Assessment of river channel shifting and socio-economic impacts on local settlements of the Jamuna River, Pabna, Bangladesh.

By

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This Thesis Report Presented in Partial Fulfilment of the Requirements for the Degree of Bachelor of Science (B. Sc) in Environmental Science and Disaster Management (ESDM)

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APPROVAL

This thesis report titled**, "Assessment of river channel shifting and socio-economic impacts on local settlements of the Jamuna River, Pabna, Bangladesh"**, submitted by Md. Mahmudul Hasan Nishad, ID: 183-30-197 to the Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU), has been accepted as adequate for partial fulfillment of the requirements for the Bachelor of Science degree (B.Sc.) in Environmental Science and Disaster Management (ESDM) and approved as to its style and contents. The presentation has been held on 29th November of 2022.

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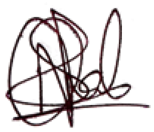
DECLARATION

I therefore declare that, I have accomplished this research study under the supervision of **Dr. Mahfuza Parveen, Associate Professor, Department of Environmental Science and Disaster Management (ESDM),** Daffodil International University (DIU). I further state that neither this research study nor any portion of this research study has been submitted for the granting of any degree elsewhere.



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DEDICATION

To,

my loving parents

Mst. Shahnaj Parvin

Late Mamun Hasan Miah Nabab

my younger sister and brother

Mst. Mysha Hasan Adhora

Md. Mahir Shahriar Nabil

my grandparents

Mst. Selina Begum

Late Nurul Islam Miah

my maternal grandparents

Md. Samsul Haque

Late Mahfuza Haque

Specially,

Md. Nuruzzaman Miah Khokon

my respected teachers

Dr. A. B. M. Kamal Pasha, PhD

Md. Azharul Haque Chowdhury

Dr. Mahfuza Parveen, PhD

Md. Sadril Islam Khan

And

to the loving memory of my beloved friends, seniors, juniors, coordination officers and staffs from the ***Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU)*** *with whom I spent a single second of my undergrad life in last four years.*

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Abstract

One of the largest rivers in the world, the Brahmaputra changed its course and started flowing into a new channel known as the Jamuna in 1787 as a result of a geological upheaval and an extraordinary flood. Bangladesh is a riverine floodplain country. The Jamuna's bank erosion has already caused thousands of people to lose their homes and irreparably damaged a number of institutions. The whole course of the Jamuna River that passes through the Pabna area is only covered by the Bera bpazila. People from several villages of the Bera upazila directly interact with the river in their daily work purpose. The research area “Bera upazila” which stretched from Bera to Dhalarchar of Pabna district with the area about twenty-five (25) kilometers long and from Nagarbari to Kallyanpur with the area average four (4) kilometers wide. To collect and analyze the data here both qualitative and quantitative tactics have been implemented on this study. For collecting primary data, local interview, direct observation and additionally GIS and RS data have been used. Secondary data has been collected from different published books, journals, articles, and websites. This study has three major objectives: examining patterns in river channel movement through RS and GIS, quantifying the accretion and erosion trends of the Jamuna River in Bera upazila zone and finding out the socio-economic impact on local settlements due to river erosion-accretion process. The study has found that, the amount of erosion and accretion during the study period from 2002 to 2012 along both banks of the river were 2053 ha and 1162 ha, respectively. In the next decade, the amount of erosion and accretion during 2012 to 2022 along both banks of the river were 1627 ha and 640 ha, respectively. Which justify the river channel shifting of Jamuna. The study has also found that, the Jamuna River's accretion rate increased more than its erosion rate. From the field survey data, it has been informed that, erosion and accretion are both dangerous and negatively effective at the same time for both people and environment. It causes various social and economic effects as well as it degrades the nature. In addition, people who are victim of river erosion or river related disasters become helpless and they do not get any emergency support or facilities like, emergency shelter, medication, transportation, pure drinking water, sanitation, and etc. Specially people of char areas who directly or indirectly depend on agriculture, become helpless while river erosion or similar disasters occur. Therefore, necessary supports are required for making the solution of present problems.

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Structure of the Study Report

This research project report has been grouped into five (05) different chapters. The chapters are as follows:

Chapter 01: Introduction

This introduction chapter contains the research project's introductory material, which includes a brief description about the background of the study, statement of the problems, and objectives. This chapter also displays and briefly explains the format of this research study report. There are four (04) parts in total in this chapter.

Chapter 02: Review of Literatures

This chapter gives a detailed description about river erosion, river accretion, along with reasons and mechanisms behind these processes in various rivers, as well as related research that have been conducted there. There are twelve (12) reviews of literatures given in this chapter.

Chapter 03: Methodology

This chapter explains the subject area in depth and discusses the many systematic methods that were employed to carry out the research. There are four (04) main sections in this chapter.

Chapter 04: Discussion and Results

The findings and outcomes of my research have been broadly discussed in this section in a different format. I have assumed three separate objectives for my study endeavor at the outset and worked toward them. By examining the information and findings in various ways, I have attempted to gain a clear grasp of the objectives in this chapter. So, there are six (06) sections in this chapter containing results and discussion.

Chapter 05: Conclusion and Recommendation

I have tried my best to summarize all research points from the review of literatures, data collecting, data analysis, results, and comments in this study's concluding chapter. Here, I have also made an attempt to defend the study's goals. Additionally, suggestions have been made for the researchers to help them comprehend the results of the next investigation. There are two (02) parts of this chapter.

CHAPTER 1 INTRODUCTION

The introductory details of this research project have been covered in this chapter's introduction. These contain a comprehensive overview of the study's aims, problem statement, and social record. This section also describes and briefly displays the report's organizational structure. There are four (04) sections in this chapter. These are as follows:

1.1. Background:

One of the largest rivers in the world, the Brahmaputra rises in Tibet in the Himalayas and runs across a distance of more than 3000 kilometers through China, India, and Bangladesh. The Brahmaputra changed its course and started flowing into a new channel known as the Jamuna in 1787 as a result of a geological upheaval and an extraordinary flood (N. I. Khan & Islam, 2003). The Old Brahmaputra, sometimes referred to as the "Jamuna," is the largest braided river that flows across Bangladesh's low-lying subsiding deltaic floodplain. The Brahmaputra-Jamuna is one of the biggest braided fluvial systems in the world. Up until the early 1990s, the river was naturally flowing across Bangladesh and had an average width of 14 km (Bhuiyan et al., 2015). It is one of the three important rivers in terms of water transportation, irrigation, fishing, and fresh water for communities downstream (M. T. Islam, 2010). Before interacting with the Ganges, the Meghna, and eventually the Bay of Bengal, the Jamuna travels roughly 2740 kilometers from its source and 220 kilometers from Bangladesh's northern boundaries. The Jamuna, one of the oldest rivers, has a generation period of around 250 years (M. A. Hassan et al., 2017). The Jamuna River is rated fifth in terms of flow and twelfth in terms of drainage area. For a number of factors, including geological uplift, sediment compaction, and increasingly, flooding events, many river channels vary in form (A. Khan et al., 2018). The Jamuna is referred to as a braided river because it contains several islands made up of suspended and bedload sediments in between the channel banks. Which demonstrates that the river's flow is unable to transport the silt, resulting in the formation of sandbars locally known as "chars." Typically, a braided river is regarded to have broad, unstable banks, weak limning, swift sideways flow, shallow depths, and numerous channel splits that surround alluvial islands.

1.2. Problem Statement:

The Jamuna's bank erosion has already caused thousands of people to lose their homes and irreparably damaged a number of institutions (Nahid et al., 2020). According to definitions, erosion is the process of removing sediment and other materials from the land's surface. It can also refer to the removal and transportation of soil materials brought on by flow, waves, tidal oscillations, and other hydrological factors that regulate a channel's flow condition. Flooding is one of the primary causes of riverbank erosion. Bangladesh is a nation with large floodplains; hence floods occur there almost every year. On both sides of the Jamuna, erosion amounted to an average of 3300 hectares each year from the 1970s to the early 1990s. River banks are eroded by flood and water flow when it rains during the monsoon season and when it is chilly outside. Along riverbanks, sandbanks develop throughout the winter. These sandbanks resemble a vast desert in the winter. Sandbank expansion, deposition, and erosion cause channel migration on an ongoing basis (M. T. Islam, 2010). Erosion has a substantial influence on both the bank line settlements of displaced people and the differential population change on rotating human occupancy. A diversity of sizes, forms, and mega- and macro-bar formations from a hierarchical bed of categorization differentiate the Jamuna River. The Jamuna River's water management increased the speed of channel flow before 1996. However, the water flow also changed throughout those years due to floods and heavy monsoon rain in 1988 and 1998 (M. A. Hassan et al., 2017). In the 40 years from 1973 to 2015, the 220 km long Jamuna River lost a net amount of land, or around 88,462 acres. During a flood, the Jamuna can braid into a plain that is up to 15 km broad, and scour depths as deep as 40 m have been seen. According to the formula of 1.6 tons per cubic metric ton of silt, the Jamuna River moves around 400 million tons of sediment yearly (R. Islam et al., 2017). Because of the varying flow patterns throughout the year, the Jamuna River's channel and char patterns change every year. Due to snowmelt from the Himalayas and monsoon rains, the Jamuna River normally has a high annual flow from June through September (N. I. Khan & Islam, 2003). The natural flow system of this river reach was changed by river training operations done in 1998 during the building of the Jamuna Multipurpose Bridge. JMB is 4.8 kilometers long in total. The lengths of the guiding bunds on either side of the bridge are 3,07 Km and 3,26 km, respectively. While the west bank is 532 meters broad, the east guide bank is 500 meters wide. In reality, the Bridge was constructed on 50 round piers that were 83 meters long and 8 meters broad. Due to quick sedimentation, bar growth steadily increased as the channel corridor widened. The river's natural width there was 11 kilometers before the bridge's structural alterations. Later, it was trained across a distance of around 6 kilometers for the building of the bridge. The braided system's bridge site, which is too narrow to accommodate the whole flow, acts as a sluice gate. As a result of the changed sedimentation process, many river bar types, including as construction, sharpened, sand wing, sand tongue, and bank side bars, are changing swiftly and are also having a severe effect on the environment in the area (Bhuiyan et al., 2015). Residents in Bangladesh suffer from permanent evictions and economic suffering as a result of riverbank erosion. The Jamuna River's flood plain occupies much of Bangladesh's northern area. Local Jamuna River channels have impulsively and sporadically wandered over the landscape, eroding banks and destroying everything in their path. People are compelled to relocate as a result of desertification, a growing water deficit, and climatic extremes like flooding and storms, and river bank erosion is common both there and on nearby floodplains (Mollah & Ferdaush, 2015).

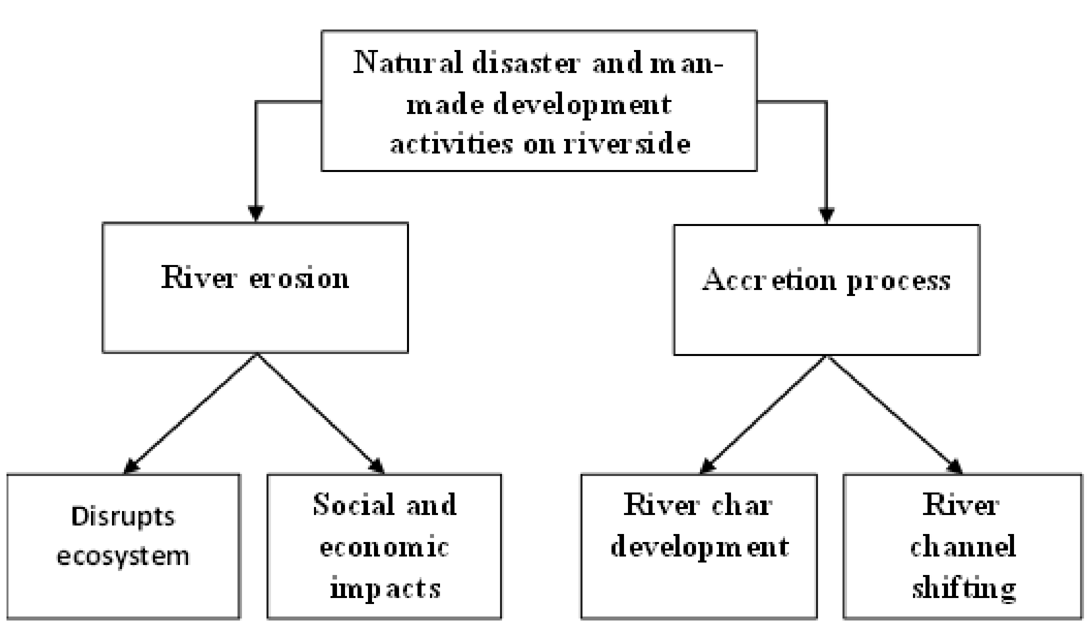

Figure 1: Flow chart of the problem statement (own illustration)

1.3. Justification of the Study:

There has been a lot of study done on the Jamuna River in Bangladesh regarding the behavior of the river in relation to numerous causes (such as erosion, accretion, bar morphology, etc.). The research on river erosion and accretion and their consequences on nearby villages in Bangladesh's Pabna area has certain limitations. Particularly, no investigation of this kind has been conducted on the Pabna district's Jamuna River. Pabna is an important district of Rajshahi division. Pabna district's Jamuna River is a significant river. The whole stretch of the Jamuna River that passes through the Pabna area is only covered by the Bera Upazila of the Paba district. Regarding river channel shifting and the Jamuna River, Pabna, no study has been done. Therefore, this topic has been chosen for my research project in order to discover new facts and phenomena regarding that place.

1.4. Objectives of the Study:

This project aims to follow the movement of the Jamuna River channel from 2002 to 2022 using RS, GIS and questionnaire survey. This research aims to investigate spatial and temporal changes of the river bank of the Jamuna River, Bera, Pabna, especially both Nagarbari and Kallyanpur are the major areas of interest. This study has three major objectives.

- Examining the patterns in river channel movement through RS and GIS, is the first objective in comprehending how rivers behave.
- The second objective is to quantify the accretion and erosion trends of the Jamuna River in Bera upazila zone.
- The third objective is to find out the socio-economic impact on local settlements due to river erosion-accretion process.

The research area which stretched from Bera to Dhalarchar of Pabna district with the area about 25 kilometers long and average four (4) kilometers wide.

CHAPTER 2: REVIEW OF LITERATURES

2.1. Erosion:

Erosion is a natural, geological phenomena caused by soil particles being carried away by water or wind and into new locations, but some human actions, such as agricultural practice, the conversion of forest to farmland, etc., would lead to higher rates of erosion. Steep slopes, climate (such as lengthy dry spells followed by heavy rain), improper land use, and patterns of the land cover all contribute to erosion. Additionally, a soil's natural characteristics may make it more vulnerable to erosion (Ganasri & Ramesh, 2016).

2.2. Riverbank erosion:

Riverbank erosion is a geomorphological process that involves the erosion of a river's banks in the alluvial floodplain. Rivers wouldn't meander and change wouldn't take place without bank erosion; it's a natural process. Significant river bank erosion results in significant displacements along the river's bank line. New, fragile lands are formed through the activities of erosion and sedimentation in the spaces between some rivers' flow courses. The river carries the sediment and silt that has been eroded, and it builds up to create a new sand bed. These areas are known as braided bars or mid-channel bars (Momen et al., 2020).

2.3. Accretion:

Accretion is the term which applies to the gradual increase or acquisition of land by the action of natural forces washing up sand, soil or silt from the water course or seashore (Armentano, 2017, January 13).

2.4. Channel migration:

Channel migration is a significant geomorphological activity in the floodplain region. Another prominent issue that is destroying the techniques of natural channel adjustment as well as channel behavior is human interference in the form of engineering constructions (Hasanuzzaman & Mandal, 2020).

2.5. River channel movement and changes in land use and land cover:

This study has been conducted using geographic information systems and remote sensing methods, to analyze the river shifting and assessment of associated impact on the land-use/land-cover between 1955 and 2016 for Padma River in Bangladesh. The best accuracy was achieved by applying the maximum likelihood supervised image classification to determine the kind of erosional effect and land use/land cover. Results of long-term river channel migration demonstrated that sand bar, water body, and cultivated land area were oscillating, settlement area was rising, vegetation area was decreasing, and land area was influencing with river erosion.

Objectives: River boundaries may be located using satellite images and normalized difference in water index (NDWI) migration from a reference year. Dividing the river channel into equal reaches and measuring each reach's sinuosity, migration rate, erosion rate, and accretion rate. River shifting impact assessment using LULC map correction, accuracy evaluation, and change detection over time.

Erosion and accretion: On the right bank, erosion was at its highest between 1955 and 1973, whereas on the left bank, erosion was at its lowest or nonexistent between 1973 and 1999.

Riverbank shifting: Analysis of riverbank shifting revealed that the Padma River's riverbank was not stable. Occasionally, the right bank may move in the left direction, the left bank may move in the right direction, and both banks may move in either the left or the right way.

Land-use/land-cover categorization (LULC): The outcome revealed that while settlement area has grown and vegetation area has shrunk, cultivated land, aquatic bodies, and sand bars have fluctuated (Arefin et al., 2021).

2.6. Investigating the effects and vulnerability of rural households to riverbank erosion hazards:

The study was based on the investigation of the riverbank erosion hazard in study area, its impacts on local people and livelihood vulnerability due to land loss. From the study, it was found that from 1973 to 2011, about 189.4 square kilometer land was eroded from the left bank section and only 23.66 square kilometer land was accreted with a net loss of 155 square kilometer land. Instead, right bank of the Padma River behaved in the opposite manner with 166.53 square kilometer land erosion and 134.45 square kilometer land accretions. Comparing to the right bank, left bank was more vulnerable to erosion which destroyed the permanent stable lands. Many wealthy farmers of the study area have turned into marginal farmer and even landless due to the erosional hazard.

Objective: The study has tried to better understand the socioeconomic effects of riverbank erosion on the local population in the study region near the Harirampur Char-Vadrason site. The study has also aimed to pinpoint possible riverbank erosion sensitive regions for future disaster management efforts.

Result: The communities in the study region that have been impacted by riverbank erosion suffer significant harm. The agriculture land's cropping pattern has undergone a significant alteration and occasionally turned into arid land. The neighborhood has suffered significant damages to its infrastructure. The locals constantly move around throughout the area. The standing of farmers declined, turning affluent and medium-income farmers into marginal farmers and landless people. Social crises were caused by the livelihood of farmers often shifting. The majority of the landless individuals in the research region migrated to metropolitan areas in search of work, according to usual practice. As one of the most dangerous processes in the research region and one that has long-term effects, riverbank erosion should be accommodated with the proper policies and programs to enhance the livelihood situation of the susceptible areas (Bhuiyan et al., 2017).

2.7. Jamuna River Channel Migration Characteristics:

In this study the distance between the oldest Jamuna River profile position and the recent Jamuna River profile position was estimated using Remote Sensing. From the 1954 river profile to the most recent river profile for the study area showed large-scale migration in the meandering positions. This study documented the river migration change of the Yamuna River between two locations in India, using topographic maps and satellite images acquired between 1954 and 2015. Results indicated a considerable southward shift of river course with an average rate of 1.51 meter/yr. They concluded that the considerable reduction in river discharge over last several years occurred for construction of barrages and canals which has reduced the erosional potential of the channel that resulted in decreased rate of channel-planform changes.

Objectives: Evaluating the sources of mobility, discussing the implications of meander movements, and quantifying the mobility of meander migration across decadal periods. And addressing a number of geomorphometric and fluvial management challenges required an understanding of how river channels have been changed through time.

Result: Using topographic maps and satellite pictures, this study captured the Yamuna River's migration shift at the designated areas. The river's path has changed significantly, according to the results. The river's path has shifted south as a result. Analysis of the channel's sinuosity showed that it is simultaneously spreading and contracting, with a diminishing tendency in the River Yamuna's discharge rate (P. Y. Ali et al., 2019).

2.8. Migration of river channels in Padma and Jamuna River. Remotely sensed data and GIS analysis:

In that study Padma and the Jamuna rivers were observed since 1977 to 2004 using remote sensing and GIS. The Jamuna and the Padma are the rivers with peculiar characteristics. The Jamuna had a lot of islands which were inundated in the monsoon in normal water level. Due to the heavy water flow in the monsoon and flood, the locations of the Jamuna River channel were always changing. The same phenomenon was also observed for the Padma.

Objectives: This study's objective was to use GIS and RS to track the Padma and Jamuna rivers' channel movement from 1977 to 2004. The main patterns of river channel movement at several Padma and Jamuna places have been noticed in this study.

Result: In the Padma and the Jamuna rivers, erosion and accretion happened too quickly. According to this research employing RS and GIS, the Jamuna's river channel was moving more quickly than the Padma. This cost a lot, devastated land and property, harmed agricultural goods, interfered with water transport, etc. One of the main natural catastrophes to blame for Bangladesh's poverty is river channel movement, erosion, and riverbank deposition. It significantly affected Bangladesh's rural unemployment rate. Regular riverbank line monitoring, comprehension of river channel movement trends, and the development of adaption measures based on likely effects might reduce possible risk and loss (M. T. Islam, 2010).

2.9. Using Remote sensing and GIS to analyze the spatiotemporal changes in river banks of the Jamuna River:

The analysis evaluated the east bank and the west bank erosion and accretion of Jamuna River. An unsupervised classification algorithm and post-classification change employing skills in Geographic Information System were performed to evaluate spatial and temporal dynamics of erosion and accretion for different points of Jamuna River in Bangladesh.

Objective: The primary goal of this work was to employ remote sensing and GIS to examine the geographical and temporal changes of the east and west banks of the Jamuna River between 1995 and 2015, including determining bank shifting by bank line analysis in addition to erosion-accretion measurement. Invaluable data from remote sensing (RS), gathered at predetermined intervals, used to analyze and monitor riverbank shifting and erosion. By analyzing the bank line's shifting pattern, it was possible to determine the movement of bank line. This study was important for visualizing Jamuna's varied spatial range.

Result: It has been noted that the Jamuna River's riverbanks alter continually every year. Land loss and land creation were caused by the ongoing processes of river bank erosion and accretion. According to a comparison study, the erosion rate decreased from 58.1% to 54.9% as the rate of river bank accretion increased. This study has also demonstrated the value of riverbank mapping and the efficient use of geospatial data. The study's findings may serve as a starting point for more research into potential long-term erosion control techniques in the Jamuna. By taking into account Char lands and using better quality expert geographical data, the outcome may be made more exact (M. A. Hassan et al., 2017).

2.10. Evaluation of Jamuna River bank accretion and erosion:

In the river Jamuna, from 1988 to 2003, land accretion was 9% whereas erosion was only 6%. But from 2003 to 2018 percentage of land erosion and land accretion was less than previous 15 years which showed reduction of river pathway of the river Jamuna. Area of Land Accretion and erosion, unchanged area of water-body and unchanged area of non-water-body have been calculated using GIS and Remote Sensing Software in this study.

Objective: The study was about the channel shifting of Jamuna River based on the analysis of the satellite images of several years in order to find out susceptible location of erosion and accretion and assess the morphological change of Jamuna River.

Result: The Jamuna River has significantly shrunk over the previous 30 years; it has been observed. The rate of land accumulation has dramatically accelerated. Although less than in the preceding 15 years, both land erosion and accretion were nevertheless present. However, land accretion continued to outweigh land erosion, which was not good news. According to this analysis, the river Jamuna's channel layout was rapidly shifting. In the last 30 years, the percentage of change in land erosion has been greatly outpaced by the percentage of change in land accretion. This finding suggested that the Jamuna River's waterway was getting smaller every day (Momen et al., 2020).

2.11. GIS and Remote Sensing Approach to River Bank Shifting in the Jamuna River:

In this study the average value of right bank erosion rate was found. This research also showed the increasing trend of average width of the Jamuna River with respect to time. This study concluded that the width of river was increasing day by day. This could be one of the factors of west ward migration of Jamuna River.

Objective: The research examined the average erosion rate of the Jamuna River and its banks in their current state, as well as the river's rising average width through time. Another objective was to demonstrate that the shifting transverse slopes of the right and left banks may be contributing to the westward movement.

Result: The study demonstrated how fragile the Jamuna River is. The erosion rate was 48.9 meter/yr. At its highest between the years 1985 and 1995. From 2015 to 2019, the erosion rate was 14 meter/yr. at its lowest. The right bank shifting pace was 31.236 meters per year and was moving westward. The left bank shifting rate was on average -25.18 meter/yr. In 1976, the average width of Jamuna was 9 km, while in 2019, it was 11.56 km. It has been shown that there was a consistent difference between the transverse gradients of the right bank and the left bank, indicating that the right bank was steeper than the left bank, which may be a contributing factor in the Jamuna's propensity to migrate westward (Nahid et al., 2020).

2.12. The effects of the Jamuna multi-purpose bridge upon the evolution of bar formation in Bangladesh's Jamuna River:

The research was attempted to study and analyze the impacts of bridge construction and the bar morphology of Jamuna River. The study has been done by using Satellite and Google Earth imagery and GIS techniques. After the construction of bridge, the river became widened by being obstacle or sluice gate of the flowing water. The channel shifting process of Jamuna river started in 1973, which aggregated after the bridge construction. The bridge caused channel shifting in incidence towards the left due to the change in direction of flowing water of the river.

Objective: This study was conducted to ascertain the effects of the Bangabandhu Jamuna Multi-purpose Bridge on the Jamuna River's bar morphology. It also assessed how the immediate environment has changed morphologically as a result of the altered bar morphology.

Result: The bridge's construction from 1994 to 1998 was expected to increase riverbank erosion along the left bank by 25%. The average bar area at the time before bridge building was 236.53147 square kilometers, or 13.51% of the whole area. It became more than doubles in size following bridge building. As a result of the bridge's construction, the area of linked bars had been increased. In relation to the whole study area of 1750 square kilometers, the average total area of connected bars increased after the bridge construction by roughly 8.69%. The average area covered in sand was relatively large prior to bridge building (R. Islam et al., 2017).

CHAPTER 3: METHODOLOGY

3.1. Study Area:

Bera upazila of Pabna district covers an area of 248.60 square kilometers and is located between 23°48' and 24°06' north latitudes and 89°35' and 89°44' east longitudes. Chauhali, Daulatpur, and Shivalaya Upazilas on the east (Halder, 2015), Sujanagar, and Santhia Upazilas on the west, Shahjadpur and Chauhali Upazilas on the north, Goalanda and Rajbari Sadar Upazilas on the south. Bera upazila has a total population of about 231430. Waterbody of Padma, Jamuna, Ichamati, and Hurasagar are the principal rivers (Morsheduzzaman et al., 2010). Dhalai Beel, Ichar Beel, and Nandiar Beel are noteworthy. Mathura Thana, which had been established in 1828 but had been buried by river erosion, was relocated to Bera. Bera Thana became an upazila in 1983. Agriculture accounts for 40.07% of total income, followed by non-agricultural laborers 3.94%, industry 7.92%, commerce 21.80%, communication and transportation 4.92%, services 5.77%, construction 1.08%, religious service 0.21%, lease and remittance 0.48%, and others 13.81%. ownership of agricultural land: urban 28.52% and rural 48.42%; landowner 44.60%, landless 55.40%. Rice, wheat, sugarcane, mustard, onions, garlic, potatoes, and vegetables are the main crops. Settlements and crops in the upazila suffered severe devastation as a result of 1988 and 1989 floods (Figure 2)

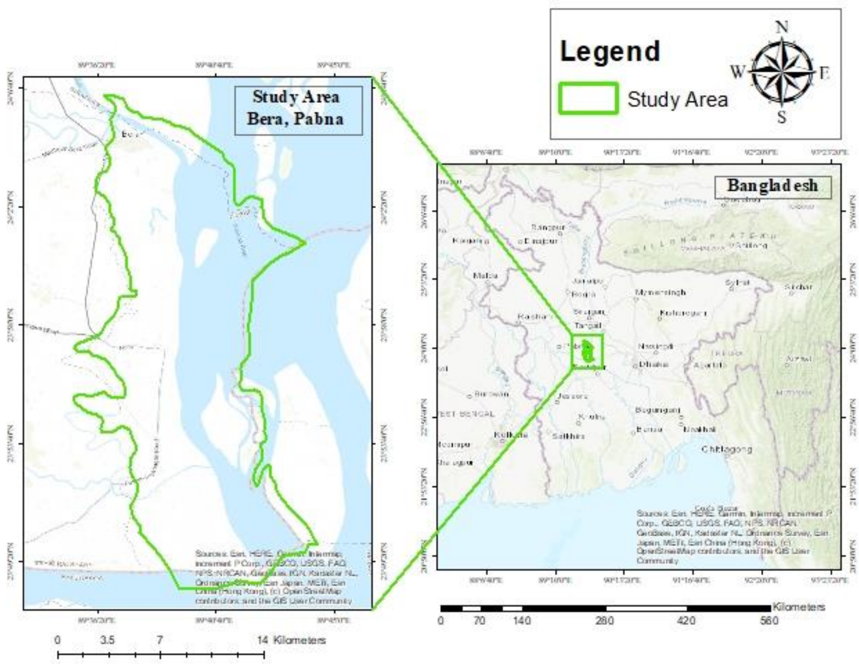

Figure 2: Study Area map (own illustration)

3.2. Data Collection Techniques of the Study:

To collect and analyze the data, here both the qualitative and quantitative tactics have been implemented on this study. The process of describing, categorizing, and connecting phenomena with the researcher's concepts is known as qualitative data analysis. First, a thorough description of the phenomenon under inquiry was required. A conceptual framework has been constructed and the data has been categorized in order for the researcher to be able to analyze and explain the data. Concepts have been developed and interconnected after that. The bulk of qualitative data analysis approaches have relied on these four fundamental steps: data collection, data processing, data visualization, conclusion formulation and confirmation. Data was gathered through interviews and observation (Mayer, 2015). Understanding linkages within the facts and relating those patterns to the study setting are key aspects of quantitative data. Quantitative data emphasizes the practical relevance and the need for the data obtained. In order to give evidence for any assertions of practical value, quantitative analysis is a technique of critical thinking on how to identify the hidden patterns and relationships in the data and their relationship to the research scenario. Practical importance requires that the data analysis techniques make a direct link to the research issue. What questions should be asked during the phases of a data acquisition, how to assess the relevance of prospective inquiries, and how to understand the in-depth relationships within the data are the three main aims of quantitative data analysis (Albers, 2017). The study has widely focused on primary data collection through face-to-face questionnaire interviews in the study area as well as RS and GIS techniques. Primary data collection has been done to address the issue at hand. Primary data, in contrast to secondary data, are unique. Surveys, focus groups, in-depth interviews, taste testing, and other experiments, all can be used to gather primary data. Among the most common ways to gather primary data is through surveys, which come in a variety of forms (Curtis, 2008). The secondary data mainly has been assembled by reviewing published literatures, journals, articles and reliable websites in order to evaluate various information related to this study. Here the data collection techniques of this study have been structured (Figure 3).

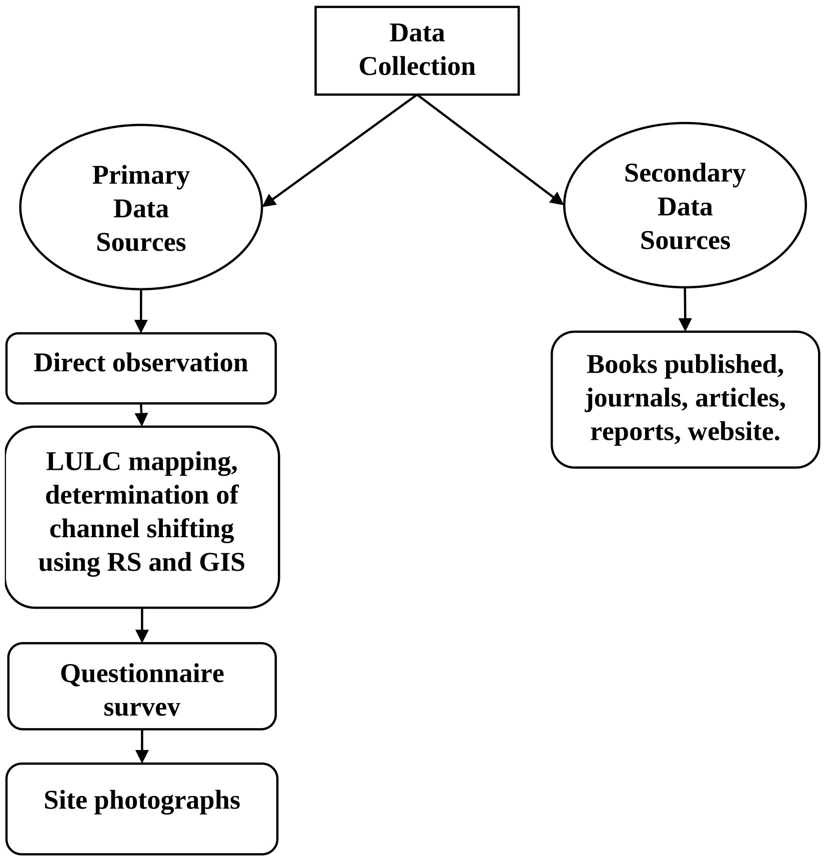

Figure 3: Data Collection Techniques of the Study. (Own illustration)

3.2.1. Primary Data Collection:

The amount of land that have been eroded and accreted has been estimated in this study using LANDSAT satellite pictures as one of its main data sources. Satellite images have been examined using GIS technology to calculate land use / land cover erosion and accretion. Satellite images came from the USGS. A 10-year gap separated the image collection from the years 2002 to 2022. 2002, 2012, and 2022 has been considered as three particular research years. The spatial resolution of Landsat images is appropriate for examining river courses, calculating their velocity, and calculating the degraded and deposited riverbanks. These photos have been captured after the monsoon season as there was no cloud (Momen M. A.). (Table 1).

Table 1: Landsat Image Collection (own illustration).

Year	2002	2012	2022
Month	February	March	March
WRS Path	138	138	138
WRS Row	43	43	43
Cloud Cover	0	0	0.02
Landsat	7	7	8

In order to get the public response, there were total seventy (70) questionnaire survey interviews were taken from nine (9) different places including: Char Kallyanpur, Nagarbari, Boshontopur, Natiabari, Raksha, Koitola, Nakalia, Ghopshelenda and Kazirhat. The basic requirements of respondents were: respondent should be over 30 years old and must have been living in this place for over 20 years. Considering the common factors this survey has found that, everyone has observed the river channel shifting in their lifetime and crops including rice, wheat, corn, jute, mustard, Vegetables, etc. are commonly cultivated in all the survey area (Figure 4).

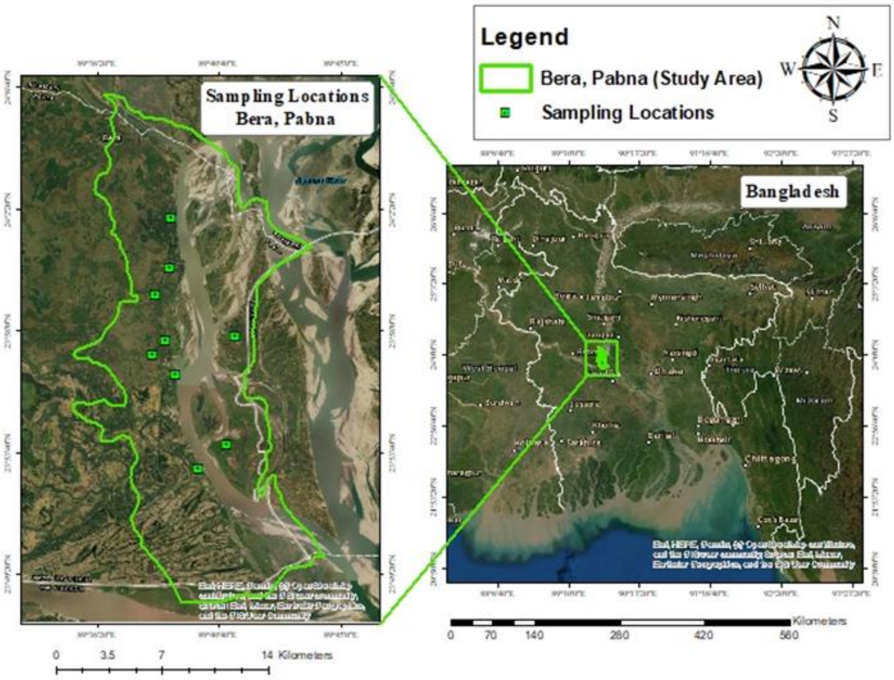

Figure 4: Sampling Location map (own illustration)

Figure 5: Primary Data Collection. *Source:* Photography, Nishad, 2022.

3.2.2. Secondary Data Collection:

Studying with secondary data offers the following advantages: somebody else has already gathered the information and therefore the researcher is not required to spend money to this research phase. The method of gathering data is frequently guided by professionalism and knowledge that may not be accessible to smaller research organizations. A secondary set of data should be carefully evaluated to ensure that it contains the relevant information and that the information has been specified and structured in a way that enables the analysis that is requested. A different approach was to start by choosing from the available secondary data sets, creating a study-questions that can be addressed with the data, and finally analyzing the data (Boslaugh, 2007). In order to collect the secondary data, books, journals, articles, and reports which are published in google scholars have been reviewed. Specially, books, journals, articles and reports with the similar methodology has got the highest priority. However, information gathered from website were valid and reliable.

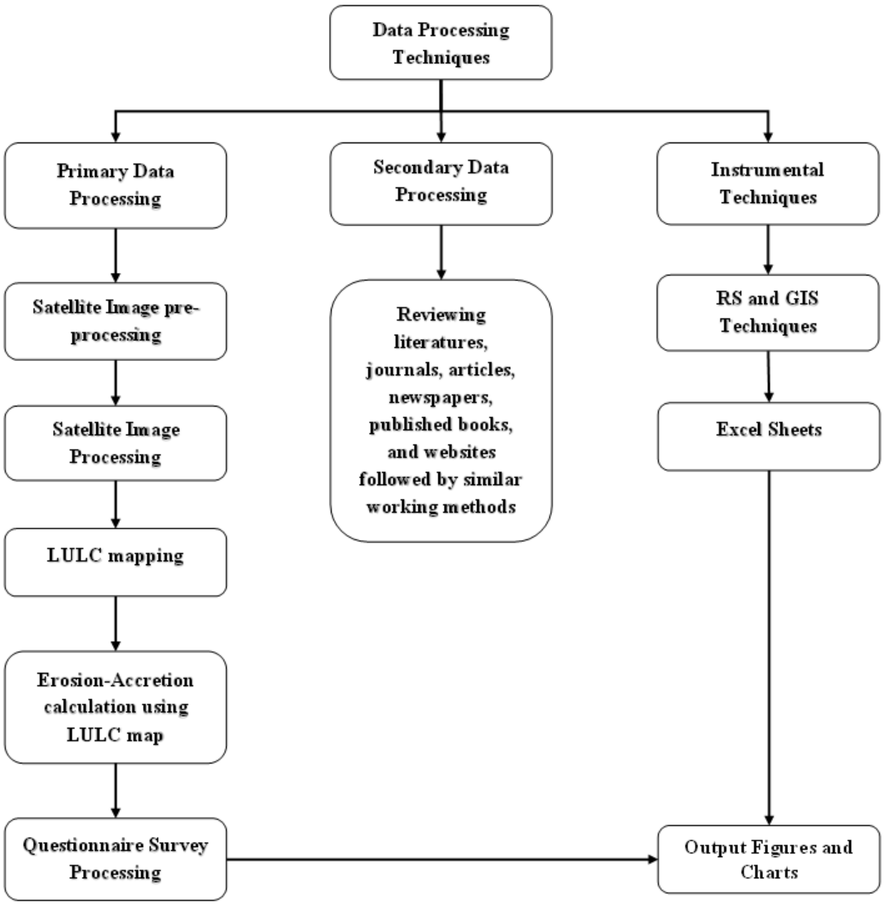

Figure 6: Data processing techniques (own illustration)

3.3. Data Processing:

This section has described all the process and procedures of data analysis for both primary and secondary data. The process and procedures according to figure 6.

3.3.1. Primary Data Processing:

This section gives the information about the primary data analyzing techniques which have been grouped into five different stages

3.3.1.1. Image pre-processing:

There was no need for further georectification because of USGS's Landsat Level 1 satellite image has been already radiometrically and geometrically corrected. In 2002, a problem with the Scan-Line Corrector (SLC) on Landsat's ETM + sensor prevented about 25percent pixels for each image from being scanned. The black striped lines were gap-filled using the Landsat toolbox for ArcMap to fix the SLC problem. ArcMap 10.8

additionally carried out operations such band stacking and research area extraction (Abir & Saha, 2021).

3.3.1.2. Image Processing:

As the image processing technique, an area of interest (AOI) and a folder holding the extracted picture files were loaded into the ArcMap 10.8 application. To merge all the bands, use the composite tool. The clip tool was then used to remove the AOI layer from the picture. The specific study region was located for further investigation. Polygons that represented regions of waterbody, bare land, agriculture, and vegetation were then created as part of the procedure. All of the samples for a particular feature were pooled to establish the actual coverage area. When the sample was finished, the various aspects were highlighted and shown in different colors (Abir & Saha, 2021).

3.3.1.3. LULC mapping:

Between 2002 and 2012, supervised classification has been used to construct LULC maps. Landsat satellite images have been classified into four land types to use the Maximum Likelihood Classification (MLC) Method in ArcMap 10.8. (Water body, bare land, vegetation, and agriculture) (Okeke et al., 2020). MLC has been used to derive LULC because its pixel-based supervised classification technique can forecast urban land cover with an accuracy of roughly 90%.(Prasad et al., 2021) All Landsat data were band-composed; bands 1 through 5 and band 7 have been utilized for Landsat ETM+ and Landsat OLI/TIRS, respectively (Mishra & Rai, 2016). In order to offer exact training samples for various false-color composites, efficient band combinations have been developed. For each LULC class, a minimum of 50 training samples have been collected (Abir & Saha, 2021).

3.3.1.4. Erosion-Accretion calculation using LULC map:

In order to calculate the erosion and accretion area in hectare unit the following data processing has been followed:

At first holding the mouse, right button has been clicked selecting LULC map layer, then conversion tool has been selected from the toolbox, then raster data has been converted to polygon and the input and output locations has also been set. A polygon layer map has been created (Kabir et al., 2020). The polygon layer has been opened to go to properties and all values have been added. After that, the river area has been extracted from the map. After that, going to data export data has been selected, and output location has been set. A new river layer has been created (Debnath et al., 2017). Then right click has been applied on the river layer and properties has been selected and the name has been set as 2002. The same process has been applied for 2012 and 2022. After that, right click has been applied on 2002 and attribute table has been opened and then add field selected and the field has been named as area and has been set type double, area unit as hectares then click ok. A new area column has been created in the attribute table. Right click has been applied on area, then calculate geometry has been selected, unit has been set in hectares (ha), then click ok. The area of the total river line has been shown in hectares in the area column (S. M. T. Hassan et al., 2017). However, the same technique has been applied for 2012 and 2022 river maps. However, again the 2002 map layer has been selected and going to the insert option new data frame has been added. It has been renamed as 2002-2012. Then another data frame has been added for 2012-2022. Then going to the geoprocessing option, choosing the insert tool, 2002 and 2012 have been inserted and then the output location has been selected. The unchanged area between 2002 and 2012 have been displayed. In order to calculate the unchanged area, right click has been applied on the layer and then opened attribute table, then field has been added, the area has been renamed. Right click has been applied on the area, then geometry has been calculated, unit has been set as hectares, then clicked ok. The unchanged area has also been calculated in hectares (Langat et al., 2019). In order to calculate erosion, attribute table has been opened, field has been added, type has been set as double and renamed as erosion. Then right clicked on erosion, field calculator, then double clicked on the items in order to insert in the formula bar like, [Area 2002] – [Area Unchanged] then clicked ok. In order for calculating accretion, attribute table has been opened, field has been added, renamed it as accretion, type has been set to double, then clicked ok. Right click has been applied on accretion bar and going to field calculator, the formula has been set like, [Area 2012] – [Area Unchanged], then clicked ok (M. T. Islam, 2009). The same technique has been applied for 2012-2022 data. Hence the area of both the erosion and accretion have been calculated in hectares unit. In order to export data in excel file, attribute table has been opened, by selecting export data, output location has been set. The type has been set to "dBase Table" then clicked on save and ok. The same process has been followed for other layers. After that, the excel sheet has been opened and clicked on file, then browse, and then opened those dBase files, all files have been selected, then clicked ok. The dBase files have been shown in excel file separately according to year range. However, keeping the necessary data including: year range, previous 10 years, next 10 years, unchanged area, erosion area, accretion area, rest of the data have been removed. Then data range has been selected and created different chart from add chart option. Therefore, these are all the techniques that have been applied for calculating erosion, accretion and unchanged area by using a LULC map.

3.3.1.5. Questionnaire Survey Processing:

Questionnaire surveys have been used to gather necessary information. Several villages in Bera upazila which are directly interacting with the river in their regular activities, have been surveyed. The majority of the inhabitants of the villages were either directly or indirectly impacted by the river system changing phenomenon, that is why they have been chosen. Physically, I have visited there and conducted a poll by choosing random people and I have taken into account their age, level of experience, and other common characteristics.

3.3.2. Secondary Data Processing:

Secondary data have been obtained from different published books, journals, articles, reports and websites have been analyzed and described in the literature review section.

3.4. Instrumental Techniques: In order for processing all the data, two major software in the computer have been used in this study and they are: ArcMap 10.8, and Microsoft Excel. The techniques of data processing have been given below.

3.4.1. GIS Techniques:

Four distinct types of software, including ArcMap 10.8, USGS Earth Explorer, Google Earth Pro, and Google Maps, have been utilized to conduct this study. The research region, Bera upazila, has been initially identified using Google Maps, and a picture has been obtained to be utilized in future investigation. A shapefile (.kml) and polygon has been created for the area of interest using Google Earth Pro software. However, the region of interest has been re-searched on the USGS website, and the latitudes and longitudes that have been chosen were sufficient to emphasize the research area. The evaluation of river bank erosion-accretion and identification of bank line shifting pattern has been done using remote sensing (RS) and geographic information system

(GIS) approaches. Two distinct types of the three multi-spectral Landsat images including: Landsat 7 ETM + and Landsat 8 OLI/TIRS have been used in this investigation. Every image from 2002, 2012, and 2022 have been obtained from the USGS archives (https://earthexplorer.usgs.gov/) in order to determine the LULC change (Ophra et al., 2018). Data has been downloaded using the row code 43 and path code 138. Bangladesh's winter season lasts from December to February (Hamer, 2019). Hence pictures have been downloaded in the months of February and March. Since March in Bangladesh seems to be a less cloudy month, images have been downloaded as frequently as possible in order to provide a representative sample of accurate data. Three Landsat pictures for each year have been utilized for LST estimation because to the limitations of cloud cover. All of the satellite images were cloudless. LST and LULC index retrieval have required a total of three pictures (Abir).

3.4.2. Excel Sheets:

Excel is simply a brilliant tool for conducting the primary data analysis (Guerrero, 2010). Raw data has been input in excel forms and then various interpretation have been done. For RS data analysis, river erosion, accretion, and the unchanged areas have been evaluated moreover, graph and charts have been also generated by using excel. Similarly, the questionnaire survey data has been input in the excel file and the percentage has been evaluated for the people responses. Here also graphs and charts have been generated using excel.

CHAPTER 4: DISCUSSION AND RESULTS

4.1. RS and GIS Result of Jamuna River study area:

This section describes about the remotely sensed data result that has been obtained from GIS work in the ArcMap 10.8 software. The result mainly shows about the erosion and accretion amount along the Jamuna River of Bera upazila. It shows a dramatic change of erosion and accretion area between two decades. The results are as follows:

Table 2: Erosion-accretion result of Jamuna river study area (own illustration).

Years	Total waterbody (ha)	Unchanged area (ha)	Erosion (ha)	Accretion (ha)
2002	3426	N/A	N/A	N/A
2012	2535	1373	2053	1162
2022	1548	909	1627	640

4.1.1. Erosion-accretion result of Jamuna river study area:

The table 2 containing erosion-accretion result of Jamuna river study area has shown the amount of erosion-accretion in hectare unit in twenty (20) years' time period. Moreover, the result has described the erosion-accretion amount in ten (10) years interval which means from 2002 to 2012 and from 2012 to 2022. However, in 2002, the area of total waterbody was 3426 ha. In 2012, the area of total waterbody was 2535 ha, the river erosion amount was about 2053 ha, on the other hand the accretion amount was about 1162 ha, and the unchanged area was about 1373 ha. In the next decade in 2022, the area of total waterbody was 1548 ha, the river erosion amount was about 1627 ha, on the other hand the accretion amount was about 640 ha, and the unchanged area was about 909 ha. Finally, it has been assumed that, the erosion and accretion amount gradually decreased in twenty years. Due to less water flow during the monsoon period, this year in 2022, the Jamuna river erosion and accretion rate have been decreased comparing to previous years. But another fact is that, due to less water level, the accreted lands have begun to be covered by green vegetation.

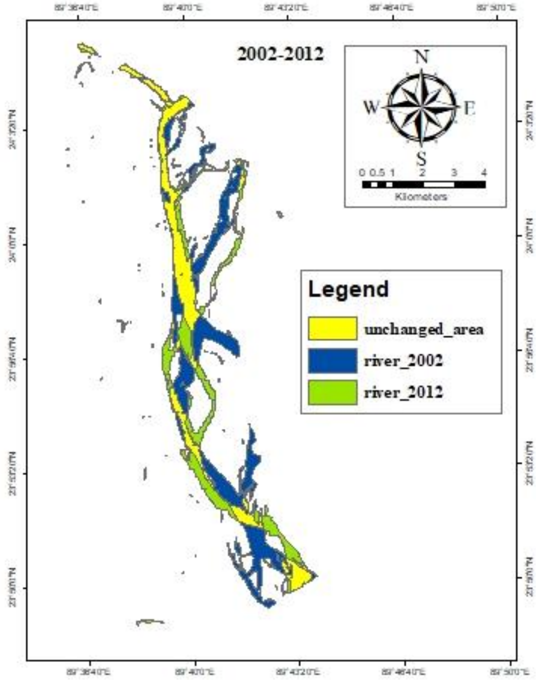

Figure 7: RS and GIS Result of Jamuna River study area 2002-2012 (own illustration)

In figure 7, the situation of Jamuna river study area in 2002 and 2012 have been shown. Where the blue colored channel indicates the river in 2002, the green colored channel indicates about the river in 2012 and the yellow color indicates about the unchanged area of ten (10) years which means from 2002 to 2012. Here, it has been clearly seen that, the river channel has been changed its path during ten years' time period. It has been clearly observed that, the channel in 2002 has been shifted in 2012, from its previous state. Somewhere the channel started braiding and somewhere it became narrower. Here the change detection is clearly visible. In figure 8, the river paths of 2012 and 2022 have been shown. Where the green colored pathway indicates about the river in 2012, red colored pathway indicates about the river in 2022 and the yellow color indicates about the unchanged area of ten (10) years which means from 2012 to 2022. Here, some major changes have been seen. From the figure 8, it has been clearly seen that, the river channel has been changed dramatically during ten years' time period. The unchanged area amount is less than figure 7, which means the change detection has become higher in this decade rather than the previous one. The river pathway of 2022 is quite narrower comparing to 2002 and 2012. The waterbody has become narrower in

2022 comparing to other decades. However, the change detection has been seen very clearly.

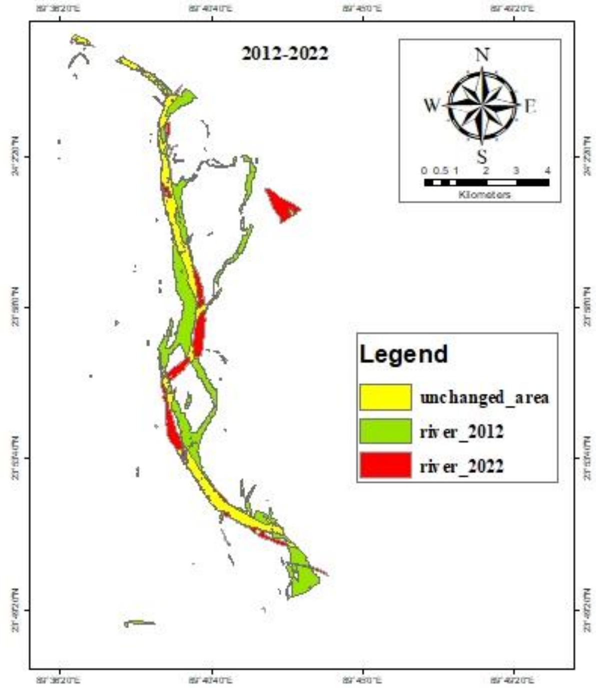

Figure 8: RS and GIS Result of Jamuna River study area 2012-2022 (own illustration)

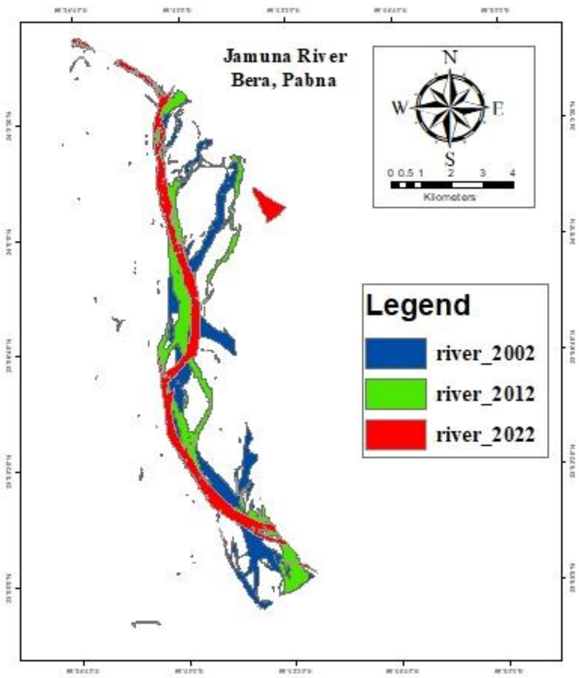

Figure 9: Change Detection Comparison of Jamuna River study area 2002-2022 (own illustration)

In figure 9, the river channels of 2002, 2012 and 2022 have been compared with one another. Where the blue colored channel indicates the river in 2002, green colored channel indicates about the river in 2012 and the red color indicates river in 2022. In the comparison figure, the change detection of Jamuna river, Bera, Pabna in twenty (20) years has been shown. Which means from 2002 to 2022. From the very first one it has been clearly seen that the river channel was wider comparing to other years. After a decade in 2012 the river became narrower comparing to 2002. Finally in 2022 the river became the narrowest comparing to the previous years. Therefore, it has been clearly seen that the river channel has been migrated and became narrower decade by decade. According to my observation, public response and RS, GIS data, I have come to know that, the river channel has been shifted, it has become narrower, the surrounding nature has been degraded day by day and finally the river channel has been started to die, as there are a lot of bare lands have been created and they have started to turn in green vegetation. In the last decade from 2012 to 2022, the highest number of bare lands have been developed at the middle of the channel which led the channel to migrate.

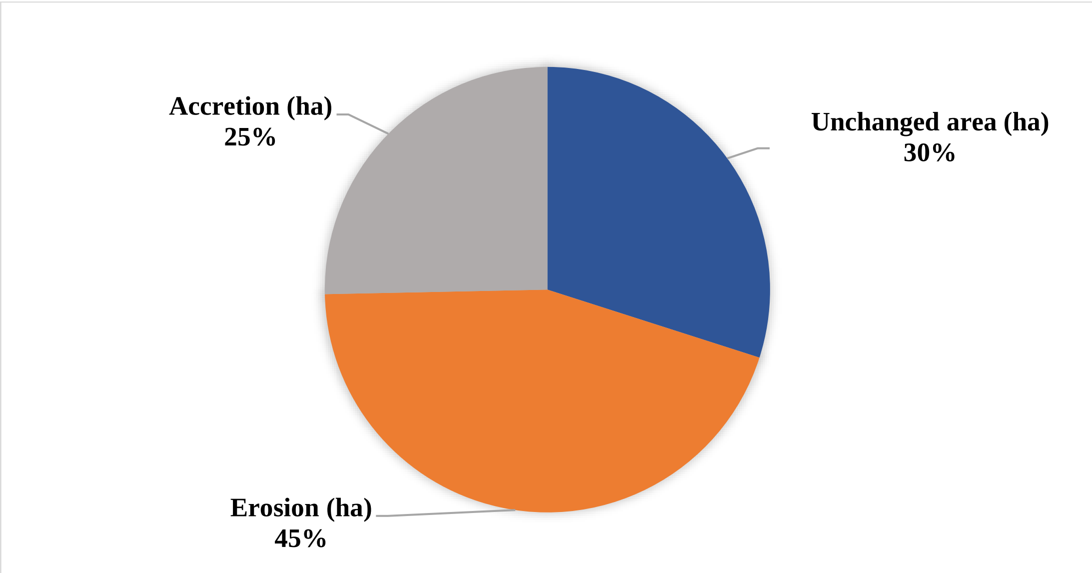

Figure 10: Erosion-accretion result, Jamuna river study area 2002-2012 (own illustration)

In figure 10, the erosion-accretion result of the Jamuna river study area has been shown from 2002 to 2012. However, the blue colored area indicates about the river unchanged area, orange color indicates about the eroded area and finally the green color indicates about the accreted area. Here all the measurements of the area have been calculated in hectare (ha) unit. If the figure 10 is considered as 10 years' time period, it can be said that, 30% of the total area has remained unchanged during the decade, 45% area has been eroded and 25% area has been accreted in that ten years.

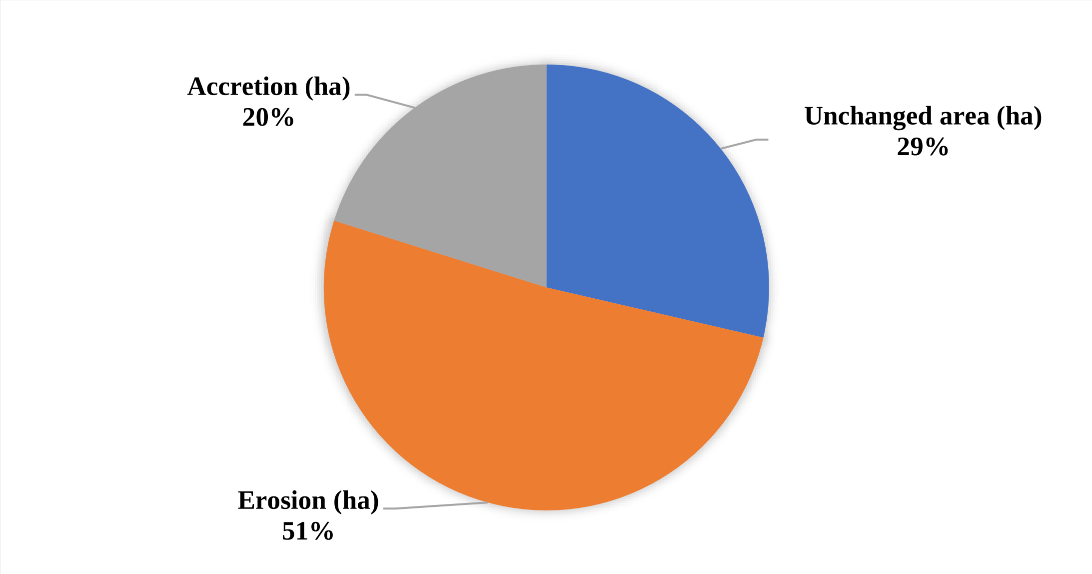

Figure 11: Erosion-accretion result, Jamuna river study area 2012-2022 (own illustration)

In figure 11, the erosion-accretion result of the Jamuna river study area has been shown from 2012 to 2022. However, the blue colored area indicates about the river unchanged area, orange color indicates about the eroded area and finally the grey color indicates about the accreted area. Here all the measurements of the area have been calculated in hectare (ha) unit. If the figure 11 is considered as 10 years' time period, it can be said that, 29% of the total area remained unchanged during the decade, 51% area has been eroded and 20% area has been accreted in these ten years.

4.1.2. River channel shifting:

From the result of the study, it can be said that the river path has been shifted gradually from decade to decade. At the very first period of this study, the river was flowing friendly to the environment, comparing to previous studies. In 2012, the waterbody started to decrease and several river chars have been increased due to erosion-accretion process. At the last period of this study in 2022, the waterbody has become the narrowest and more river char have been developed and additionally the bare lands has begun to turn in green vegetation. Therefore, it can be said that because of the variations in between erosion and accretion process the river channel has been shifted. Sand bars or river char area have been generated in many places and the river became narrower and more braided.

4.2. Questionnaire survey result:

Raw data that have been found from the questionnaire survey according to the figure 12, 84% of the total population have directly experienced damage/loss of households, cultivation lands, crops, domestic animals, etc. due to river erosion while rest of the 16% have not experienced that. 93% people have seen others in their neighborhood who have faced the same problem where 7% people have not seen anyone like this or even did not have experience in real life. 84% people have been affected by various social effects which include: lack of food, education, transportation, living problem, etc. while the other 16% have not. 86% people have been affected by various economic factors including: loss of capital, loss of property, loss of commercial product, unemployment, etc. while the other 14% have not experienced it. Almost everyone supported that river erosion is bad for them. Similarly, 10% agreed that river accretion is good for them and rest of the 90% denied. 96% people said that the river channel has been shifted and other 4% did not notice at all. 90% people said that fish population has been reduced comparing to previous twenty years while the other 10% said no. 90% of the interviewees said there were trees, households, and agricultural lands near the river bank area in previous decades while the other 10% did not notice that. 57% people have the emergency facilities including concrete road, medical center, transport system, multipurpose disaster shelter, pure drinking water, sanitation etc. while rest of the 43% people do not have these facilities and most of them are from Char Kallyanpur.

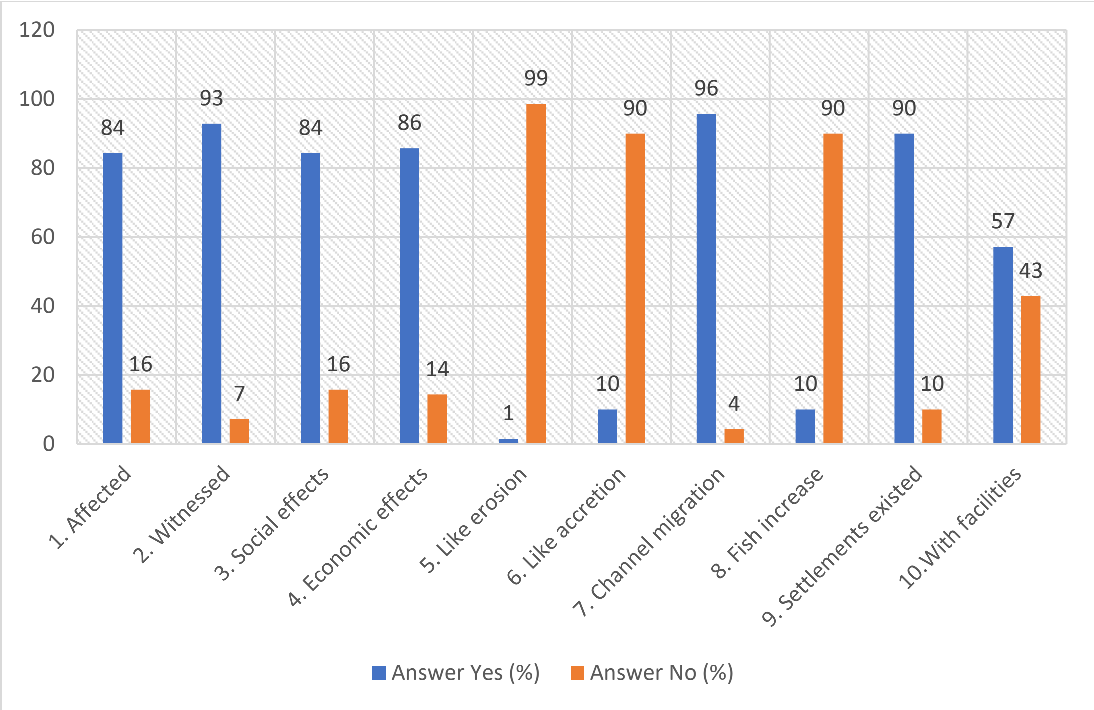

Figure 12: Questionnaire survey result analysis of Jamuna river study area (own illustration). **Source:** Field survey, Nishad, 2022.

4.3. Social impacts on local settlements due to river channel shifting:

Due to river channel movement, people have been affected by various social problems. According to majority of the respondents, people mainly face living problem as because they loss their property as well as households due to river erosion, moreover transportation become difficult, no food available for eating and education facilities also disrupted. People become helpless. They may not have drinkable water and good sanitation system when a disaster occurs.

4.4. Economic impacts on local settlements due to river channel shifting:

The economic impacts mainly people suffer, generates from the social impacts. Because when they have no lands to cultivate, people run out of money and become workless. Business people do not get enough amount of product supply which causes economic loss to them. People loss their domestic animals and so on. The community becomes helpless and weak as necessary supply and support do no reach there properly.

4.5. Impact on river char area:

The survey analysis has also found that, people living in the char area especially in Kallyanpur char do not get emergency facilities. Those facilities include: multipurpose disaster shelter, pure drinking water facility, concrete road for transportation and movement, medical center and healthy sanitation facilities. Those factors informed us that, people in any extreme moment like typhoon, flood, river erosion or in other disaster moment, become helpless and even many people have died because of those phenomena.

CHAPTER 5: CONCLUDING REMARKS

5.1. Study limitations:

- It was difficult to move in the places of river char area. There is no transport vehicle available there. Therefore, it is hard to collect data by walking place to place in that particular area.
- The boat service from Nagarbari to Kallyanpur Char is provided according to public demand and available only at day time. Therefore, anyone cannot go or come back after 06:00 pm.
- People in unknown places like char areas are sometimes dangerous and not cooperative. It is better to go with a friend or find someone familiar with the community.

5.2. Recommendations:

- Assessment of the water quality and the impact of dumping (fertilizers, cement, and coal) on the Jamuna River bank at Nagarbari business area.
- The Kallyanpur Char can be a valuable zone for cultivation of crops which can increase the GDP of Pabna district. Necessary support and agricultural projects can be taken as an initiative to make it possible.
- The government easily can provide emergency facilities including concrete roads, medical center, transport system, disaster shelter etc. which will turn the village as an economic zone.

5.3. Conclusion:

The river Jamuna in Pabna district only flows through the Bera upazila. There are several villages has been developed near the river bank area including the river char e.g., Kallyanpur Char, and several has been eroded due to the erosion phenomena. Nagarbari is one of the popular business points in Bera upazila which is directly dependent on the river for transportation of goods including fertilizer, cement, coal etc. Before the construction of Jamuna multi-purpose bridge, Protabpur, a place in Nagarbari and Kazirhat were used to be two temporary ghats (M. M. Ali & Bhuiyan, 2015). Nagarbari-Aricha ferry ghat used to be considered as the only connecting sites from east to the northwest regions and it was provided by BIWTC (Jenkins & Shukla, 1997). However, due to the construction of bridge the river system has been changed. River erosion-accretion process made the river to change its channel which caused a great loss of lands as well as developed bar areas. There is no study have been done before, regarding the socio-economic impacts of river channel migration in Jamuna River especially in Pabna district. The study has found that, the amount of erosion and accretion during the study period from 2002 to 2012 along both banks of the river were 2053 ha and 1162 ha, respectively. In the next decade, the amount of erosion and accretion during 2012 to 2022 along both banks of the river were 1627 ha and 640 ha, respectively. Which justify the river channel shifting of Jamuna river, Bera, Pabna area. Besides, from my field survey data, it can be informed that, river erosion is both dangerous and negatively effective at the same time for both people and environment. Because it causes various social and economic effects as well as it degrades the nature. Similarly, accretion causes barrier to the natural flow of river which further causes death of a river channel as well as reduce fish population. Finally, it causes death to a natural channel flow. In addition, people who are victim of river erosion or river related disasters become helpless and they do not get any emergency support or facilities like, emergency shelter, medication, transportation, pure drinking water, sanitation, and etc. Specially people of char areas who directly or indirectly depend on agriculture, become helpless while river erosion or similar disasters occur. Therefore, necessary support is required for making the solution of present problems. Especially the people of river char area draw an attention of the government of Bangladesh to take initiatives so that they can lead a better life even in any extreme situation.

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Appendix – I

Table 1: Survey questionnaires (Source: field survey, Nishad, 2022).

Questions	Answer Yes(%)	Answer No(%)
Have you ever faced any of the following situations including: damage/loss of households, cultivation lands, crops, domestic animals, etc. due to river erosion?	84	16
Have you ever seen anyone in your neighborhood who is/are victim of these phenomena (damage/loss of households, cultivation lands, crops, domestic animals, etc.) due to river erosion?	93	7
Have you ever experienced any of these social difficulties caused by river erosion including: lack of food, education, transportation, living problem, etc.?	84	16
Have you ever experienced any of these economic impacts due to river erosion including: loss of capital, loss of property, loss of commercial product, unemployment, etc.?	86	14
Is river erosion good for you?	1	99
Is river accretion good for you?	10	90
Has the river become narrower and less deeper comparing to last twenty years in your own perception?	96	4
Do the fishermen get more fishes now, comparing to twenty years ago?	10	90
Were there many trees/agricultural lands/households near the river bank before twenty years?	90	10
Do you have the facilities including: concrete road, transport system, multipurpose disaster shelter, pure drinking water, sanitation, medical center in your locality?	57	43

Table 2: Acquired Landsat satellite images and uses (own illustration).

Year	**Acquisition Date**	**Collection**	**Level**	**Sensor's Name**	**LST Retrieval**	**Land Surface Indicators**	**LULC Classification**
2002	24 February 2002	1	1	Landsat 7 ETM+	√	√	√
2012	23 March 2012	1	1	Landsat 7 ETM+	√	√	√
2022	03 March 2022	2	1	Landsat 8 OLI/TIRS	√	√	√

Table 3: Landsat 7 Enhanced Thematic Mapper Plus (ETM+) (own illustration).

Landsat 7 Bands	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.77-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	60 (30)
Band 7	2.09-2.35	30
Band 8	.52-.90	15

Table 4: Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) (own illustration).

Landsat 8 Bands	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1 – Coastal aerosol	0.43-0.45	30
Band 2 – Blue	0.45-0.51	30
Band 3 – Green	0.53-0.59	30
Band 4 – Red	0.64-0.67	30
Band 5 – Near Infrared (NIR)	0.85-0.88	30
Band 6 – SWIR 1	1.57-1.65	30
Band 7 – SWIR 2	2.11-2.29	30
Band 8 – Panchromatic	0.50-0.68	15
Band 9 – Cirrus	1.36-1.38	30
Band 10 – Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 – Thermal Infrared (TIRS) 2	11.50-12.51	100

Appendix – II

Photographs

Illustration:
I: Questionnaire survey on local people of Kallyanpur Char, Bera, Pabna.
II: Capturing photograph of direct observation. Location: Nagarbari, Bera, Pabna.

Illustration:
III: River Jamuna Braiding Process. Location: Char Buramara, Bera, Pabna.

Illustration:

IV: Bankline shifting due to less water level. Location: Nagarbari business area, Bera, Pabna.

Illustration:

V: Kallyanpur Char temporary boat station, Bera, Pabna.

Illustration:

VI: New char area increasing due to accretion between Kallyanpur and Nagarbari.

VII: Accreted land area turning into vegetation cover, Nagarbari, Bera, Pabna.

Illustration:

VIII & IX: Visit to the house of a river erosion victim. Location: Kazirhat, Bera, Pabna.

Illustration:

X: Questionnaire survey and open discussion. Location: Kallyanpur Bazar, Bera, Pabna.