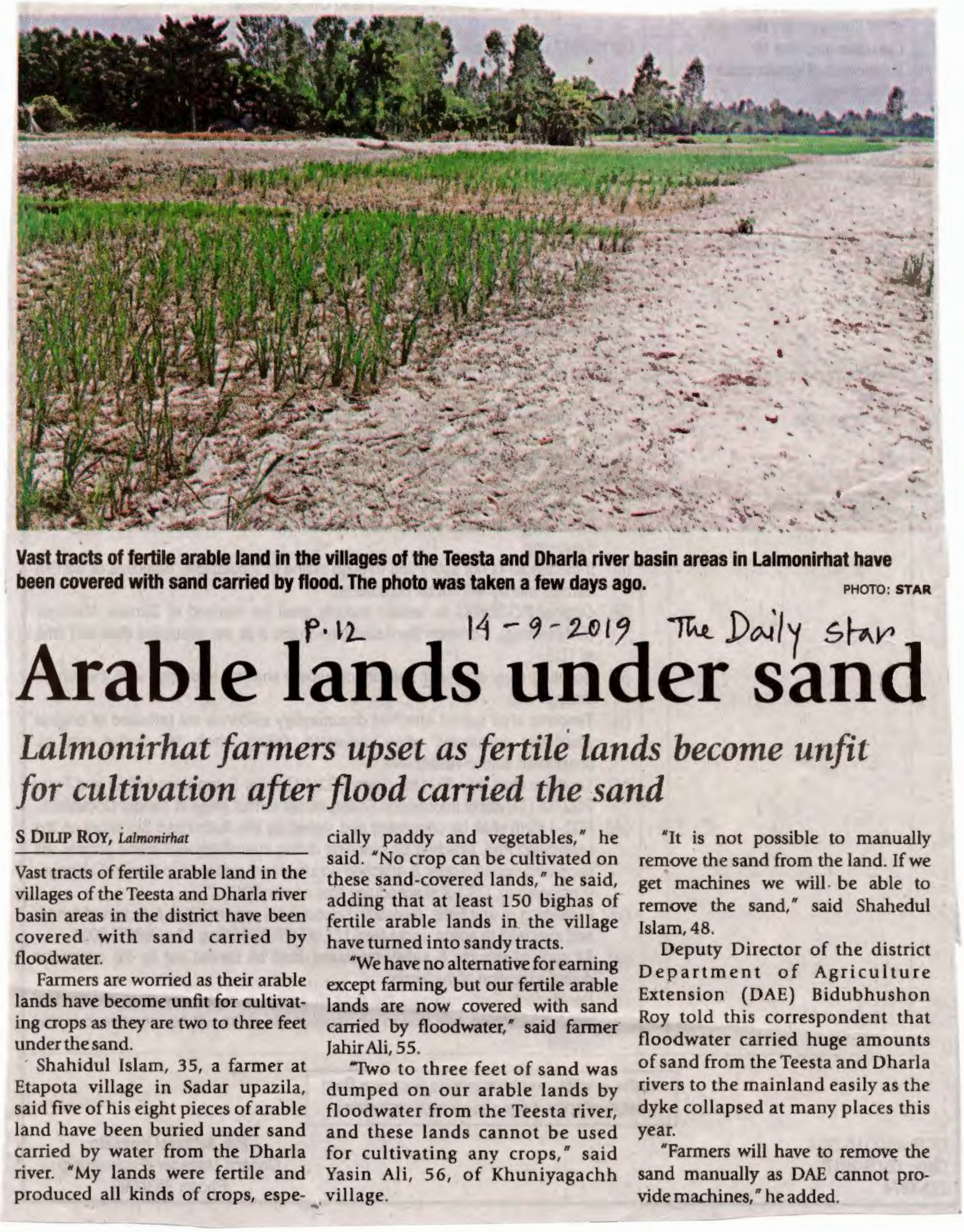
According to the Indian media reports, flood situation in Assam worsened on Friday, affecting around 4.5 lakh people in 17 districts. Three more people were killed, taking the death toll to 22, reports the Times of India yesterday.

The water level of the Teesta has meanwhile been increasing as most of the gates of India's Gajoldoba Barrage were left open, a WDB official said.

The flood situation in the Sylhet region saw little improvement yesterday as the water level in two major rivers -- the Surma and the Kushiyara -- flowing over the danger point showed a declining trend.

However, the situation might deteriorate again as the water level of the Kushiyara saw a rising trend last evening, Sirajul Islam, executive engineer of WDB in Sylhet, said.

SEE PAGE 2 COL 1



Vast tracts of fertile arable land in the villages of the Teesta and Dharla river basin areas in Lalmonirhat have been covered with sand carried by flood. The photo was taken a few days ago.

PHOTO: STAR

P. 12 14-9-2019 The Daily Star

Arable lands under sand

Lalmonirhat farmers upset as fertile lands become unfit for cultivation after flood carried the sand

S DILIP ROY, *Lalmonirhat*

Vast tracts of fertile arable land in the villages of the Teesta and Dharla river basin areas in the district have been covered with sand carried by floodwater.

Farmers are worried as their arable lands have become unfit for cultivating crops as they are two to three feet under the sand.

Shahidul Islam, 35, a farmer at Etapota village in Sadar upazila, said five of his eight pieces of arable land have been buried under sand carried by water from the Dharla river. "My lands were fertile and produced all kinds of crops, especially paddy and vegetables," he said. "No crop can be cultivated on these sand-covered lands," he said, adding that at least 150 bighas of fertile arable lands in the village have turned into sandy tracts.

"We have no alternative for earning except farming, but our fertile arable lands are now covered with sand carried by floodwater," said farmer Jahir Ali, 55.

"Two to three feet of sand was dumped on our arable lands by floodwater from the Teesta river, and these lands cannot be used for cultivating any crops," said Yasin Ali, 56, of Khuniyagachh village.

"It is not possible to manually remove the sand from the land. If we get machines we will be able to remove the sand," said Shahedul Islam, 48.

Deputy Director of the district Department of Agriculture Extension (DAE) Bidubhushon Roy told this correspondent that floodwater carried huge amounts of sand from the Teesta and Dharla rivers to the mainland easily as the dyke collapsed at many places this year.

"Farmers will have to remove the sand manually as DAE cannot provide machines," he added.

DHAKA **TUESDAY SEPTEMBER 19, 2017,** ***ASHWIN 4, 1424 BS*** **COUNTRY**

POST FLOOD EFFECTS

The Daily star

River erosion makes many homeless in Lalmonirhat

S DILIP ROY, *Lalmonirhat*

During the recession of floodwater, many people are losing their houses and lands due to erosion by Teesta and Dharla rivers in different areas of five upazilas under the district.

"I with my five-member family started staying beside the rail line as floodwater entered our house on August 11. We returned home when the water receded on August 17 but we had to take shelter beside the rail line again after a week as the Dharla river devoured our homestead," said Saiful Islam, 46, at Mogholhat village in Lalmonirhat Sadar upazila.

Anwar Hossain, 65, of Etapota village in the upazila said at least 20 houses of the village went into the Dharla riverbed that also devoured part of a mosque.

"Erosion by the Teesta river has turned serious, threatening houses, croplands and infrastructures. I lost three bighas of arable land to the Teesta river after the recession of floodwater and now our homestead on eight decimals is under threat," said Altafur Rahman, 52, of Gobordhan Ismailpara village in Aditmari upazila.

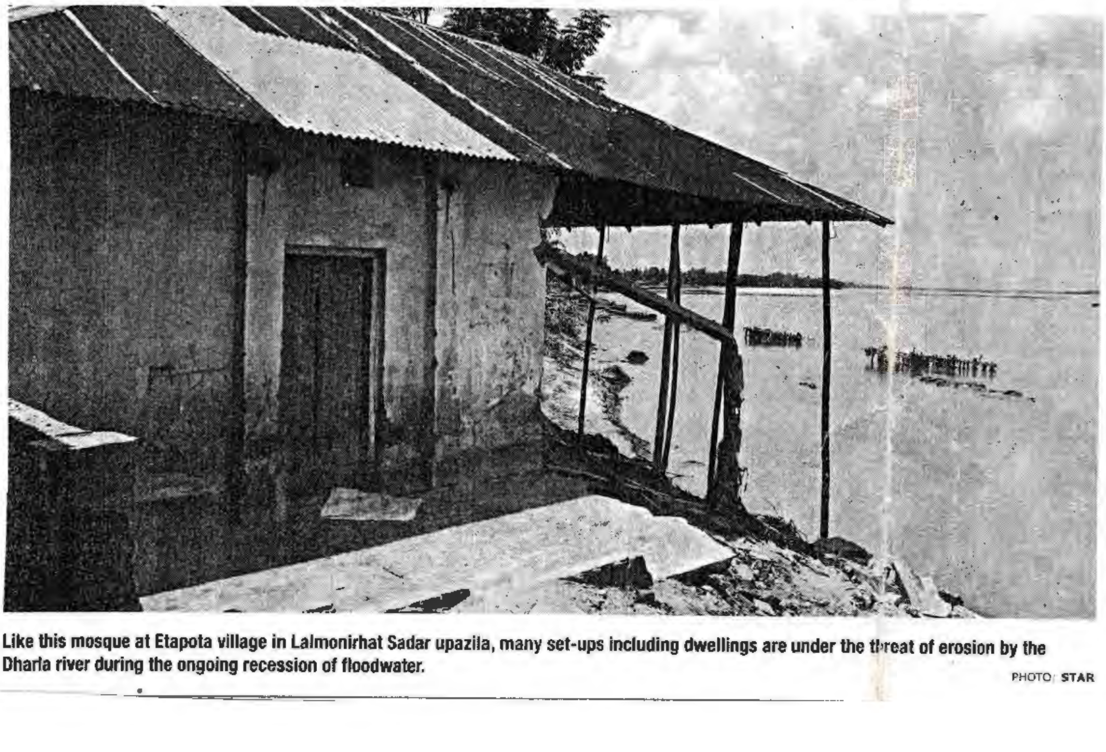
"Fifty-five families of Gobordhan, Islamipara and Kutirpar villages in my union have become homeless due to erosion by the Teesta in last two weeks," said Mosaddeque Hossain Chowdhury, chairman of Mahishkhocha Union Parishad (UP) in Aditmari.

The river has continued erosion, devouring homesteads, croplands and orchards, he said adding that Water Development Board officials visited the area but no step has been taken yet.

Atiar Rahman, chairman of Gaddimari UP in Hatibandha, said the Teesta has continued devouring homesteads, arable lands and structures in eight villages of the union for the last two weeks, following recession of floodwater.

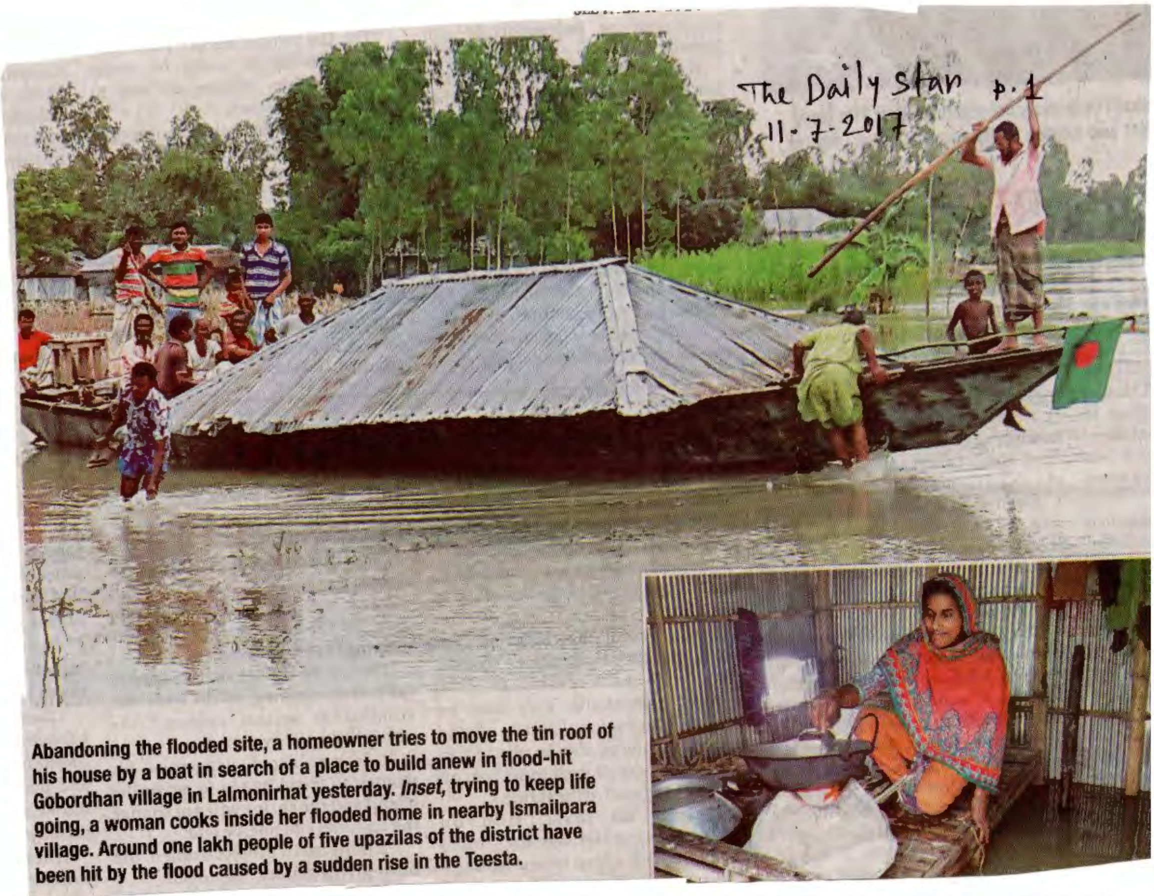
Krishna Kamol Sarker, executive engineer of WDB in Lalmonirhat, said, WDB officials are providing input and technical support to local people for setting bamboo pilings to check the erosion at the primary stage.

"We are preparing an assessment report on houses and lands that went into the riverbed due to the flood," he said.



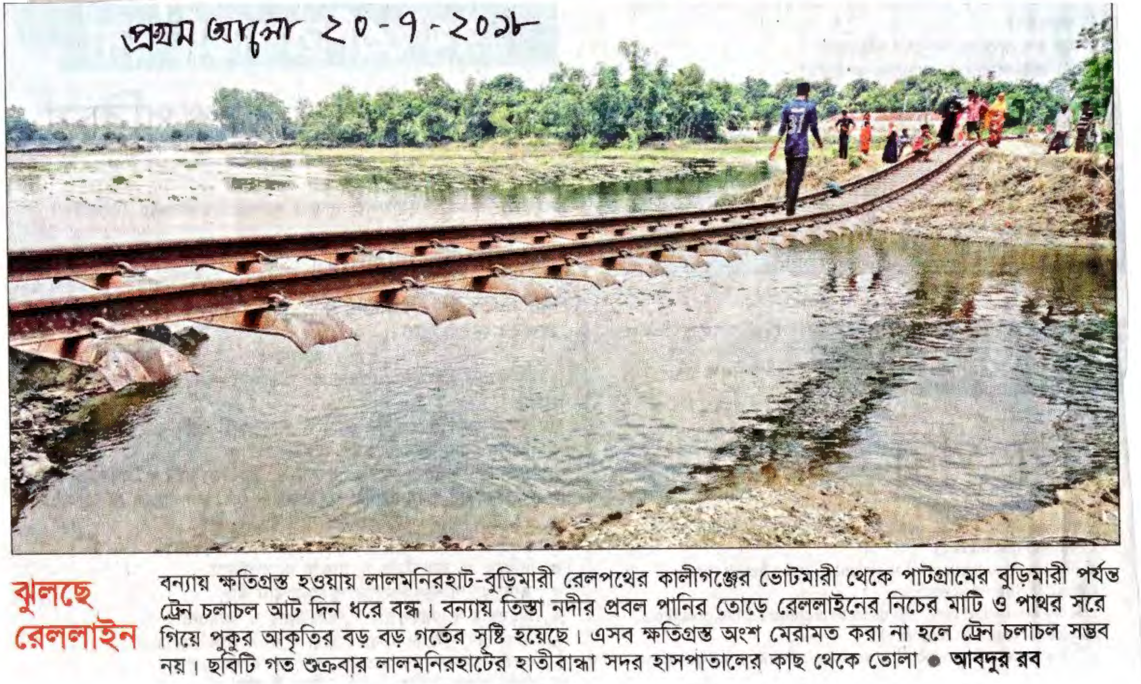
Like this mosque at Etapota village in Lalmonirhat Sadar upazila, many set-ups including dwellings are under the threat of erosion by the Dharla river during the ongoing recession of floodwater.

PHOTO: STAR



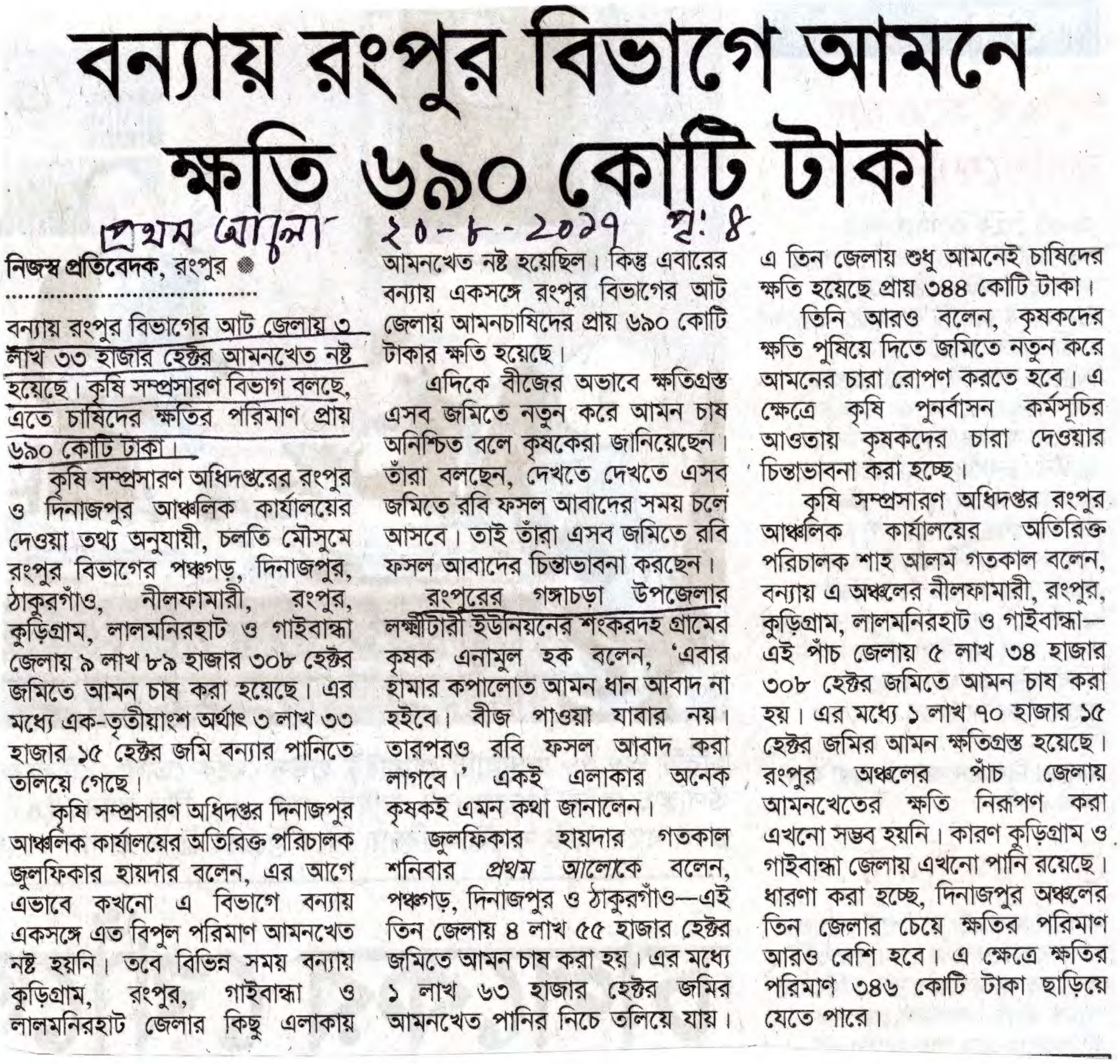
The Daily Star p.1
11-7-2017

Abandoning the flooded site, a homeowner tries to move the tin roof of his house by a boat in search of a place to build anew in flood-hit Gobordhan village in Lalmonirhat yesterday. *Inset*, trying to keep life going, a woman cooks inside her flooded home in nearby Ismailpara village. Around one lakh people of five upazilas of the district have been hit by the flood caused by a sudden rise in the Teesta.



প্রথম আলো ২০-৭-২০১৮

ঝুলছে রেললাইন বন্যায় ক্ষতিগ্রস্ত হওয়ায় লালমনিরহাট-বুড়িমারী রেলপথের কালীগঞ্জের ভোটমারী থেকে পাটগ্রামের বুড়িমারী পর্যন্ত ট্রেন চলাচল আট দিন ধরে বন্ধ। বন্যায় তিস্তা নদীর প্রবল পানির তোড়ে রেললাইনের নিচের মাটি ও পাথর সরে গিয়ে পুকুর আকৃতির বড় বড় গর্তের সৃষ্টি হয়েছে। এসব ক্ষতিগ্রস্ত অংশ মেরামত করা না হলে ট্রেন চলাচল সম্ভব নয়। ছবিটি গত শুক্রবার লালমনিরহাটের হাতীবান্ধা সদর হাসপাতালের কাছ থেকে তোলা ● **আবদুর রব**



বন্যায় রংপুর বিভাগে আমনে ক্ষতি ৬৯০ কোটি টাকা

প্রথম আলো ২০-৮-২০১৭ পৃ: ৪

নিজস্ব প্রতিবেদক, রংপুর ●

বন্যায় রংপুর বিভাগের আট জেলায় ৩ লাখ ৩৩ হাজার হেক্টর আমনখেত নষ্ট হয়েছে। কৃষি সম্প্রসারণ বিভাগ বলছে, এতে চাষিদের ক্ষতির পরিমাণ প্রায় ৬৯০ কোটি টাকা।

কৃষি সম্প্রসারণ অধিদপ্তরের রংপুর ও দিনাজপুর আঞ্চলিক কার্যালয়ের দেওয়া তথ্য অনুযায়ী, চলতি মৌসুমে রংপুর বিভাগের পঞ্চগড়, দিনাজপুর, ঠাকুরগাঁও, নীলফামারী, রংপুর, কুড়িগ্রাম, লালমনিরহাট ও গাইবান্ধা জেলায় ৯ লাখ ৮৯ হাজার ৩০৮ হেক্টর জমিতে আমন চাষ করা হয়েছে। এর মধ্যে এক-তৃতীয়াংশ অর্থাৎ ৩ লাখ ৩৩ হাজার ১৫ হেক্টর জমি বন্যার পানিতে তলিয়ে গেছে।

কৃষি সম্প্রসারণ অধিদপ্তর দিনাজপুর আঞ্চলিক কার্যালয়ের অতিরিক্ত পরিচালক জুলফিকার হায়দার বলেন, এর আগে এভাবে কখনো এ বিভাগে বন্যায় একসঙ্গে এত বিপুল পরিমাণ আমনখেত নষ্ট হয়নি। তবে বিভিন্ন সময় বন্যায় কুড়িগ্রাম, রংপুর, গাইবান্ধা ও লালমনিরহাট জেলার কিছু এলাকায় আমনখেত নষ্ট হয়েছিল। কিন্তু এবারের বন্যায় একসঙ্গে রংপুর বিভাগের আট জেলায় আমনচাষিদের প্রায় ৬৯০ কোটি টাকার ক্ষতি হয়েছে।

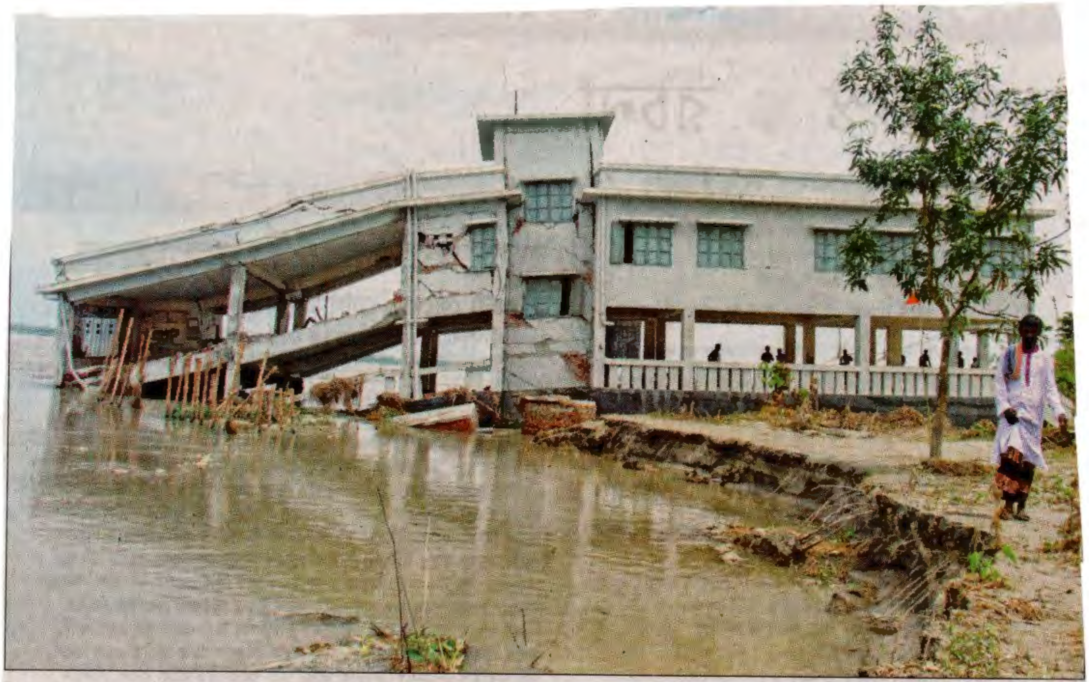
এদিকে বীজের অভাবে ক্ষতিগ্রস্ত এসব জমিতে নতুন করে আমন চাষ অনিশ্চিত বলে কৃষকেরা জানিয়েছেন। তাঁরা বলছেন, দেখতে দেখতে এসব জমিতে রবি ফসল আবাদের সময় চলে আসবে। তাই তাঁরা এসব জমিতে রবি ফসল আবাদের চিন্তাভাবনা করছেন।

রংপুরের গঙ্গাচড়া উপজেলার লক্ষ্মীটারী ইউনিয়নের শংকরদহ গ্রামের কৃষক এনামুল হক বলেন, 'এবার হামার কপালোত আমন ধান আবাদ না হইবে। বীজ পাওয়া যাবার নয়। তারপরও রবি ফসল আবাদ করা লাগবে।' একই এলাকার অনেক কৃষকই এমন কথা জানালেন।

জুলফিকার হায়দার গতকাল শনিবার *প্রথম আলো*কে বলেন, পঞ্চগড়, দিনাজপুর ও ঠাকুরগাঁও—এই তিন জেলায় ৪ লাখ ৫৫ হাজার হেক্টর জমিতে আমন চাষ করা হয়। এর মধ্যে ১ লাখ ৬৩ হাজার হেক্টর জমির আমনখেত পানির নিচে তলিয়ে যায়। এ তিন জেলায় শুধু আমনেই চাষিদের ক্ষতি হয়েছে প্রায় ৩৪৪ কোটি টাকা।

তিনি আরও বলেন, কৃষকদের ক্ষতি পুষিয়ে দিতে জমিতে নতুন করে আমনের চারা রোপণ করতে হবে। এ ক্ষেত্রে কৃষি পুনর্বাসন কর্মসূচির আওতায় কৃষকদের চারা দেওয়ার চিন্তাভাবনা করা হচ্ছে।

কৃষি সম্প্রসারণ অধিদপ্তর রংপুর আঞ্চলিক কার্যালয়ের অতিরিক্ত পরিচালক শাহ আলম গতকাল বলেন, বন্যায় এ অঞ্চলের নীলফামারী, রংপুর, কুড়িগ্রাম, লালমনিরহাট ও গাইবান্ধা—এই পাঁচ জেলায় ৫ লাখ ৩৪ হাজার ৩০৮ হেক্টর জমিতে আমন চাষ করা হয়। এর মধ্যে ১ লাখ ৭০ হাজার ১৫ হেক্টর জমির আমন ক্ষতিগ্রস্ত হয়েছে। রংপুর অঞ্চলের পাঁচ জেলায় আমনখেতের ক্ষতি নিরূপণ করা এখনো সম্ভব হয়নি। কারণ কুড়িগ্রাম ও গাইবান্ধা জেলায় এখনো পানি রয়েছে। ধারণা করা হচ্ছে, দিনাজপুর অঞ্চলের তিন জেলার চেয়ে ক্ষতির পরিমাণ আরও বেশি হবে। এ ক্ষেত্রে ক্ষতির পরিমাণ ৩৪৬ কোটি টাকা ছাড়িয়ে যেতে পারে।



তিস্তার ভাঙনে বিলীন হওয়ার পথে রংপুরের পীরগাছা উপজেলার ছাওলা ইউনিয়নের পূর্ব শিবদেবচর সরকারি প্রাথমিক বিদ্যালয়টি। ছবিটি গতকাল দুপুরে তোলা ● প্রথম আলো ■ **খবর : পৃষ্ঠা-৮**

২৬-৮-২০১৭, প্রথম আলো

শিক্ষাপ্রতিষ্ঠানে বন্যার ক্ষত

নিজস্ব প্রতিবেদক ●

কোনো কোনো শিক্ষাপ্রতিষ্ঠানে বন্যার পানি ঢুকে পাঠদান বন্ধ হয়ে গেছে। পিছিয়ে গেছে পরীক্ষা। অনেক বিদ্যালয়ে আশ্রয়কেন্দ্র খোলা হয়েছে। কিছু কিছু বিদ্যালয়ের শ্রেণিকক্ষের ক্ষতি হয়েছে। সব মিলিয়ে গত কয়েক দিনের বন্যা শিক্ষাক্ষেত্রে ক্ষতের দাগ রেখে গেছে।

ইতিমধ্যে বন্যাকবলিত জেলাগুলোর ৩ হাজার ৭২৪টি শিক্ষাপ্রতিষ্ঠানে ব্যাপক ক্ষতি হয়েছে। এগুলোর বেশির ভাগ এখনো বন্ধ। কিছু বিদ্যালয় খোলা থাকলেও রাস্তাঘাটে পানি থাকায় শিক্ষাপ্রতিষ্ঠানে যেতে পারছে না শিক্ষার্থীরা। ফলে ওই সব এলাকার শিক্ষার্থীদের পড়াশোনায় ব্যাঘাত ঘটছে।

মাধ্যমিক ও উচ্চশিক্ষা অধিদপ্তর (মাউশি) এবং প্রাথমিক শিক্ষা অধিদপ্তরের প্রাপ্ত তথ্য ও সরেজমিনে ক্ষয়ক্ষতির এই চিত্র পাওয়া গেছে। মাউশি ও প্রাথমিক শিক্ষা অধিদপ্তরের কর্মকর্তারা *প্রথম আলো*কে বলেছেন, পানি নেমে যাওয়ার পর প্রকৃত ক্ষতির চাহিদা অনুযায়ী অগ্রাধিকার ভিত্তিতে ক্ষতিগ্রস্ত শিক্ষাপ্রতিষ্ঠানগুলো মেরামত বা সংস্কার করা হবে।

মাধ্যমিক ও উচ্চশিক্ষা অধিদপ্তরের সূত্রমতে, স্থানীয় শিক্ষা কর্মকর্তাদের মাধ্যমে তারা ক্ষতিগ্রস্ত ও পাঠদান বন্ধ হওয়া শিক্ষাপ্রতিষ্ঠানের তালিকা সংগ্রহ করেছে। এতে দেখা যায়, ২১ আগস্ট পর্যন্ত মাধ্যমিক বিদ্যালয়, কলেজ ও মাদ্রাসা মিলিয়ে ১ হাজার ৫৫৮টি শিক্ষাপ্রতিষ্ঠানের পাঠদান বন্ধ রয়েছে। এর মধ্যে শুধু বিদ্যালয়ই আছেই ৮৫৫টি। আশ্রয়কেন্দ্র খোলা হয়েছে ৩৯৩টি শিক্ষাপ্রতিষ্ঠানে।

মাউশির একজন দায়িত্বশীল কর্মকর্তা *প্রথম আলো*কে বলেন, প্রাথমিকভাবে স্থানীয় শিক্ষা কর্মকর্তাদের কেউ কেউ ক্ষতির বিবরণও দিয়েছেন। এতে দেখা যায়, অনেক প্রতিষ্ঠান আংশিক এবং কোনো কোনো প্রতিষ্ঠানের পুরোপুরি ক্ষতি হয়েছে। তবে ক্ষতির বিবরণ আরও যাচাই-বাছাই করে পরবর্তী পদক্ষেপ নেওয়া হচ্ছে।

শিক্ষা প্রকৌশল অধিদপ্তরের প্রধান প্রকৌশলী দেওয়ান মোহাম্মদ হানজালা গতকাল মঙ্গলবার *প্রথম আলো*কে বলেন, ক্ষয়ক্ষতির প্রকৃত তথ্য পাওয়ার পর ক্ষতিগ্রস্ত শিক্ষাপ্রতিষ্ঠানগুলো দ্রুত সংস্কারের উদ্যোগ নেওয়া হবে।

- ৩,৭২৪ স্কুল-কলেজ-মাদ্রাসার ক্ষতি

> “ ক্ষয়ক্ষতির প্রকৃত তথ্য পাওয়ার পর ক্ষতিগ্রস্ত শিক্ষাপ্রতিষ্ঠানগুলো দ্রুত সংস্কারের উদ্যোগ নেওয়া হবে
>
> **দেওয়ান মোহাম্মদ হানজালা**
> প্রধান প্রকৌশলী, শিক্ষা প্রকৌশল অধিদপ্তর

সরেজমিন কয়েকটি বিদ্যালয়ে

দিনাজপুরের সরকারি প্রাথমিক বিদ্যালয়গুলোতে ১৯ আগস্ট থেকে দ্বিতীয় সাময়িক পরীক্ষা হওয়ার কথা ছিল। কিন্তু ১০ আগস্ট থেকে বন্যা শুরু হওয়ায় পরীক্ষা পিছিয়ে ৭ সেপ্টেম্বর থেকে শুরুর সিদ্ধান্ত নেওয়া হয়েছে। মাধ্যমিক পর্যায়ের শিক্ষার্থীদেরও লেখাপড়ায় ক্ষতি হচ্ছে।

জেলা প্রাথমিক শিক্ষা কর্মকর্তার কার্যালয় এবং মাধ্যমিক শিক্ষা কর্মকর্তার কার্যালয়ের তথ্য অনুযায়ী, বন্যার কারণে মাধ্যমিক পর্যায়ের ২৮২টি এবং প্রাথমিক পর্যায়ে ৩৪৮টি শিক্ষাপ্রতিষ্ঠান বন্ধ রয়েছে। এর মধ্যে ২১৬টি প্রাথমিক বিদ্যালয়ে আশ্রয়কেন্দ্র খোলা হয়েছে। গতকাল দুপুরে দিনাজপুর শহরের উপশহর সরকারি প্রাথমিক বিদ্যালয়ে গিয়ে দেখা যায়, প্রধান শিক্ষকসহ কয়েকজন মিলে বিদ্যালয়টি পরিষ্কার করছেন। কয়েকজন শিক্ষার্থী মাঠে খেলাধুলা করছে।

পঞ্চম শ্রেণির ছাত্র জীবন ইসলাম বলে, 'স্কুল বন্ধ থাকায় আমাদের পড়াশোনার খুবক্ষতি হইছে। স্কুলে না আসলে পড়াশোনা তো হয় না। সামনে পরীক্ষার আগে হঠাৎ স্কুল বন্ধ হয়ে যাওয়ায় পড়া তো এলোমেলো হইছে।'

দিনাজপুর জিলা স্কুলে গিয়ে দেখা যায়, স্কুল বন্ধ। তবে অফিস খোলা রয়েছে। কয়েকজন শিক্ষক আছেন। ভারপ্রাপ্ত প্রধান শিক্ষক মো. জহুরুল ইসলাম বলেন, ১৫ আগস্ট থেকে তাঁদের বিদ্যালয়ে আশ্রয়কেন্দ্র খোলা হয়। ২৭ আগস্ট স্কুল খোলা হবে। এত দিন বন্ধ থাকায় শিক্ষার্থীদের লেখাপড়ার ব্যাপক ক্ষতি হচ্ছে।

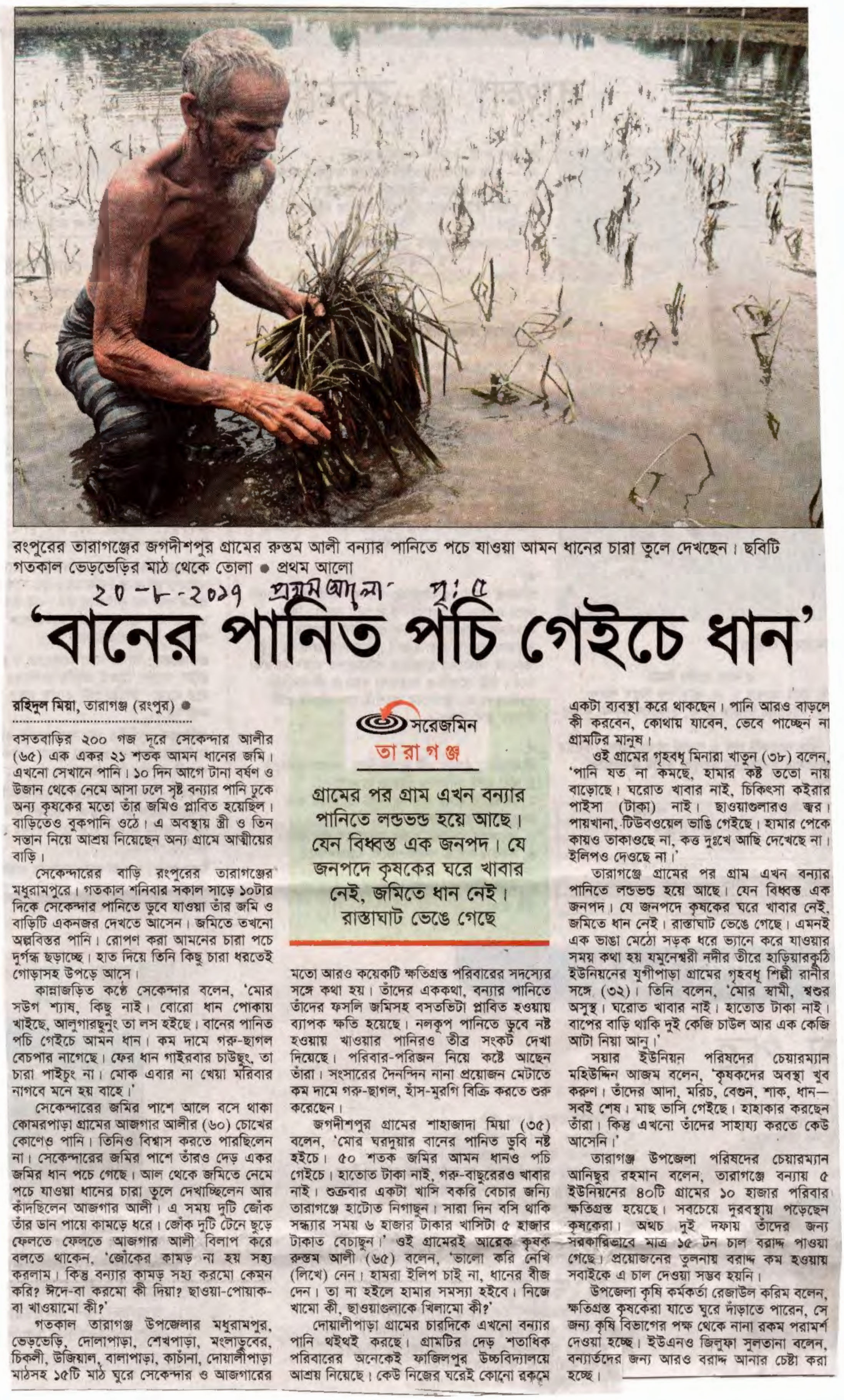
বন্যার কারণে নওগাঁয় ১৯৬টি শিক্ষাপ্রতিষ্ঠান বন্ধ রয়েছে। এ ছাড়া আশ্রয়কেন্দ্র খোলায় আরও ১৫টি শিক্ষাপ্রতিষ্ঠানে শিক্ষা কার্যক্রম এগোচ্ছে না। ১৯ থেকে ২১ আগস্ট পর্যন্ত বন্যাকবলিত উপজেলা মান্দা, পত্নীতলা ও সদর উপজেলার অন্তত ৩০টি বিদ্যালয় ঘুরে দেখা যায়, বিদ্যালয়গুলোর আঙিনা ও শ্রেণিকক্ষে পানি। এসব বিদ্যালয়ের কোনোটিতে হাঁটুপানি, কোনোটিতে কোমরপানি। যেসব বিদ্যালয়ে শ্রেণিকক্ষে পানি ঢোকেনি, সেগুলোতে আবার আশ্রয় নিয়েছেন বন্যাকবলিত মানুষেরা।

গতকাল দুপুরে নওগাঁ সদর উপজেলার বোয়ালিয়া সরকারি প্রাথমিক বিদ্যালয়ে গিয়ে দেখা যায়, বিদ্যালয়ের আঙিনায় হাঁটুপানি। বোয়ালিয়াসহ আশপাশের গ্রামের মানুষের বাড়িঘরে পানি ঢুকে পড়ায় অনেকে বিদ্যালয়ের শ্রেণিকক্ষে আশ্রয় নিয়েছে। বিকেলে মুঠোফোনে বিদ্যালয়ের প্রধান শিক্ষক বেলাল হোসেন বলেন, তাঁর শিক্ষাপ্রতিষ্ঠানে ২৬৫ জন শিক্ষার্থী রয়েছে। গত শনিবার উপজেলার ইকরতাড়া এলাকায় ছোট যমুনা নদীর বাঁধ ভেঙে এলাকার বাড়িঘর, শিক্ষাপ্রতিষ্ঠান—সব তলিয়ে গেছে। প্রাথমিক বিদ্যালয়ে শিশু শিক্ষার্থী পড়াশোনা করায় তাদের নিরাপত্তার কথা বিবেচনা করে রোববার থেকে বিদ্যালয় বন্ধ ঘোষণা করা হয়।

জেলা প্রাথমিক শিক্ষা কর্মকর্তা এ কে এম আমিরুল ইসলাম বলেন, বন্যাকবলিত বিদ্যালয়গুলোতে শিক্ষা কার্যক্রম চালানোর বিষয়টি বিদ্যালয়ের শিক্ষক ও ব্যবস্থাপনা কমিটির সদস্যদের ওপর দেওয়া রয়েছে। তাঁরা উপযুক্ত মনে করলে পাঠদান চালাবেন, আর ঝুঁকি থাকলে চালাবেন না। তবে বন্যার পানি নেমে গেলে সব বিদ্যালয়ে পুরোদমে শিক্ষা কার্যক্রম চলবে।

সিরাজগঞ্জে ৪২৯টি শিক্ষাপ্রতিষ্ঠানে বন্যার পানি প্রবেশ করায় পাঠদান বন্ধ হয়ে গেছে। তবে স্থানীয় শিক্ষা কর্মকর্তারা বলেছেন, বন্যা পরিস্থিতির উন্নতি হওয়ায় বিদ্যালয়ও খুলতে শুরু করেছে। তবে কিছু বিদ্যালয়ে আশ্রয়কেন্দ্র খোলায় সেগুলোতে অসুবিধা হচ্ছে।

[প্রতিবেদন তৈরিতে সহায়তা করেছেন **সিরাজগঞ্জ, নওগাঁ ও বিরামপুর (দিনাজপুর) প্রতিনিধি**]



রংপুরের তারাগঞ্জের জগদীশপুর গ্রামের রুস্তম আলী বন্যার পানিতে পচে যাওয়া আমন ধানের চারা তুলে দেখছেন। ছবিটি গতকাল ভেড়ভেড়ির মাঠ থেকে তোলা ● প্রথম আলো

২০-৮-২০১৭ প্রথম আলো পৃ: ৫

‘বানের পানিত পচি গেইচে ধান’

রহিদুল মিয়া, তারাগঞ্জ (রংপুর) ●

সরেজমিন

তা রা গ ঞ্জ

গ্রামের পর গ্রাম এখন বন্যার পানিতে লন্ডভন্ড হয়ে আছে। যেন বিধ্বস্ত এক জনপদ। যে জনপদে কৃষকের ঘরে খাবার নেই, জমিতে ধান নেই। রাস্তাঘাট ভেঙে গেছে

বসতবাড়ির ২০০ গজ দূরে সেকেন্দার আলীর (৬৫) এক একর ২১ শতক আমন ধানের জমি। এখনো সেখানে পানি। ১০ দিন আগে টানা বর্ষণ ও উজান থেকে নেমে আসা ঢলে সৃষ্ট বন্যার পানি ঢুকে অন্য কৃষকের মতো তাঁর জমিও প্লাবিত হয়েছিল। বাড়িতেও বুকপানি ওঠে। এ অবস্থায় স্ত্রী ও তিন সন্তান নিয়ে আশ্রয় নিয়েছেন অন্য গ্রামে আত্মীয়ের বাড়ি।

সেকেন্দারের বাড়ি রংপুরের তারাগঞ্জের মধুরামপুরে। গতকাল শনিবার সকাল সাড়ে ১০টার দিকে সেকেন্দার পানিতে ডুবে যাওয়া তাঁর জমি ও বাড়িটি একনজর দেখতে আসেন। জমিতে তখনো অল্পবিস্তর পানি। রোপণ করা আমনের চারা পচে দুর্গন্ধ ছড়াচ্ছে। হাত দিয়ে তিনি কিছু চারা ধরতেই গোড়াসহ উপড়ে আসে।

কান্নাজড়িত কণ্ঠে সেকেন্দার বলেন, ‘মোর সউগ শ্যাষ, কিছু নাই। বোরো ধান পোকায় খাইছে, আলুগারছুনুং তা লস হইছে। বানের পানিত পচি গেইচে আমন ধান। কম দামে গরু-ছাগল বেচপার নাগেছে। ফের ধান গাইরবার চাউছুং, তা চারা পাইচুং না। মোক এবার না খেয়া মরিবার নাগবে মনে হয় বাহে।’

সেকেন্দারের জমির পাশে আলে বসে থাকা কোমরপাড়া গ্রামের আজগার আলীর (৬০) চোখের কোণেও পানি। তিনিও বিশ্বাস করতে পারছিলেন না। সেকেন্দারের জমির পাশে তাঁরও দেড় একর জমির ধান পচে গেছে। আল থেকে জমিতে নেমে পচে যাওয়া ধানের চারা তুলে দেখাচ্ছিলেন আর কাঁদছিলেন আজগার আলী। এ সময় দুটি জোঁক তাঁর ডান পায়ে কামড়ে ধরে। জোঁক দুটি টেনে ছুড়ে ফেলতে ফেলতে আজগার আলী বিলাপ করে বলতে থাকেন, ‘জোঁকের কামড় না হয় সহ্য করলাম। কিন্তু বন্যার কামড় সহ্য করমো কেমন করি? ঈদে-বা করমো কী দিয়া? ছাওয়া-পোয়াক-বা খাওয়ামো কী?’

গতকাল তারাগঞ্জ উপজেলার মধুরামপুর, ভেড়ভেড়ি, দোলাপাড়া, শেখপাড়া, মংলাডুবের, চিকলী, উজিয়াল, বালাপাড়া, কাচাঁনা, দোয়ালীপাড়া মাঠসহ ১৫টি মাঠ ঘুরে সেকেন্দার ও আজগারের মতো আরও কয়েকটি ক্ষতিগ্রস্ত পরিবারের সদস্যের সঙ্গে কথা হয়। তাঁদের এককথা, বন্যার পানিতে তাঁদের ফসলি জমিসহ বসতভিটা প্লাবিত হওয়ায় ব্যাপক ক্ষতি হয়েছে। নলকূপ পানিতে ডুবে নষ্ট হওয়ায় খাওয়ার পানিরও তীব্র সংকট দেখা দিয়েছে। পরিবার-পরিজন নিয়ে কষ্টে আছেন তাঁরা। সংসারের দৈনন্দিন নানা প্রয়োজন মেটাতে কম দামে গরু-ছাগল, হাঁস-মুরগি বিক্রি করতে শুরু করেছেন।

জগদীশপুর গ্রামের শাহাজাদা মিয়া (৩৫) বলেন, ‘মোর ঘরদুয়ার বানের পানিত ডুবি নষ্ট হইচে। ৫০ শতক জমির আমন ধানও পচি গেইচে। হাতোত টাকা নাই, গরু-বাছুরেরও খাবার নাই। শুক্রবার একটা খাসি বকরি বেচার জন্যি তারাগঞ্জে হাটোত নিগাছুন। সারা দিন বসি থাকি সন্ধ্যার সময় ৬ হাজার টাকার খাসিটা ৫ হাজার টাকাত বেচাছুন।’ ওই গ্রামেরই আরেক কৃষক রুস্তম আলী (৬৫) বলেন, ‘ভালো করি নেখি (লিখে) নেন। হামরা ইলিপ চাই না, ধানের বীজ দেন। তা না হইলে হামার সমস্যা হইবে। নিজে খামো কী, ছাওয়াগুলাকে খিলামো কী?’

দোয়ালীপাড়া গ্রামের চারদিকে এখনো বন্যার পানি থইথই করছে। গ্রামটির দেড় শতাধিক পরিবারের অনেকেই ফাজিলপুর উচ্চবিদ্যালয়ে আশ্রয় নিয়েছে। কেউ নিজের ঘরেই কোনো রকমে একটা ব্যবস্থা করে থাকছেন। পানি আরও বাড়লে কী করবেন, কোথায় যাবেন, ভেবে পাচ্ছেন না গ্রামটির মানুষ।

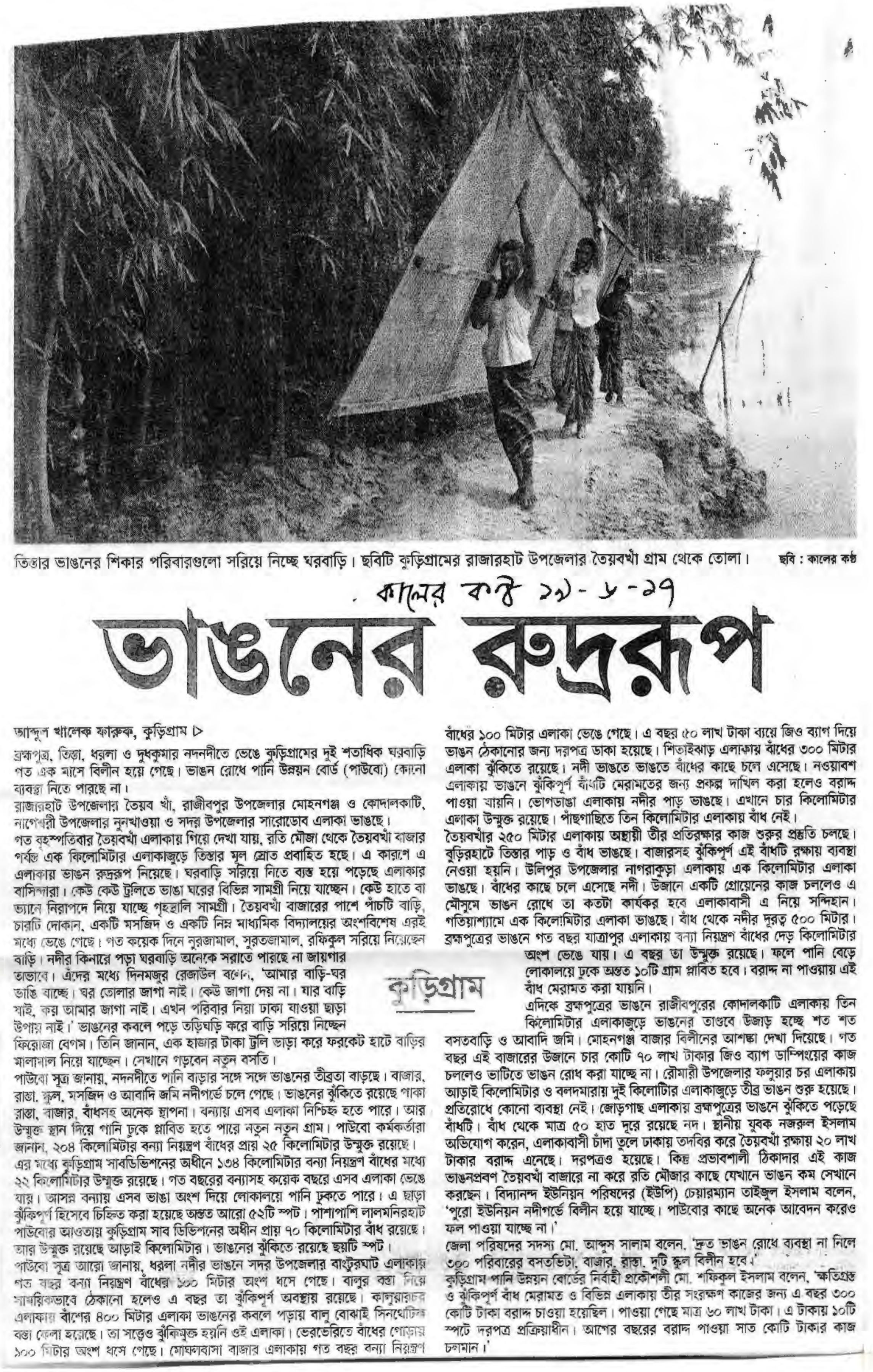
ওই গ্রামের গৃহবধূ মিনারা খাতুন (৩৮) বলেন, ‘পানি যত না কমছে, হামার কষ্ট ততো নায় বাড়োছে। ঘরোত খাবার নাই, চিকিৎসা কইরার পাইসা (টাকা) নাই। ছাওয়াগুলারও জ্বর। পায়খানা, টিউবওয়েল ভাঙি গেইছে। হামার পেকে কায়ও তাকাওছে না, কত্ত দুঃখে আছি দেখেছে না। ইলিপও দেওছে না।’

তারাগঞ্জে গ্রামের পর গ্রাম এখন বন্যার পানিতে লন্ডভন্ড হয়ে আছে। যেন বিধ্বস্ত এক জনপদ। যে জনপদে কৃষকের ঘরে খাবার নেই, জমিতে ধান নেই। রাস্তাঘাট ভেঙে গেছে। এমনই এক ভাঙা মেঠো সড়ক ধরে ভ্যানে করে যাওয়ার সময় কথা হয় যমুনেশ্বরী নদীর তীরে হাড়িয়ারকুঠি ইউনিয়নের যুগীপাড়া গ্রামের গৃহবধূ শিল্পী রানীর সঙ্গে (৩২)। তিনি বলেন, ‘মোর স্বামী, শ্বশুর অসুস্থ। ঘরোত খাবার নাই। হাতোত টাকা নাই। বাপের বাড়ি থাকি দুই কেজি চাউল আর এক কেজি আটা নিয়া আনু।’

সয়ার ইউনিয়ন পরিষদের চেয়ারম্যান মহিউদ্দিন আজম বলেন, ‘কৃষকদের অবস্থা খুব করুণ। তাঁদের আদা, মরিচ, বেগুন, শাক, ধান—সবই শেষ। মাছ ভাসি গেইছে। হাহাকার করছেন তাঁরা। কিন্তু এখনো তাঁদের সাহায্য করতে কেউ আসেনি।’

তারাগঞ্জ উপজেলা পরিষদের চেয়ারম্যান আনিছুর রহমান বলেন, তারাগঞ্জে বন্যায় ৫ ইউনিয়নের ৪০টি গ্রামের ১০ হাজার পরিবার ক্ষতিগ্রস্ত হয়েছে। সবচেয়ে দুরবস্থায় পড়েছেন কৃষকেরা। অথচ দুই দফায় তাঁদের জন্য সরকারিভাবে মাত্র ১৫ টন চাল বরাদ্দ পাওয়া গেছে। প্রয়োজনের তুলনায় বরাদ্দ কম হওয়ায় সবাইকে এ চাল দেওয়া সম্ভব হয়নি।

উপজেলা কৃষি কর্মকর্তা রেজাউল করিম বলেন, ক্ষতিগ্রস্ত কৃষকেরা যাতে ঘুরে দাঁড়াতে পারেন, সে জন্য কৃষি বিভাগের পক্ষ থেকে নানা রকম পরামর্শ দেওয়া হচ্ছে। ইউএনও জিলুফা সুলতানা বলেন, বন্যার্তদের জন্য আরও বরাদ্দ আনার চেষ্টা করা হচ্ছে।



তিস্তার ভাঙনের শিকার পরিবারগুলো সরিয়ে নিচ্ছে ঘরবাড়ি। ছবিটি কুড়িগ্রামের রাজারহাট উপজেলার তৈয়বখাঁ গ্রাম থেকে তোলা। ছবি : কালের কণ্ঠ

কালের কণ্ঠ ১৯-৮-১৭

ভাঙনের রুদ্ররূপ

আব্দুল খালেক ফারুক, কুড়িগ্রাম ▷

ব্রহ্মপুত্র, তিস্তা, ধরলা ও দুধকুমার নদনদীতে ভেঙে কুড়িগ্রামের দুই শতাধিক ঘরবাড়ি গত এক মাসে বিলীন হয়ে গেছে। ভাঙন রোধে পানি উন্নয়ন বোর্ড (পাউবো) কোনো ব্যবস্থা নিতে পারছে না।

রাজারহাট উপজেলার তৈয়ব খাঁ, রাজীবপুর উপজেলার মোহনগঞ্জ ও কোদালকাটি, নাগেশ্বরী উপজেলার নুনখাওয়া ও সদর উপজেলার সারোডোব এলাকা ভাঙছে।

গত বৃহস্পতিবার তৈয়বখাঁ এলাকায় গিয়ে দেখা যায়, রতি মৌজা থেকে তৈয়বখাঁ বাজার পর্যন্ত এক কিলোমিটার এলাকাজুড়ে তিস্তার মূল স্রোত প্রবাহিত হছে। এ কারণে এ এলাকায় ভাঙন রুদ্ররূপ নিয়েছে। ঘরবাড়ি সরিয়ে নিতে ব্যস্ত হয়ে পড়েছে এলাকার বাসিন্দারা। কেউ কেউ ট্রলিতে ভাঙা ঘরের বিভিন্ন সামগ্রী নিয়ে যাচ্ছেন। কেউ হাতে বা ভ্যানে নিরাপদে নিয়ে যাচ্ছে গৃহস্থালি সামগ্রী। তৈয়বখাঁ বাজারের পাশে পাঁচটি বাড়ি, চারটি দোকান, একটি মসজিদ ও একটি নিম্ন মাধ্যমিক বিদ্যালয়ের অংশবিশেষ এরই মধ্যে ভেঙে গেছে। গত কয়েক দিনে নুরজামাল, সুরতজামাল, রফিকুল সরিয়ে নিয়েছেন বাড়ি। নদীর কিনারে পড়া ঘরবাড়ি অনেকে সরাতে পারছে না জায়গার অভাবে। এঁদের মধ্যে দিনমজুর রেজাউল বলেন, 'আমার বাড়ি-ঘর ভাঙি যাচ্ছে। ঘর তোলার জাগা নাই। কেউ জাগা দেয় না। যার বাড়ি যাই, কয় আমার জাগা নাই। এখন পরিবার নিয়া ঢাকা যাওয়া ছাড়া উপায় নাই।' ভাঙনের কবলে পড়ে তড়িঘড়ি করে বাড়ি সরিয়ে নিচ্ছেন ফিরোজা বেগম। তিনি জানান, এক হাজার টাকা ট্রলি ভাড়া করে ফরকেট হাটে বাড়ির মালামাল নিয়ে যাচ্ছেন। সেখানে গড়বেন নতুন বসতি।

পাউবো সূত্র জানায়, নদনদীতে পানি বাড়ার সঙ্গে সঙ্গে ভাঙনের তীব্রতা বাড়ছে। বাজার, রাস্তা, স্কুল, মসজিদ ও আবাদি জমি নদীগর্ভে চলে গেছে। ভাঙনের ঝুঁকিতে রয়েছে পাকা রাস্তা, বাজার, বাঁধসহ অনেক স্থাপনা। বন্যায় এসব এলাকা নিশ্চিহ্ন হতে পারে। আর উন্মুক্ত স্থান দিয়ে পানি ঢুকে প্লাবিত হতে পারে নতুন নতুন গ্রাম। পাউবো কর্মকর্তারা জানান, ২০৪ কিলোমিটার বন্যা নিয়ন্ত্রণ বাঁধের প্রায় ২৫ কিলোমিটার উন্মুক্ত রয়েছে।

এর মধ্যে কুড়িগ্রাম সাবডিভিশনের অধীনে ১৩৪ কিলোমিটার বন্যা নিয়ন্ত্রণ বাঁধের মধ্যে ২২ কিলোমিটার উন্মুক্ত রয়েছে। গত বছরের বন্যাসহ কয়েক বছরে এসব এলাকা ভেঙে যায়। আসন্ন বন্যায় এসব ভাঙা অংশ দিয়ে লোকালয়ে পানি ঢুকতে পারে। এ ছাড়া ঝুঁকিপূর্ণ হিসেবে চিহ্নিত করা হয়েছে অন্তত আরো ৫২টি স্পট। পাশাপাশি লালমনিরহাট পাউবোর আওতায় কুড়িগ্রাম সাব ডিভিশনের অধীন প্রায় ৭০ কিলোমিটার বাঁধ রয়েছে। আর উন্মুক্ত রয়েছে আড়াই কিলোমিটার। ভাঙনের ঝুঁকিতে রয়েছে ছয়টি স্পট।

পাউবো সূত্র আরো জানায়, ধরলা নদীর ভাঙনে সদর উপজেলার বাংটুরঘাট এলাকায় গত বছর বন্যা নিয়ন্ত্রণ বাঁধের ১০০ মিটার অংশ ধসে গেছে। বালুর বস্তা দিয়ে সাময়িকভাবে ঠেকানো হলেও এ বছর তা ঝুঁকিপূর্ণ অবস্থায় রয়েছে। কালুয়ারচর এলাকায় বাঁশের ৪০০ মিটার এলাকা ভাঙনের কবলে পড়ায় বালু বোঝাই সিনথেটিক বস্তা ফেলা হয়েছে। তা সত্ত্বেও ঝুঁকিমুক্ত হয়নি ওই এলাকা। ভেরভেরিতে বাঁধের গোড়ায় ১০০ মিটার অংশ ধসে গেছে। মোঘলবাসা বাজার এলাকায় গত বছর বন্যা নিয়ন্ত্রণ বাঁধের ১০০ মিটার এলাকা ভেঙে গেছে। এ বছর ৫০ লাখ টাকা ব্যয়ে জিও ব্যাগ দিয়ে ভাঙন ঠেকানোর জন্য দরপত্র ডাকা হয়েছে। শিতাইঝাড় এলাকায় বাঁধের ৩০০ মিটার এলাকা ঝুঁকিতে রয়েছে। নদী ভাঙতে ভাঙতে বাঁধের কাছে চলে এসেছে। নওয়াবশ এলাকায় ভাঙনে ঝুঁকিপূর্ণ বাঁধটি মেরামতের জন্য প্রকল্প দাখিল করা হলেও বরাদ্দ পাওয়া যায়নি। ভোগডাঙা এলাকায় নদীর পাড় ভাঙছে। এখানে চার কিলোমিটার এলাকা উন্মুক্ত রয়েছে। পাঁছগাছিতে তিন কিলোমিটার এলাকায় বাঁধ নেই।

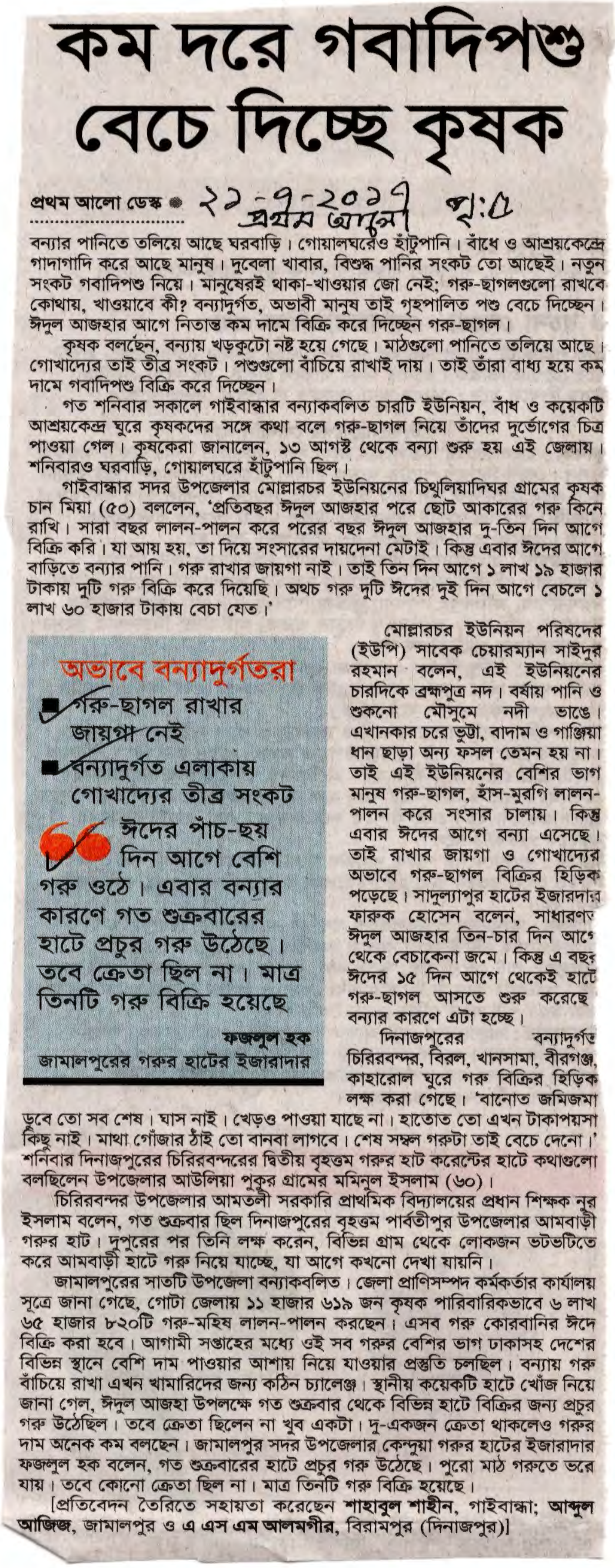
তৈয়বখাঁর ২৫০ মিটার এলাকায় অস্থায়ী তীর প্রতিরক্ষার কাজ শুরুর প্রস্তুতি চলছে। বুড়িরহাটে তিস্তার পাড় ও বাঁধ ভাঙছে। বাজারসহ ঝুঁকিপূর্ণ এই বাঁধটি রক্ষায় ব্যবস্থা নেওয়া হয়নি। উলিপুর উপজেলার নাগরাকুড়া এলাকায় এক কিলোমিটার এলাকা ভাঙছে। বাঁধের কাছে চলে এসেছে নদী। উজানে একটি গ্রোয়েনের কাজ চললেও এ মৌসুমে ভাঙন রোধে তা কতটা কার্যকর হবে এলাকাবাসী এ নিয়ে সন্দিহান। গতিয়াশ্যামে এক কিলোমিটার এলাকা ভাঙছে। বাঁধ থেকে নদীর দূরত্ব ৫০০ মিটার। ব্রহ্মপুত্রের ভাঙনে গত বছর যাত্রাপুর এলাকায় বন্যা নিয়ন্ত্রণ বাঁধের দেড় কিলোমিটার অংশ ভেঙে যায়। এ বছর তা উন্মুক্ত রয়েছে। ফলে পানি বেড়ে লোকালয়ে ঢুকে অন্তত ১০টি গ্রাম প্লাবিত হবে। বরাদ্দ না পাওয়ায় এই বাঁধ মেরামত করা যায়নি।

কুড়িগ্রাম

এদিকে ব্রহ্মপুত্রের ভাঙনে রাজীবপুরের কোদালকাটি এলাকায় তিন কিলোমিটার এলাকাজুড়ে ভাঙনের তাণ্ডবে উজাড় হচ্ছে শত শত বসতবাড়ি ও আবাদি জমি। মোহনগঞ্জ বাজার বিলীনের আশঙ্কা দেখা দিয়েছে। গত বছর এই বাজারের উজানে চার কোটি ৭০ লাখ টাকার জিও ব্যাগ ডাম্পিংয়ের কাজ চললেও ভাটিতে ভাঙন রোধ করা যাচ্ছে না। রৌমারী উপজেলার ফলুয়ার চর এলাকায় আড়াই কিলোমিটার ও বলদমারায় দুই কিলোটার এলাকাজুড়ে তীব্র ভাঙন শুরু হয়েছে। প্রতিরোধে কোনো ব্যবস্থা নেই। জোড়গাছ এলাকায় ব্রহ্মপুত্রের ভাঙনে ঝুঁকিতে পড়েছে বাঁধটি। বাঁধ থেকে মাত্র ৫০ হাত দূরে রয়েছে নদ। স্থানীয় যুবক নজরুল ইসলাম অভিযোগ করেন, এলাকাবাসী চাঁদা তুলে ঢাকায় তদবির করে তৈয়বখাঁ রক্ষায় ২০ লাখ টাকার বরাদ্দ এনেছে। দরপত্রও হয়েছে। কিন্তু প্রভাবশালী ঠিকাদার এই কাজ ভাঙনপ্রবণ তৈয়বখাঁ বাজারে না করে রতি মৌজার কাছে যেখানে ভাঙন কম সেখানে করছেন। বিদ্যানন্দ ইউনিয়ন পরিষদের (ইউপি) চেয়ারম্যান তাইজুল ইসলাম বলেন, 'পুরো ইউনিয়ন নদীগর্ভে বিলীন হয়ে যাচ্ছে। পাউবোর কাছে অনেক আবেদন করেও ফল পাওয়া যাচ্ছে না।'

জেলা পরিষদের সদস্য মো. আব্দুস সালাম বলেন, 'দ্রুত ভাঙন রোধে ব্যবস্থা না নিলে ৩০০ পরিবারের বসতভিটা, বাজার, রাস্তা, দুটি স্কুল বিলীন হবে।'

কুড়িগ্রাম পানি উন্নয়ন বোর্ডের নির্বাহী প্রকৌশলী মো. শফিকুল ইসলাম বলেন, 'ক্ষতিগ্রস্ত ও ঝুঁকিপূর্ণ বাঁধ মেরামত ও বিভিন্ন এলাকায় তীর সংরক্ষণ কাজের জন্য এ বছর ৩০০ কোটি টাকা বরাদ্দ চাওয়া হয়েছিল। পাওয়া গেছে মাত্র ৬০ লাখ টাকা। এ টাকায় ১০টি স্পটে দরপত্র প্রক্রিয়াধীন। আগের বছরের বরাদ্দ পাওয়া সাত কোটি টাকার কাজ চলমান।'



কম দরে গবাদিপশু বেচে দিচ্ছে কৃষক

প্রথম আলো ডেস্ক ● ২১-৭-২০১৭ প্রথম আলো পৃ:৫

বন্যার পানিতে তলিয়ে আছে ঘরবাড়ি। গোয়ালঘরেও হাঁটুপানি। বাঁধে ও আশ্রয়কেন্দ্রে গাদাগাদি করে আছে মানুষ। দুবেলা খাবার, বিশুদ্ধ পানির সংকট তো আছেই। নতুন সংকট গবাদিপশু নিয়ে। মানুষেরই থাকা-খাওয়ার জো নেই; গরু-ছাগলগুলো রাখবে কোথায়, খাওয়াবে কী? বন্যাদুর্গত, অভাবী মানুষ তাই গৃহপালিত পশু বেচে দিচ্ছেন। ঈদুল আজহার আগে নিতান্ত কম দামে বিক্রি করে দিচ্ছেন গরু-ছাগল।

কৃষক বলছেন, বন্যায় খড়কুটো নষ্ট হয়ে গেছে। মাঠগুলো পানিতে তলিয়ে আছে। গোখাদ্যের তাই তীব্র সংকট। পশুগুলো বাঁচিয়ে রাখাই দায়। তাই তাঁরা বাধ্য হয়ে কম দামে গবাদিপশু বিক্রি করে দিচ্ছেন।

গত শনিবার সকালে গাইবান্ধার বন্যাকবলিত চারটি ইউনিয়ন, বাঁধ ও কয়েকটি আশ্রয়কেন্দ্র ঘুরে কৃষকদের সঙ্গে কথা বলে গরু-ছাগল নিয়ে তাঁদের দুর্ভোগের চিত্র পাওয়া গেল। কৃষকেরা জানালেন, ১৩ আগস্ট থেকে বন্যা শুরু হয় এই জেলায়। শনিবারও ঘরবাড়ি, গোয়ালঘরে হাঁটুপানি ছিল।

গাইবান্ধার সদর উপজেলার মোল্লারচর ইউনিয়নের চিথুলিয়াদিঘর গ্রামের কৃষক চান মিয়া (৫০) বললেন, 'প্রতিবছর ঈদুল আজহার পরে ছোট আকারের গরু কিনে রাখি। সারা বছর লালন-পালন করে পরের বছর ঈদুল আজহার দু-তিন দিন আগে বিক্রি করি। যা আয় হয়, তা দিয়ে সংসারের দায়দেনা মেটাই। কিন্তু এবার ঈদের আগে বাড়িতে বন্যার পানি। গরু রাখার জায়গা নাই। তাই তিন দিন আগে ১ লাখ ১৯ হাজার টাকায় দুটি গরু বিক্রি করে দিয়েছি। অথচ গরু দুটি ঈদের দুই দিন আগে বেচলে ১ লাখ ৬০ হাজার টাকায় বেচা যেত।'

অভাবে বন্যাদুর্গতরা

- গরু-ছাগল রাখার জায়গা নেই
- বন্যাদুর্গত এলাকায় গোখাদ্যের তীব্র সংকট

> ঈদের পাঁচ-ছয় দিন আগে বেশি গরু ওঠে। এবার বন্যার কারণে গত শুক্রবারের হাটে প্রচুর গরু উঠেছে। তবে ক্রেতা ছিল না। মাত্র তিনটি গরু বিক্রি হয়েছে
>
> **ফজলুল হক**
> জামালপুরের গরুর হাটের ইজারাদার

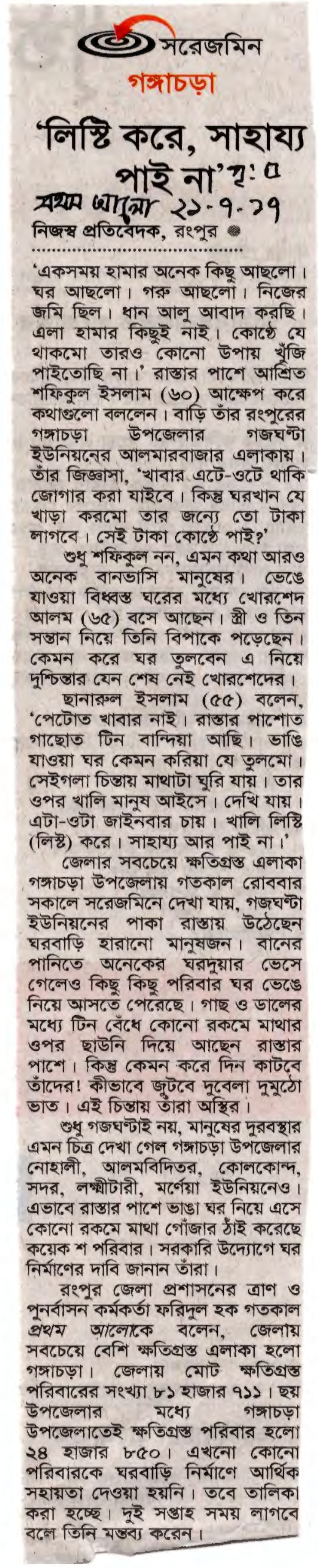
মোল্লারচর ইউনিয়ন পরিষদের (ইউপি) সাবেক চেয়ারম্যান সাইদুর রহমান বলেন, এই ইউনিয়নের চারদিকে ব্রহ্মপুত্র নদ। বর্ষায় পানি ও শুকনো মৌসুমে নদী ভাঙে। এখানকার চরে ভুট্টা, বাদাম ও গাঞ্জিয়া ধান ছাড়া অন্য ফসল তেমন হয় না। তাই এই ইউনিয়নের বেশির ভাগ মানুষ গরু-ছাগল, হাঁস-মুরগি লালন-পালন করে সংসার চালায়। কিন্তু এবার ঈদের আগে বন্যা এসেছে। তাই রাখার জায়গা ও গোখাদ্যের অভাবে গরু-ছাগল বিক্রির হিড়িক পড়েছে। সাদুল্যাপুর হাটের ইজারদার ফারুক হোসেন বলেন, সাধারণত ঈদুল আজহার তিন-চার দিন আগে থেকে বেচাকেনা জমে। কিন্তু এ বছর ঈদের ১৫ দিন আগে থেকেই হাটে গরু-ছাগল আসতে শুরু করেছে বন্যার কারণে এটা হচ্ছে।

দিনাজপুরের বন্যাদুর্গত চিরিরবন্দর, বিরল, খানসামা, বীরগঞ্জ, কাহারোল ঘুরে গরু বিক্রির হিড়িক লক্ষ করা গেছে। 'বানোত জমিজমা ডুবে তো সব শেষ। ঘাস নাই। খেড়ও পাওয়া যাছে না। হাতোত তো এখন টাকাপয়সা কিছু নাই। মাথা গোঁজার ঠাঁই তো বানবা লাগবে। শেষ সম্বল গরুটা তাই বেচে দেনো।' শনিবার দিনাজপুরের চিরিরবন্দরের দ্বিতীয় বৃহত্তম গরুর হাট করেন্টের হাটে কথাগুলো বলছিলেন উপজেলার আউলিয়া পুকুর গ্রামের মমিনুল ইসলাম (৬০)।

চিরিরবন্দর উপজেলার আমতলী সরকারি প্রাথমিক বিদ্যালয়ের প্রধান শিক্ষক নুর ইসলাম বলেন, গত শুক্রবার ছিল দিনাজপুরের বৃহত্তম পার্বতীপুর উপজেলার আমবাড়ী গরুর হাট। দুপুরের পর তিনি লক্ষ করেন, বিভিন্ন গ্রাম থেকে লোকজন ভটভটিতে করে আমবাড়ী হাটে গরু নিয়ে যাচ্ছে, যা আগে কখনো দেখা যায়নি।

জামালপুরের সাতটি উপজেলা বন্যাকবলিত। জেলা প্রাণিসম্পদ কর্মকর্তার কার্যালয় সূত্রে জানা গেছে, গোটা জেলায় ১১ হাজার ৬১৯ জন কৃষক পারিবারিকভাবে ৬ লাখ ৬৫ হাজার ৮২০টি গরু-মহিষ লালন-পালন করছেন। এসব গরু কোরবানির ঈদে বিক্রি করা হবে। আগামী সপ্তাহের মধ্যে ওই সব গরুর বেশির ভাগ ঢাকাসহ দেশের বিভিন্ন স্থানে বেশি দাম পাওয়ার আশায় নিয়ে যাওয়ার প্রস্তুতি চলছিল। বন্যায় গরু বাঁচিয়ে রাখা এখন খামারিদের জন্য কঠিন চ্যালেঞ্জ। স্থানীয় কয়েকটি হাটে খোঁজ নিয়ে জানা গেল, ঈদুল আজহা উপলক্ষে গত শুক্রবার থেকে বিভিন্ন হাটে বিক্রির জন্য প্রচুর গরু উঠেছিল। তবে ক্রেতা ছিলেন না খুব একটা। দু-একজন ক্রেতা থাকলেও গরুর দাম অনেক কম বলছেন। জামালপুর সদর উপজেলার কেন্দুয়া গরুর হাটের ইজারাদার ফজলুল হক বলেন, গত শুক্রবারের হাটে প্রচুর গরু উঠেছে। পুরো মাঠ গরুতে ভরে যায়। তবে কোনো ক্রেতা ছিল না। মাত্র তিনটি গরু বিক্রি হয়েছে।

[প্রতিবেদন তৈরিতে সহায়তা করেছেন **শাহাবুল শাহীন**, গাইবান্ধা; **আব্দুল আজিজ**, জামালপুর ও **এ এস এম আলমগীর**, বিরামপুর (দিনাজপুর)]



সরেজমিন

গঙ্গাচড়া

'লিস্টি করে, সাহায্য পাই না'

পৃ:৫ প্রথম আলো ২১-৭-১৭

নিজস্ব প্রতিবেদক, রংপুর ●

'একসময় হামার অনেক কিছু আছলো। ঘর আছলো। গরু আছলো। নিজের জমি ছিল। ধান আলু আবাদ করছি। এলা হামার কিছুই নাই। কোন্ঠে যে থাকমো তারও কোনো উপায় খুঁজি পাইতোছি না।' রাস্তার পাশে আশ্রিত শফিকুল ইসলাম (৬০) আক্ষেপ করে কথাগুলো বললেন। বাড়ি তাঁর রংপুরের গঙ্গাচড়া উপজেলার গজঘণ্টা ইউনিয়নের আলমারবাজার এলাকায়। তাঁর জিজ্ঞাসা, 'খাবার এটে-ওটে থাকি জোগার করা যাইবে। কিন্তু ঘরখান যে খাড়া করমো তার জন্যে তো টাকা লাগবে। সেই টাকা কোন্ঠে পাই?'

শুধু শফিকুল নন, এমন কথা আরও অনেক বানভাসি মানুষের। ভেঙে যাওয়া বিধ্বস্ত ঘরের মধ্যে খোরশেদ আলম (৬৫) বসে আছেন। স্ত্রী ও তিন সন্তান নিয়ে তিনি বিপাকে পড়েছেন। কেমন করে ঘর তুলবেন এ নিয়ে দুশ্চিন্তার যেন শেষ নেই খোরশেদের।

ছানারুল ইসলাম (৫৫) বলেন, 'পেটোত খাবার নাই। রাস্তার পাশোত গাছোত টিন বান্দিয়া আছি। ভাঙি যাওয়া ঘর কেমন করিয়া যে তুলমো। সেইগলা চিন্তায় মাথাটা ঘুরি যায়। তার ওপর খালি মানুষ আইসে। দেখি যায়। এটা-ওটা জাইনবার চায়। খালি লিস্টি (লিস্ট) করে। সাহায্য আর পাই না।'

জেলার সবচেয়ে ক্ষতিগ্রস্ত এলাকা গঙ্গাচড়া উপজেলায় গতকাল রোববার সকালে সরেজমিনে দেখা যায়, গজঘণ্টা ইউনিয়নের পাকা রাস্তায় উঠেছেন ঘরবাড়ি হারানো মানুষজন। বানের পানিতে অনেকের ঘরদুয়ার ভেসে গেলেও কিছু কিছু পরিবার ঘর ভেঙে নিয়ে আসতে পেরেছে। গাছ ও ডালের মধ্যে টিন বেঁধে কোনো রকমে মাথার ওপর ছাউনি দিয়ে আছেন রাস্তার পাশে। কিন্তু কেমন করে দিন কাটবে তাঁদের! কীভাবে জুটবে দুবেলা দুমুঠো ভাত। এই চিন্তায় তাঁরা অস্থির।

শুধু গজঘণ্টাই নয়, মানুষের দুরবস্থার এমন চিত্র দেখা গেল গঙ্গাচড়া উপজেলার নোহালী, আলমবিদিতর, কোলকোন্দ, সদর, লক্ষ্মীটারী, মর্ণেয়া ইউনিয়নেও। এভাবে রাস্তার পাশে ভাঙা ঘর নিয়ে এসে কোনো রকমে মাথা গোঁজার ঠাঁই করেছে কয়েক শ পরিবার। সরকারি উদ্যোগে ঘর নির্মাণের দাবি জানান তাঁরা।

রংপুর জেলা প্রশাসনের ত্রাণ ও পুনর্বাসন কর্মকর্তা ফরিদুল হক গতকাল *প্রথম আলোকে* বলেন, জেলায় সবচেয়ে বেশি ক্ষতিগ্রস্ত এলাকা হলো গঙ্গাচড়া। জেলায় মোট ক্ষতিগ্রস্ত পরিবারের সংখ্যা ৮১ হাজার ৭১১। ছয় উপজেলার মধ্যে গঙ্গাচড়া উপজেলাতেই ক্ষতিগ্রস্ত পরিবার হলো ২৪ হাজার ৮৫০। এখনো কোনো পরিবারকে ঘরবাড়ি নির্মাণে আর্থিক সহায়তা দেওয়া হয়নি। তবে তালিকা করা হচ্ছে। দুই সপ্তাহ সময় লাগবে বলে তিনি মন্তব্য করেন।

Appendix-9

Journal papers related to this thesis

- Sultana, M. R., Hassan, M.Z. and Paul, S.K. (2018). Indigenous practices for coping with flood: an assessment of the riparian people living in the Teesta floodplain. *Rajshahi University Journal of Environmental Science, 7,* 18-29.
- Sultana, M. R., Hassan, M.Z. and Paul, S.K. (2018). Mitigation of erosion-induced disaster through indigenous practices: evidence from rural community of Teesta river bank. *Journal of Life and Earth Science, 13*, 23-31.

Conference/Seminar paper presentation during PhD

- Exploring the impacts of river morphology change associated natural disasters on Teesta riparian environment of Bangladesh. International Conference on Agriculture, Food, Water, Biodiversity and Health in Changing Climate, Department of Geography, The University of Burdwan, Burdwan-713104, West Bengal, India, 6-8 March, 2020.
- Understanding the health impacts in a changing climate: A study on the vulnerable community of Teesta river basin. International Symposium on Environment, Disaster and Health, Institute of Disaster Management and Vulnerability Studies (IDMVS), University of Dhaka, 18-20 December, 2019.
- Indigenous practices for coping with flood: An assessment of the riparian people living in the Teesta floodplain. 1st International Conference on Prospects and Challenges of Sustainable Development in Developing Countries, Faculty of Social Science, University of Rajshahi, 19-20 July, 2019.
- Mitigation of erosion induced disaster through indigenous practices: Evidence from rural community of Teesta river bank. National Conference on Population and Sustainable Development: Issues and Challenges in Bangladesh, University of Rajshahi, 13 July, 2019.
- Influences of river morphology change on livelihood: A study on the riverine communities of the downstream Teesta river. XXIX Biennial Conference of North East India Geographical Society cum XI International Geographical Union (IGU) Commission Seminar on Environment and Sustainable Livelihood, B. Borooah College, Guwahati, Assam, India, 8-10 February, 2018.

Poster presentation during PhD

- Influences of river morphology change on livelihood: A study on the riverine communities of the downstream Teesta river. XXIX Biennial Conference of North East India Geographical Society cum XI International Geographical Union (IGU) Commission Seminar on Environment and Sustainable Livelihood, B. Borooah College, Guwahati, Assam, India, 8-10 February, 2018.