Abstract

The study aimed to evaluate the morphological changes of the Meghna River and Tetulia River of Bhola district associated with sand mining activities. It makes an effort to show the impact of sand mining on changes in river morphology and the results of riverbank erosion. The evaluation of changes in morphology of the rivers were basically conducted using bathymetry data and landsat imagery from different years in that area. A field survey was conducted from July 6 to July 10, 2023, to evaluate the real situation and find out the perceptions regarding the impact of sand mining on the local community and environment. During fieldwork, borehole data from both the riverbed and riverbank has been collected to assess the sediment properties. Secondary data analysis was done using ArcMap 10.8, Erdas Imagine 2014, R Studio, and Microsoft Excel. The findings of the study demonstrated a causal relationship between river bathymetry changes and riverbank erosion as a result of excessive sand mining. The Meghna river has a higher rate of erosion than the Tetulia river because the Meghna river has a higher rate of sand mining in terms of time and area. Additionally, it demonstrated that the Meghna River's erosion rate increased between 2020 and 2021. At this point, the riverbed was growing at a rate of 8.37% annually. This figure shows that the Meghna River's erosion rate was higher at that time than it had previously been.

Acknowledgement

This report would not have been complete without the help and kind support of my family. I would like to express my sincere gratitude to my supervisor, Professor Dr. M. Shahidul Islam. Without his supervision, this study would not be possible for me.

I am really grateful to the Bangladesh Inland Water Transport Authority. The data on river bathymetry was collected from them.

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Chapter-1: Introduction

1.1 Introduction

The Meghna estuary is such a dynamic region of Bangladesh that erosion and accretion occur regularly. The Meghna River Estuary is one of the largest estuaries in Bangladesh and supports a wide range of various ecosystems (Hossain et al., 2012). The transportation system of Bhola district is based on waterways. As the largest island district in Bangladesh, there are no road transportation systems. The riverbodies like Meghna and Tetulia play a significant role in the transportation systems of that region. However, due to the rising demand for sand due to rapid urbanization in Bangladesh, it needs a huge amount of sand regularly, which is basically extracted from various riverbeds. It is estimated that about 60–70% of extracted sand is illegally mined in Bangladesh (Khan, 2022). Due to its fine-grained nature, the excavated sand from the Meghna riverbed and surrounding rivers is primarily utilized for landfilling. The local government claims that while there is currently no legal authorization for sand mining in river beds, it is happening often. This could have an effect on river morphological changes and riverbank erosion, and all of these changes eventually have an influence on the local community and ecosystem.

1.2 Background of the Study

Erosion is a burning issue for the coastal regions of Bangladesh, especially the people near riverbank areas of Meghna. The erosion rate is getting higher due to various human interventions, especially sand mining in that area. It is necessary to address the actual impact of sand mining on the coastal geomorphology of Bangladesh. So, this was a prior focus to evaluate the impact of sand mining on river morphology changes and erosion. Various studies regarding the impact of sand mining on river morphology, the environment, ecosystems, and related issues have been occurring in different countries, including Vietnam, Indonesia, and India. But there is a lack of study in this area of the field that can give detailed insights into the rivers of Bangladesh. So, this topic was selected to evaluate the actual impact of sand mining on coastal geomorphology changes. To assess the bathymetry changes, bathymetry data were collected from the Bangladesh Inland Water

Transport Authority (BIWTA), and to show the erosion of that area, Google Earth imagery and Landsat imagery were used.

1.3 Statement of the Research Problem

It is already assumed that excessive sand mining causes a higher rate of erosion. But there is a lack of knowledge that can properly address it in a scientific research paper. We still need to know the exact impact of sand mining, as the place is quite dynamic by nature. So, this study will focus on the impact of sand mining on river morphology. It will make an attempt to show the connection between sand mining, changes in river morphology, riverbank erosion, and the impact on the local community and environment.

1.4 Objectives of the Study

Some major objectives need to be set to evaluate the study properly. As the main focus of this study is to evaluate the impact of sand mining on coastal morphology changes, So, following are some objectives of the study:

- To measure the volume of sand mining in the study area.
- Assess the morphological changes of the study area due to sand mining.
- Evaluate the environmental and ecological implications of sand mining.

1.5 Research Techniques

The systematic procedures and approaches that researchers employ to gather, analyze, and interpret data in order to address a particular research topic or accomplish a certain research goal are referred to as research techniques. These methods change based on the objectives of the study, the sort of data needed, and the nature of the research.

1.5.1 Conceptual Development

Conceptual development is a crucial aspect of any research project, as it forms the foundation upon which the entire study is built. It involves refining the research idea, defining the research questions or hypotheses, and conceptualizing the framework for conducting the study. The steps are shown in the following:

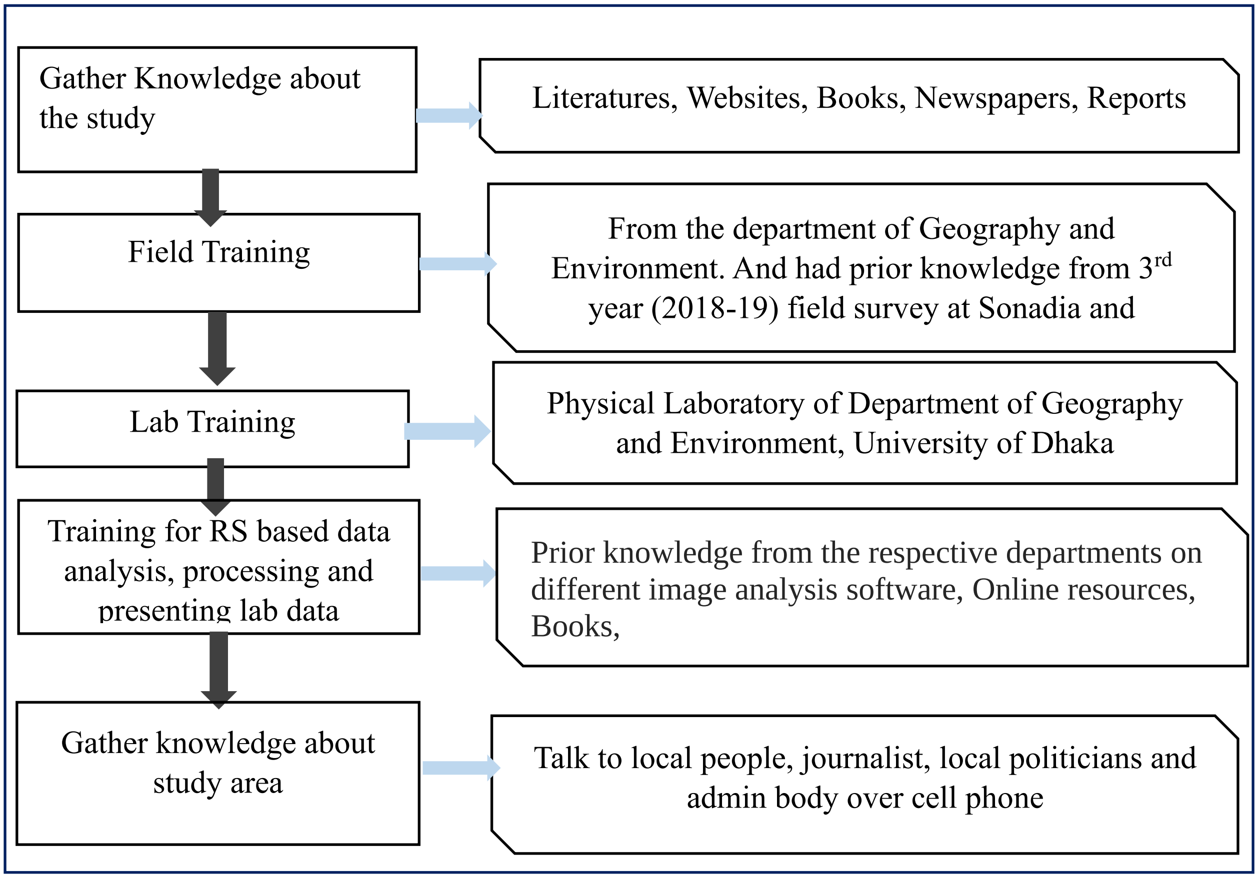


Figure 1.1: Steps of conceptual development

1.5.2 Collection of Secondary Data

The secondary data includes bathymetry data and Remote Sensing data. The bathymetry data were collected from the Bangladesh Inland Water Transport Authority (BIWTA) Dhaka office. They sell the data for the respective study area. Remote sensing data were collected from the USGS Earth Explorer.

1.5.3 Field work

Borehole: Borehole data were collected to know the properties of sediment in different layers of the riverbed and riverbank. Borehole data from four riverbeds and four riverbanks was collected from the two study sites. Collection of sand samples from study areaSand samples were collected from Nabirchar, Nazirpur, to know the properties of that sediment.Focused Group Discussion: Semi structured FGD's were done in the study sites to assess the impact of bathymetry changes and river erosion on local people.

1.5.4 Lab Work

To fully comprehend the state of the physical world, lab study is essential in any research, but it is especially important in physical geography.For my research, I analyzed the particle size of sand samples and borehole data at a 10 cm interval.

1.5.5 Analysis of Secondary Data

Analysis of secondary data was necessary to fulfill the objectives of this study. The collected data of Bathymetry and collcted landsat imagery were use for the analysis.

1.5.5.1 Analysis of Bathymetry Data: The collected bathymetry maps from BIWTA were scanned, georeferenced, and digitized to get a digital format of the map.

1.5.5.2 Analysis of Landsat images: To assess the changes in riverbed and riverbank, the NDWI was done to identify the rivers.

1.5.6 Analysis of Field data

The particle size of 31 samples was analyzed using sieve methods in the physical geography lab of my department.

1.5.7 Map and chart presentation

Maps and charts were created from the analysis results of the lab data and secondary data using a variety of applications, including MS Excel, ArcMap 10.8, R Studio, and Erdas Imagine 2014.

1.5.8 Report Writing

When the anticipated analysis was finally completed, all the findings were presented as a report with a description to help others understand them.

1.6 Outline of the Research

The outline of any research plays a significant role in understanding the insights of the report in a quick view. This thesis includes seven main chapters. The Introduction, Objectives, and brief summary of research technique are included in Chapter One. Chapter Two contains a review associated with the study of different literatures. All the issues and phenomena regarding the study area are described in Chapter 3. The Details of the methodology of the research are described in Chapter 4. All the Data and analysis results are presented in Chapter 5. Chapter Six has Results and Discussion of the Research, where it concludes the summary and discusses various impacts and policy issues regarding sand mining. Chapter Seven Concluded the Thesis with the title of Conclusions and Recommendations.

1.7 Limitations of the Study

The study contains some significant flaws. The fundamental drawback is that, for a variety of reasons, it falls short of precisely achieving the research's initial goals. Other restrictions include the inability to accurately understand the timeline of sand mining because of political difficulties because these sand mining activities are prohibited. The study focuses on the changes in riverbed morphology brought on by sand mining in the Meghna Estuary. This is all possibly related to the localized erosion of the riverbed. It was extremely difficult to choose a suitable research region since it had to cross paths with certain significant problems, including sand mining, erosion of riverbanks, changes in bathymetry, and the availability of historical bathymetry data.

Chapter-2: Literature Review

2.1 Introduction

Sand is a material that occurs naturally. This sand is used for a variety of things, including building, making cement, making ceramics, filling landfills, etc. The need for sand has grown quickly due to the urbanization of areas. Sand is the natural resource that is used the most globally, second only to water (Rentiar and Cammeraat, 2022). Therefore, it must regularly extract from different riverbeds or sea beds. According to Rentiar and Cammeraat, 2022 “The process of mining river sand involves removing sand (and gravel) from a river's drainage system.” According to a new UN Environment assessment, riverside aggregate extraction has contributed to pollution, flooding, depletion of water aquifers, and an increase in the frequency of droughts, despite the fact that the world needs 40 to 50 billion tonnes of sand and gravel annually.

2.2 Worldwide Sand Mining

Sand must be extracted in massive quantities to suit the demand, which is quite high worldwide. The Guardian reported in 2017 that Dubai, which is located on the edge of a vast desert, imports sand from Australia due to the high demand for certain types of construction sand. In South Asia, there is not a single building that can legitimately claim to have been constructed using only sand that was legally collected. In the subcontinent, illegal mining of sand from riverbeds occurs so frequently that, on the odd occasion, it is temporarily halted by a court order. Today, illegal sand mining is a problem in a number of developing and poor nations, including those in India, Malaysia, Sri Lanka, Nepal, Bangladesh, South Africa, Tanzania, Botswana, Puerto Rico, and the Philippines (Gravriletea, 2017).

2.2.1 Sand Mining in India

Since 2000, India's yearly use of building sand has more than tripled, and it is continuing growing quickly (Beiser, 2017). The most egregious instance of illicit sand mining in India is probably found at the Ganga's lowest sections, between the Farakka barrage and where the river meets the Bay of Bengal. Large pumps are installed on pontoons that are anchored in the middle of the river, and the sand is pumped up and sent to the riverside through a conduit. A study by Gavriletea, 2017 suggest that in response to a plea by an activist calling for an end to illicit sand mining in Hardwar, the Uttarakhand High Court recently issued an order defining the Ganga and the Yamuna as living creatures. The court also asked the government what steps it would take to stop illicit mining as part of the same decision, which included a four-month ban on any sand mining in the area. (Gavriletea, 2017).

However, because political power controls it and people are threatened or killed if they act against them, this law has no effect.

2.2.2 Sand Mining in Pakistan

Heavy equipment mining in Pakistan's Poonch River is ruining the habitat of the rivers. Similar circumstances exist on the other side of the Kunhar and Neelum rivers in Khyber Pakhtunkhwa as well as the Jhelum river in Punjab. By selecting and designating places from which the miners can quarry the building material, the state is not using any planning or policy to prevent the indiscriminate excavation of riverbeds (Ahmad, 2017). In the Malir region, sand mining is pervasive and mostly unregulated. (Husain et al., 2017). Further afield in Jamshoro, particularly at Lonikot and Nooriabad, as well as deeper inside Sindh, massive amounts of sand mining are occurring. Sand mining started in Malir many years ago, but as Karachi developed in the 1960s and 1970s, it became more prevalent. (Ali, 2022).

2.2.3 Sand Mining in Nepal

The Kathmandu Valley's rapid development over the past two decades has resulted in excessive sand demand for construction (Sayami and Tamrakar, 2007). A report of The Kathmandu Post highlighted that in addition to other highway towns including Gajuri, Chalise, Siddhalek, Galchhi, Belkhu, Mastar, Malekhu, Charaudi, and Bishaltar, there are several of these illicit sand mines operating (Khatiwada, 2019). The collapse of a bridge across the Bagmati River in Kathmandu as justification for the Nepali government's 1991 ban on riverbed sand mining. However, illegal sand mining is still widespread in the majority of the nation's rivers. According to a case study conducted by Tribhuvan University in 2007, illegal riverbed mining supplied around 40% of the entire sand demand in the Kathmandu valley (Ahmad, 2017). The authors of the study noted that because the activities are illegal, it was challenging to estimate how much sand was being removed. According to a 2007 survey, 3103 m3 of sand had been dug up daily to meet the demand in the Kathmandu Valley. (Sayami and Tamrakar, 2007). These sand mine operators have been conducting business by randomly collecting building materials, despite having the protection of elected officials and the police. The contaminated roadway areas and the bareness of the once-beautiful riverfront are evidence of the repercussions (Khatiwada, 2019).

2.2.4 Sand Mining in China

The world's largest constructing market is in China (Lau, 2015). Due to its growing urbanization, China has a higher-than-average need for sand. The United Nations Environment Programme estimates that over the last two decades, demand for cement has surged by 400%. According to the reports of Reuters, 2021, China has experienced decades of rapid urbanization, which has increased demand for sand used to produce glass, concrete, and other building materials. Instead of deserts and seas, rivers and lakes provide the most suitable sand for this industry. Poyang Lake, located in the eastern province of Jiangxi, has provided a significant amount of the sand used to construct the nation's megacities. In 2000, The Yangtze River's lower and middle reaches were off limits to activity by Chinese officials (Ahmad, 2017). However, since a crackdown on illegal sand mining along the Yangtze River was initiated at the beginning of this year, 368 criminal cases involving 330 million yuan (about 51.8 million USD) have been resolved by Chinese authorities, according to a report from Xinhua net, 2021.

2.2.5 Sand Mining in Developed Nation

A multi-billion dollar business relies on sand and gravel for building and industrial uses. Construction and industry demand follow economic cycles, just like frac sands. More homes are sold when more are built, as are more roads are built and repaired. Just 118 businesses with operations in 33 states generated the substance in 2015, according to a U.S. Geological Survey, 2012. The top producing states were Wisconsin, Illinois, Texas, Minnesota, Arkansas, Oklahoma, Missouri, and Iowa, in that order of tonnage produced. Together, these states produced over 80% of the nation's output. According to a report by Resilience, 2017 the beach is the only one still being mined for construction sand in the United States. An estimated 270,000 cubic meters of sand are sucked up annually by a dredger operated by Cemex, a multinational construction company with headquarters in Mexico. There were numerous similar sand mines along the California coast during the most of the 20th century, but in the late 1980s the federal government shut them down because the state's well-known beaches were eroding."

A review by Pangam, et al., 2006 said that "According to sand mining legislation from nations including France, the United Kingdom, Japan, Malaysia, The Netherlands, and the United States, sand mining is only permitted at depths larger than 10 meters (m) and a minimum of 600 meters from the shore.3 Dredging must take place in France at depths greater than 20 m and more than 5.5 km offshore of the beaches. Dredging is not permitted in the UK inland of the 19–22 m isobath or within 600 m of the coast. Dredging is not permitted in Japan within one kilometer of the coast. All procedures take place in water that is deeper than 20 meters. The Coastal Engineering Technical Centre's standards in Malaysia state that mining must be allowed seaward of the 10 m isobath, or 2 km offshore for Peninsula Malaysia's east coast. Mining is legal seaward of the 20 m isobath in The Netherlands. Seaward of the 18-meter isobath is the New York mining region (Pangam, et al., 2006). This scenario demonstrates that, in contrast to developing or undeveloped countries, sand mining activities are well controlled and closely regulated in developed nations.

2.3 Sand Mining in Bangladesh

Bangladesh, also known as the "land of rivers," is a major supply of river sand. Bangladeshi sand miners frequently extend their activities beyond of the regions they have officially leased, despite the fact that it is intended to be a regulated industry. Sand mining is a significant industry in Bangladesh. Sand mining activities are increasing in the Meghna, Brahmaputra, and Jinjiram river basins as a result of the country's fast urbanization, though they didn't start all that long ago. (Bari and Haque, 2022). According to Syeda Riswani Hasan, an attorney with the Bangladesh Environmental Lawyers Association, between 60 and 70 percent of the sand sold in Bangladesh is produced through illegal mining. (Ahmad, 2017). Massive erosion in the Hajipara area, also known locally as Bhanga bari, is a result of sand mining in the Tangail district. (Khan and Sugie, 2015). In Tangail and Sirajganj districts in northern Bangladesh, the demand for sand is endangering farmland and the flood embankments surrounding the Jamuna river, endangering the livelihoods of local farmers (Sulayman Hossain, 2021). According to a media report of Ntv Online 2017, Sand will be exported by the government to Singapore and the Maldives at a cost of one taka ($0.01) per cubic meter. The dredging will be stopped if any environmental deterioration is discovered, said Land Minister Shamsur Rahman Sharif (International Television Channel Ltd. NTV, 2017). According to Williams, 2021, with the help of elected public officials, illicit sand mining is done in rivers and wetlands in Bangladesh. Nearly all of Bangladesh's rivers, both large and small, are impacted by the widespread illegal sand mining that occurs in the Narayanganj, Tangail, Sirajganj, Munshiganj, Rajshahi, and Manikganj districts. Despite concerns from environmental campaigners, the illegal sand mining gang hardly ever receives any attention. (Williams, 2021)

2.4 Sand Mining and Morphological Changes

Sand mining from riverbed has a serious impact on morphological changes of riverbed and also causes the changes of riverbank area. Due to the considerably reduced riverbeds caused by unregulated riverbed mining, bridges are now in jeopardy. According to research, the riverbed of western Nepal's Tinau river has decreased by 2.5 meters during the past 15 years. (Ahmad, 2017). The contour of the riverbed is directly impacted by indiscriminate river sand mining. This frequently has numerous indirect impacts that add up over time on a river's physical properties and the dynamic equilibrium of erosion and sedimentation (Rentier and Cammeraat, 2022). The sediment-supply balance tends to drift upstream when sediment is removed from the riverbed in order to make up for the lack of supply (Leeuw et al., 2010). A study on Sa’ dang River shows that, the mining activities of Sa’dang River had an impact on morphological changes and dynamic physical conditions of Sa’dang River (Arsyad1 et al., 2020). A report of Dawn, 2022 showed that Dawn has found that at least 4,000 acres in the Malir and Jamshoro districts, close to BTK, have been mined for sand or are actively being mined using GPS and satellite mapping (Ali, N. S., 2022). According to Lai et al., 2014, pit excavation and bar skimming result in the riverbed becoming, respectively, deeper and broader, when examining changes along the cross-sectional area of a river. The main causes of the riverbed's enlargement are bar skimming and bank failure as a result of undercutting (Lai et al., 2014). According to a Reuters investigation in 2021, excessive sand mining is to blame for the Mekong River Delta in

Vietnam sinking 2 centimeters every year. A study by Ahammed and Pandey (2020) on Alappa, Kerala suggests that sand mining first began in the late 1960s; since then, due to overuse of the marine resource, the land has been turned into the sea. The study looked at the evolution of the shoreline over time and found that while accretion has remained consistent during that time, erosion has dramatically accelerated after 1977 (Ahammed and Pandey, 2020). Another study by Bari and Haque, 2022 on Legal and Illicit sand mining practices in Bangladesh stated that, regardless of its legal status, the majority of people have stated that sand mining operations have accelerated the rate of embankment destruction and increased the frequency of river erosion. When people were questioned about how sand mining activities had affected fish capture and its variety, similar (negative) perceptions were discovered. In conclusion, locals consider sand mining methods as having more negative effects on river morphology than positive ones, regardless of how lawful they may be (Bari and Haque, 2022). A study by Khan and Sugie, 2015 Showed that that illegal sand mining and riverbank degradation are related directly (Khan and Sugie, 2015). According to the study, BWDB is worried that boosting water flow by taking sediments out of the riverbed would speed up riverbank erosion (Khan and Sugie, 2015).

2.5 Sand Mining and Environmental Issues

Deep ecological changes brought on by sand mining operations may have an impact on the entire ecosystem. It can have a physical, biological, and chemical impact on the local environment. According to a report of Dhaka Tribune, 2022 sand mining causes habitat in mined zones to become disturbed and eventually disappear. In other words, the entire ecosystem is altered, including the physical habitats, food webs, and channel geometry. Additionally, it increases flow velocity, upsetting the flow regime and causing the river banks to erode over time (Akhter, 2022). According to a recent research, 236 million cubic meters of sand—or nearly 9% of China's entire production—are taken out of the lake every year. Poyang is now the largest sand mine in the world as a result (Lai et al., 2014). Sand mining, according to researchers, is primarily to blame for the lake's precipitous decline in water level in recent years. The neighboring wetlands, which are Asia's greatest winter migration site for imperiled Siberian cranes and white storks, are experiencing deteriorating water quality and supply as a result of the reduced water levels (Ahmad, 2017). The Guardian, 2017 reports showed that Poyang Lake is the greatest wintering location for migrating birds in Asia. It is located in a lush rural area best known for a waterfall in the neighboring hills. During the cold months, it is home to numerous rare and endangered species as well as millions of cranes, geese, and storks. The endangered freshwater porpoise still has a few habitats left, and one of them is in this area. According to studies, sand boats' noise and disturbed sediment severely impair the porpoise's vision and sonar, making it impossible for them to find fish and shrimp to eat (Beiser, 2017). The reports from Guardian, 2017, also stated that damage resulting from various sand mining methods varies. The habitat of organisms and critters that live at the bottom of rivers is destroyed by dredging (Beiser, 2017). The process of artificial accretion and erosion is caused by the disturbance of sand along the coast (Pangam, 2006). One of the elements that guarantees the (long-term) survival of many species is a stable riverbed. Many animals can be found in the sand layer on the stable riverbed. Instability and the destruction of this organisms' habitat result from the removal of the sand (Zou et al., 2019). The churned-up sediment clouds the water, suffocating fish and blocking the sunlight that sustains underwater vegetation. Kenyan officials shut down all river sand mines in one part of the country a few years ago because of the environmental damage it was causing. India's supreme court recently warned that "the alarming rate of unrestricted sand mining" is disrupting riparian ecosystems all over the country, with fatal consequences for fish and other aquatic organisms and "disaster" for many bird species (Beiser, 2017). According to a 2017 report by Ahmad, the majority of riverbed extraction destroys the aquatic environment's vegetative cover and lowers nutrient inputs into the river, which has a negative impact on aquatic life, according to Subodh Sharma, professor at the department of environmental sciences and engineering at Kathmandu University (Ahmad, 2017). A study by Husain et al., 2017 on Environmental Impact of Sand Mining in Malir River Bed Karachi, Pakistan shows that The environmental implications of sand and gravel mining in the Malir River include landscape degradation, a decline in forest cover, grazing pasture, and a decrease in water table (Husain et al., 2017). The body of literature is conclusive proof of the connection between sand mining and the degradation of the local ecology and environment.

2.6 Sand Mining and Urbanization

The environment is heavily impacted by overuse of natural resources as a result of growing urbanization. Some common images of the urbanization of any location include building construction and land filling. The rate of global urbanization, according to data from the World Bank, is 1.7%. The world is predicted to run out of construction-grade sand by 2050 due to the fast urbanization that is causing a massive increase in demand (Rentier and Cammeraat, 2022). Bangladesh is currently experiencing fast urbanization growth as a result of the global urbanization trend. In 2021, the urban population of Bangladesh was 38.9%, according to World Data Atlas. Bangladesh's urban population grew at an average yearly rate of 3.25% from 8.2% in 1972 to 38.9% in 2021.The unusual urban growth of our time is the primary cause of this catastrophe. Cities are growing faster and larger than they have ever been in human history. Approximately 4 billion people now reside in metropolitan settings, more than a fourfold increase since 1950. More than half of the world's population today resides in cities, and an additional 2.5 billion people are expected during the next thirty years according to the UN reports, 2014. Sand is more in demand in the building and ceramics sectors as a result of Bangladesh's rapid urbanization. Bangladesh's ecosystems are severely harmed by sand mining that is illegal, arbitrary, and unscientific (Akhter, 2022). Sand, a crucial component of concrete and asphalt, is being devoured in enormous quantities by the global urbanization boom. In the previous 20 years, Shanghai, China's financial hub, has grown tremendously. Since 2000, the city has seen a 7 million increase in population, bringing the total to almost 23 million. Shanghai has constructed more high-rise buildings in the last ten years than New York City combined, in addition to countless miles of highways and other infrastructure.

2.7 Conclusion

A thorough understanding of a particular study can be gained via reviewing the literature. An extensive overview of the global and Bangladeshi sand mining situations is provided by the literature that has been reviewed. It is also useful to understand how this form of sand mining affects the natural world and ecology.

Chapter-3: Study Area

3.1 Introduction

To fulfill the aim and objectives of my study, it is necessary to select the study area considering the location of the Meghna estuary, sand mining activities in the river, and river erosion in the area.The study area has been selected based on river erosion-prone areas due to sand mining. The area comprises the Bhola district, in which the Meghna and Tetulia rivers surround it from east and west, respectively. The collection of data was conducted in Hakimuddin and Lalmohon Upazilas of Bhola, which are the most erosion-prone areas due to sand mining activities.

3.2 Locational extent

Between 21°54' and 22°52' north latitude and 90°34' and 91°01' east longitude is the Bhola District (barisal division), which has an area of 3403.48 sq km. It is bordered on the north by the Lakshmipur and Barisal districts, on the south by the Bay of Bengal, on the east by the Meghna River and the Shahbazpur Channel, and on the west by the Patuakhali and Barisal districts and the Tentulia River (Banglapedia, 2021).

The largest island in Bangladesh is called Bhola. It first appeared in the Meghna Estuary some 800 years ago as a result of material deposited by the Ganges and Brahmaputra river systems. The 13th century saw the introduction of agriculture. Only 12 feet separate the island's elevation from sea level. There are no roads connecting this island to the mainland. The only means of transportation are waterways.

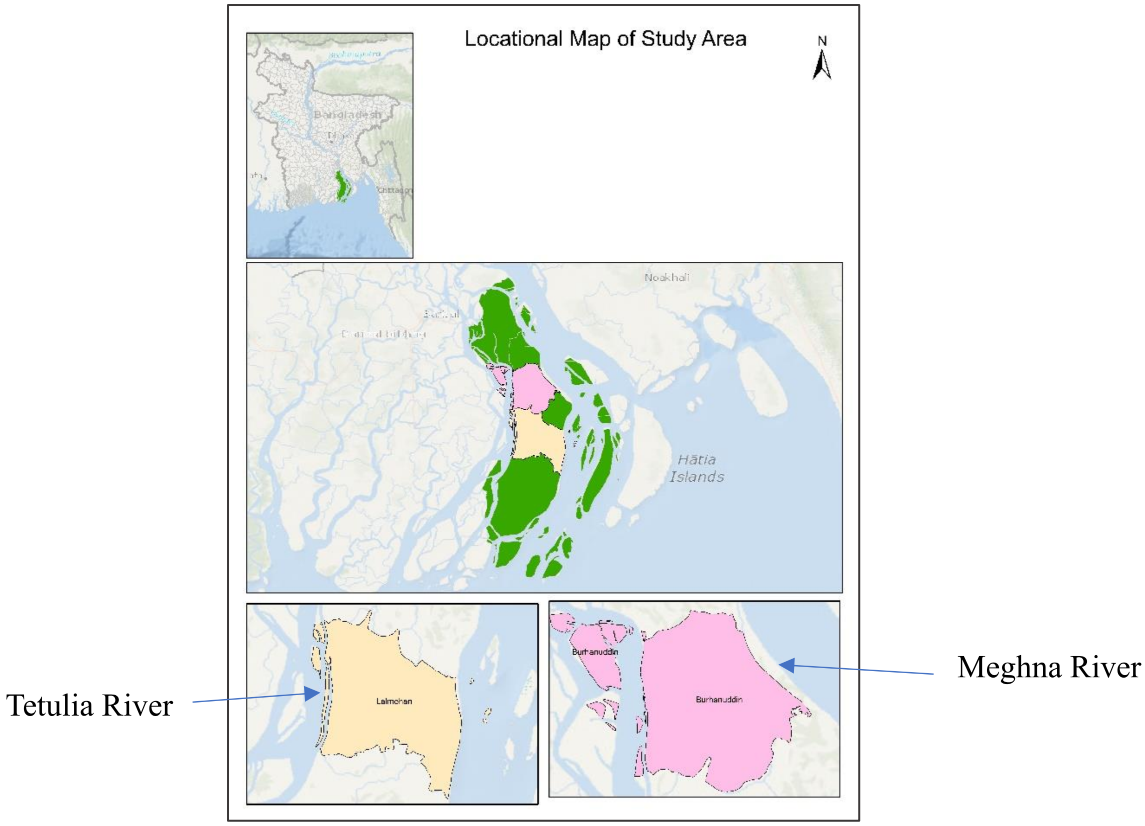


Figure 3.1: Locational Map of Study Area

3.3 Physiography

The coastal region of Bangladesh regularly experiences erosion and accretion processes. The position, arrangement, shape, and size of the coastal region have been changing continuously as a result of these activities. With the construction and development of new land and the erosion of old land, Bangladesh's estuary flood plain as well as its coastline region saw significant morphological changes during the last few centuries. In spite of the current instability, a chain interaction forms and dynamic equilibrium is preserved.

3.4 Climate

According to Koppen climatic classification of Bangladesh, The District Bhola fall under the class of Tropical Savanna Climate (Aw) (Wikipedia, 2021)

The major characteristics of this class are:

The Tropical Savanna climate, designated as "Aw" in the Köppen climate classification, is typically found in regions near the equator and is characterized by distinct wet and dry seasons. Here are some key features:

1. **Seasonal Rainfall:** The Tropical Savanna climate has a pronounced wet season and dry season. During the wet season, there is abundant rainfall, often in the form of heavy, intense, and frequent thunderstorms. This wet season is associated with the monsoon pattern, as the Inter-Tropical Convergence Zone (ITCZ) shifts northward in the summer and southward in the winter.
2. **Dry Season:** The dry season in the Tropical Savanna climate is characterized by a prolonged period of little to no rainfall. This period can last for several months, resulting in dry and arid conditions. The dry season is often associated with the movement of the ITCZ away from the region.
3. **Temperature:** The climate is generally warm to hot throughout the year, with relatively small temperature variations between seasons. Average temperatures are high, and there is often little variation between day and night temperatures.
4. **Vegetation:** The savanna climate supports a distinct type of vegetation known as savanna grassland. These are vast expanses of grasslands with scattered trees and shrubs. The vegetation has adapted to the seasonal rainfall patterns, with many plants being drought-resistant and able to survive the dry season.
5. **Wildlife:** The Tropical Savanna climate is home to a diverse range of wildlife. Many animals have also adapted to the seasonal changes and may migrate or change their behavior in response to the availability of water and food.
6. **Human Activities:** Human activities in areas with a Tropical Savanna climate often involve agriculture, especially in the wet season when there is enough water to support crops. Pastoralism, particularly for cattle and other grazing animals, is also common in savanna regions.

3.5 Land use Land cover

The following map is the representation of Land use and Land cover of Bhola. This area is comprised a number of charland. Bareland is predominated in newly formed char. Builtup area is higher in Bhola district center and all the Upazila center of the districts. Both sides of the mainland surrounded by the rivers. Vegetation cover is higher in northern part of the district.

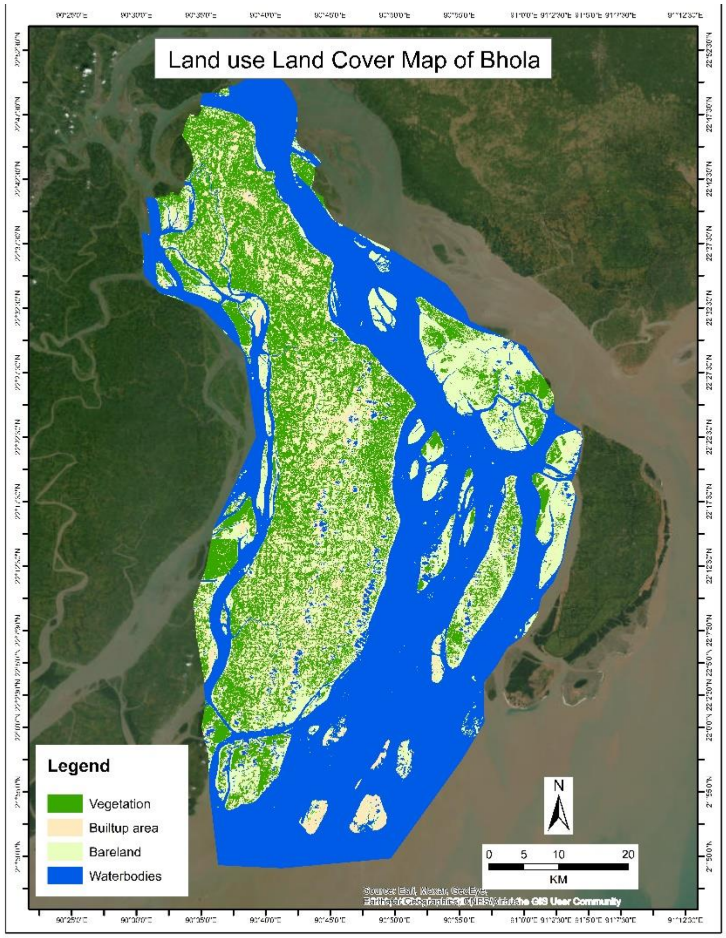


Figure 3.2: Landuse and Landcover map of Study Area

3.6 Demography

Bhola District had 448,933 houses and 1,932,514 residents as of the Bangladesh Census of 2022, with 27.6% of them living in cities. 538 persons per km2 made up the population density. In comparison to the national average of 74.7%, the literacy rate (for those aged 7 and older) was 37.1%. According to the Census of 2011, the Muslim community makes up 96.55% of the population, the Hindu community makes up 3.44%, and the other religions make up the remaining 0.01% (Wikipedia, 2021).

3.7 Economy

As the area located near the Meghna river, Most of the people ar directly or indirectly connected to the river for their livelihoods. According to Wikipedia, 2021 the 80% of the people are fisherman. While the Banglapedia shows the percentage of Occupation of people in the table below.

Table 3.1: Occupation of People of Bhola

Source of Income	Percentage of people
Agriculture	63.64
Labourer	4.95
Industry	0.5
Commerce	12.67
Transport and communication	2.47
Services	5.74
Constructions	1.55
Religious services	0.35
Rent and remitance	0.44
Others	7.67

Source: Banglapedia, 2021

The literacy rate of Bhola district is 67.12% (according to bangladesh.gov.bd). The literacy rate among the male population is 67.03% and the female population is 67.20%.

3.8 Natural calamities

The most urgent problem on the Bhola shoreline is river erosion. One of the most disaster-prone regions in the world is Bhola and the surrounding area. primarily affected by large cyclones and tidal surges. The islands in the Bay of Bengal are referred to as the Climate Ground Zero for this reason. The unprotected embankment poses a real risk to the crops and farming output.

Chapter-4: Materials and Methods

4.1 Overview of Methodology

Evaluating the river bathymetry changes due to sand mining and their potential link with river erosion was a challenging task. For this type of research, historical bathymetry data is a must. This bathymetry data shows the changing bathymetry of the riverbed. The data was collected from the Bangladesh Inland Water Transport Authority (BIWTA). This bathymetry data they provided was in hard copy map format, which was further scanned and digitized for the assessment of the bathymetry of the study areas. The extensive fieldwork was necessary to understand the real scenarios of the study area and also to know the local people's perceptions about these issues. The riverbed and riverbank sediment of the Tetulia and Meghna Rivers was collected through boring to make a comparison of the sediment properties of the areas and also to know the physical properties of riverbed and riverbank sediment. The physical properties of the sediment can give an insight into erosion. The current mined sand in Lalmohon Upazila was found during the field work. The sand sample was also collected to determine its physical properties. Landsat images were collected to assess the land use and land cover changes in that area. It would be an important parameter to know the scenario of erosion in the study areas.

4.2 Selection of The Study Area

Considering the objectives of my research, the study area should be in the Meghna estuary, which could represent coastal erosion due to sand mining. From the various literatures, the sand mining location was first found in the Meghna Estuary. Most of the current sand mining areas are in lower Meghna, around Bhola. So Bhola was selected as my study area. The two rivers Tetulia and Meghna, which are located west and east of Bhola, respectively, were selected for collecting bathymetry data and doing a field survey. These two areas near the rivers face erosion due to sand mining. Illegal or unplanned sand mining is occurring here. Sand mining in the Tetulia River has occurred recently, and the channel width is also shorter than Meghna. On the other hand, Sand extraction in the Meghna River bed has been occurring since a long time before the Tetulia River.

So, the evaluation of the impact of sand mining in these two different areas will show a spatial and temporal variation among the areas.

4.3 Data Collection

Collection of data is the prior of any research analysis. For this study both secondary and primary data were collected from different source.

4.3.1 Collection of Primary Data

Any kind of physical or geographic inquiry requires the collecting of primary data. For the research to accurately reflect the real situation of the study location, a field visit is required, along with field observation and data collection for future lab analysis. I had to gather sediment samples for my research during the fieldwork, conducted FGDs and keep a close eye on the local environment.

4.3.1.1 Collection of Sediment Sample from Study Area

A sediment sample from the riverbed and river bank of the Meghna and Tetulia rivers has been collected to assess the sediment type of the two river banks and river beds. Sediment samples have been collected through boring. For riverbed sediment, a 1-meter soil horizontal layer and a 50-cm soil horizontal layer have been collected through boring. The collected sediment is further used for particle size analysis of the rivers. A sand sample was also collected from the study area to determine its physical characteristics.

4.3.1.2 FGD

Any type of research should focus on human benefit. So, if I am conducting the research, I will focus on physical geography, even though it is necessary to know the impact on local people. The focus should be on the betterment of people through my research. Another important part of my research was to evaluate the impact of river erosion due to sand mining and the overall impact of sand mining activities on local people. How this type of human interference in natural settings can be impactful for the socioeconomic condition of marginal local people. To know the local people's perception regarding sand mining and river erosion Focus group discussions have been done in the two upazilas of Bhola. Those areas were the Burhanuddin Upazila, which is beside the Meghna River, and the Lalmohon Upazila, which is beside the Tetulia River.

4.3.2 Collection of Secondary Data

My research mainly focuses on the historical modifications to the river bank and bed. I therefore had to get secondary information from numerous sources. Secondary data can provide insight into how the riverbed and riverside regions are evolving. For the purpose of assessing the changes in land use and land cover in the region, Landsat image data was acquired along with historical bathymetry data from BIWTA for the Meghna and Tetulia rivers close to the Bhola district.

4.3.2.1 River Bathymetry Data

Historical bathymetry data for the Meghna and Tetulia rivers has been collected from BIWTA. They provided the river bathymetry data for the two rivers. This data was further used to assess the bathymetry changes of the river throughout the periods. For the Meghna River, the data was from Hakimuddin launch ghat to Tazumuddin Upazila, and for the Tetulia River, it was from Nazirpur launch ghat to the southern portion of the river.

Table 4.1: The Collected Bathymetry Data for the Areas

River	**Areal extent**	**Availability**
Meghna	Moulavir char to Munshirhat	2006
	Ramgati to kharki	2012
	Char Latia to Daulatkhan	2021
Tetulia	Nazirpur Launch ghat area	2018
	Nazirpur Launch ghat area	2020
	Nazirpur Launch ghat area	2022

4.4.2.2 Landsat Images of Study Area

Landsat images was collected from USGS Earth explorer. The analysis of the historical landsat image can give assessment regarding the landuse and landcover changes of the area also the changes of riverbed over time.

Table 4.2: List of Landsat Images

Date	Type	Band Used	Purposes	Path and Row
2014-04-15	LC_08	3,5	NDWI	137044
2016-02-16	LC_08	3,5	NDWI	137044
2018-04-26	LC_08	3,5	NDWI	137044
2020-02-27	LC_08	3,5	NDWI	137044
2021-12-30	LC_08	3,5	NDWI	137044
2023-05-10	LC_08	1-7	LULC	137044
2023-05-10	LC_08	1-7	LULC	137045
2023-04-16	LC_09	3,5	NDWI	137044
2006-12-21	LT_05	3,5	NDWI	137044

4.4 Lab Analysis

The sieve analysis was carried out for the borehole sample to determine the particle size of each layer of study area. From the analysis of particle size, the physical characteristics of layer could be identified.

Sieve method:

The sieve defines a particle diameter as the length of the side of a square hole that the particle can just fit through (Konert and Vandenberghe, 1997). The oldest and most popular method for analyzing particle size is the use of sieves. Several methods based on various concepts can be used to get information about particles (Dishman, 2000).

For the lab analysis of my research, the sieve of the Physical Geography Lab of the Department of Geography and Environment, University of Dhaka, has been used. The sieve in this lab is helpful to measure the particle diameter, which ranges from 4mm to 0.063mm.

Principle for sieve analysis:

By dividing particles into various sized portions on a number of sieves, sieve analysis is conducted. The sample is set on a nest of sieves with mesh apertures that get smaller toward the bottom as they go up. The material then falls through the apertures to a variety of fractions on each particular sieve as a result of vibrating the sieves. The sample's particle size distribution is computed using the volume of material retained on each sieve.

Procedure for sieve analysis in the lab:

Preparation of the sample:

1. Dried the samples to reduce moisture of the sample
2. For silt and clay dominated sample the dried sediment became aggregated tightly so the sediment should be broken into powdered materials using mortar and other tools.
3. Measured the powdered sample for sieve analysis

Preparing the sieve:

Sieve analysis is carried out by segmenting particles into sections of different sizes on a number of sieves. The sample is placed on a nest of sieves with mesh openings that progressively get smaller as they ascend. Vibrating the sieves causes the material to fall through the openings to a variety of fractions on each specific sieve. The volume of material retained on each sieve is used to calculate the sample's particle size distribution.

Procedures followed in the lab

1. Prepared the sieve into proper way
2. Put the measured sediment into the sieve.
3. Kept it in the shaker machine for about 12 minutes

Weighing the sieve sample

To calculate the amount in each particle size fraction, the material on each sieve is weighed. The substance shouldn't be taken out of the sieve for small sample sizes.

Procedure followed in the lab

1. Kept a pot on the electric balance and made the reading zero.
2. Put all the sample of a sieve in the put to get the amount of the sediment
3. Did this for all the sieve sample and recorded it

4.4.1 Particle Size Analysis of Riverbank Sediment

Particle size analysis of the collected 50-cm borehole sample from both riverbank sediments was done using the dry sieve method. Every 10cm layer of sediment was collected from the borehole pipe for sieve analysis. 10 samples were used for the sieve analysis of riverbank sediment for the two study areas.

4.4.2 Particle Size Analysis of Riverbed Sediment

The dry sieve method was used to determine the particle size of riverbed sediment. For Riverbed sediment, 1 meter of borehole sample was collected. From 1m of borehole, a sample was collected from each 10cm layer. Then followed the above-mentioned procedure of sieve analysis and particle size determination of riverbed sediment from the two rivers. 20 samples were used for dry sieve analysis of riverbed sediment for the two riverbeds.

4.4.3 Particle Size Analysis of Mining Sand

The mined sand from Nabirchar, Lalmohon Upazila, was collected to assess the particle size of the sand. The dry sieve method was also applied for this sample following the above-mentioned procedures of sieve analysis.

4.5 Analysis of Secondary Data

As this study is based on the historical data of bathymetry of the river so the analysis result of secondary data gives insights regarding the historical changes of the riverbank and riverbed of the area.

4.5.1 Analysis of Landsat Imagery

The collected landsat imagery data of different year for the two river areas was analysis to determine the changes of landcover of the area and also to assess the changes of riverbed.

4.5.1.1 Classification of LULC of Bhola District

The collected Landsat data were used to create the Landuse and Landcover (LULC) map of the study area, identify the riverbank over time, and detect the changes in landuse over time. For the Landcover classification of Bhola district, the LC08_L2SP_137045_20230510_20230517 and LC08_L2SP_137044_20230510_20230517 were used. The bands 1–7 were used for the classification.

As the two images don't cover the whole Bhola region individually. So, the images need to be mosaiced to join the area. ArcMap 10.8 was used for creating composite band images and mosaics. Then the supervised classification was done in Erdas Imaging 2014 software, creating more than 50 signature polygons. Then the further process of image analysis was done using ArcMap 10.8. The study area of the supervised image has been extracted using the Extract by Mask tool. The area calculation was done after converting the raster layer into a vector layer using the Conversion' tool. Then, from the Attribute table, the area of each polygon can be known. For the detailed area of classified type, Excel was used to sum up the same type of area using a pivot table'. And for creating maps, I used this vector shapefile with proper symbology.

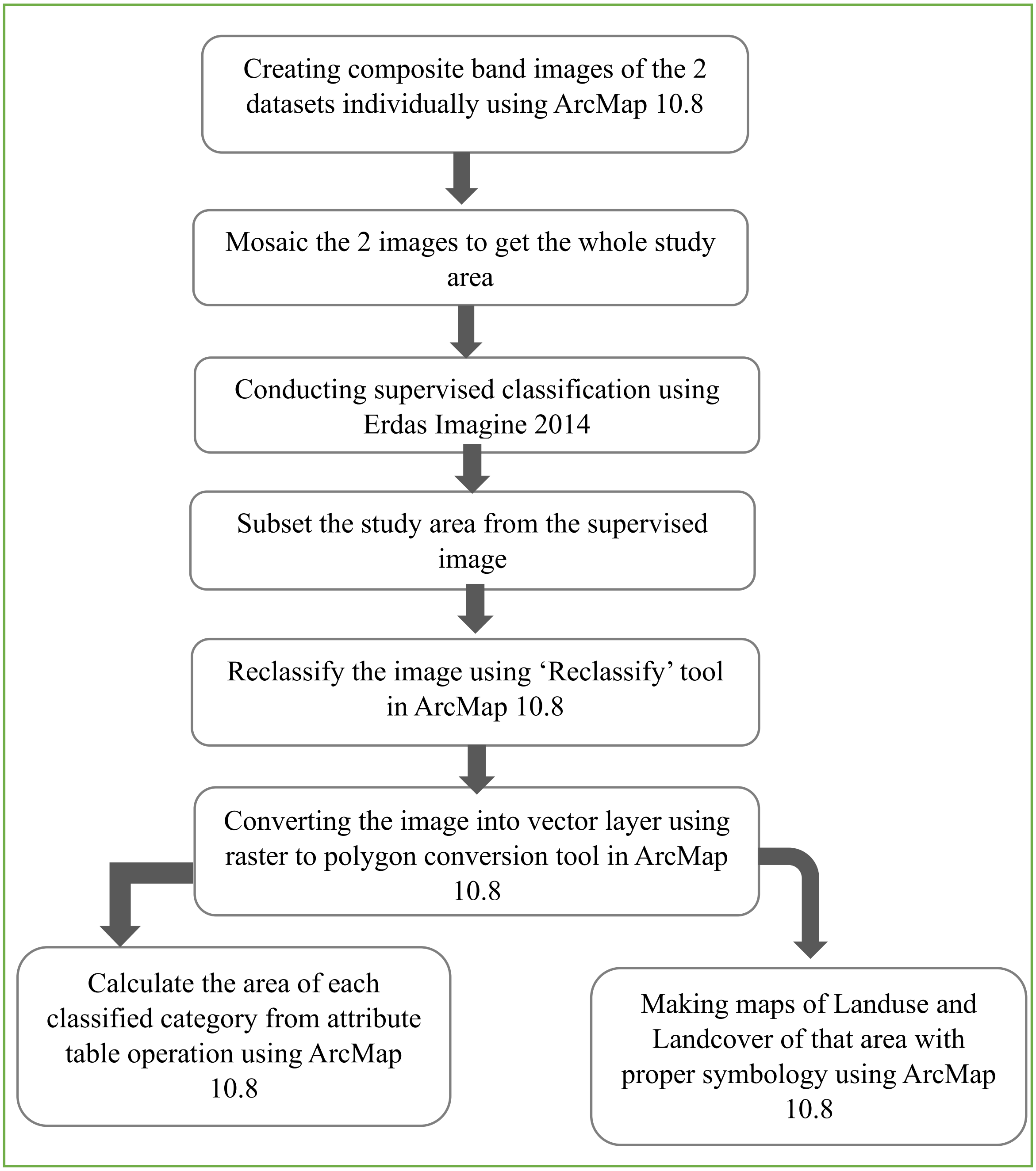


Figure 4.1: Procedure for LULC Classification

4.5.1.2 Identification of the Riverbed and Riverbank area

From the images of each year, The NDWI calculation was operated for the selected year images. Here to show the river area of Meghna and Tetulia with path and row 137044 was sufficient as this tile covered the expected area perfectly.

In this step, all the procedures were done in ArcMap 10.8.

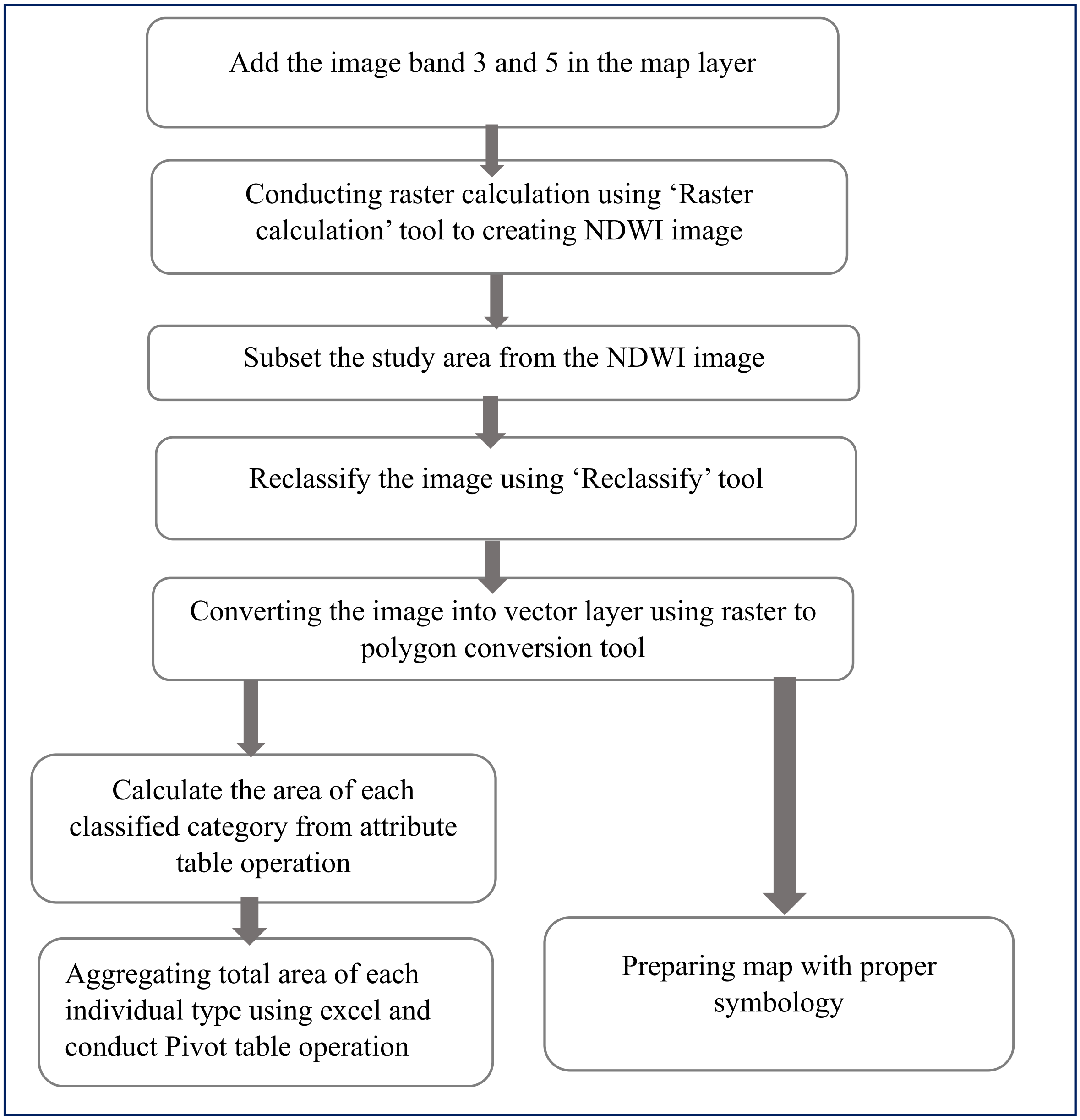


Figure 4.2: Procedure for Identification of Riverbed and Riverbank

4.5.2 Analysis of Bathymetry Data

After converting the collected bathymetry data into digital format, various analyses were carried out using ArcMap 10.8 software. The preparation of bathymetry maps of each available data point on the river was also done using this software.

The procedure for bathymetry data processing is shown in the following flow chart:

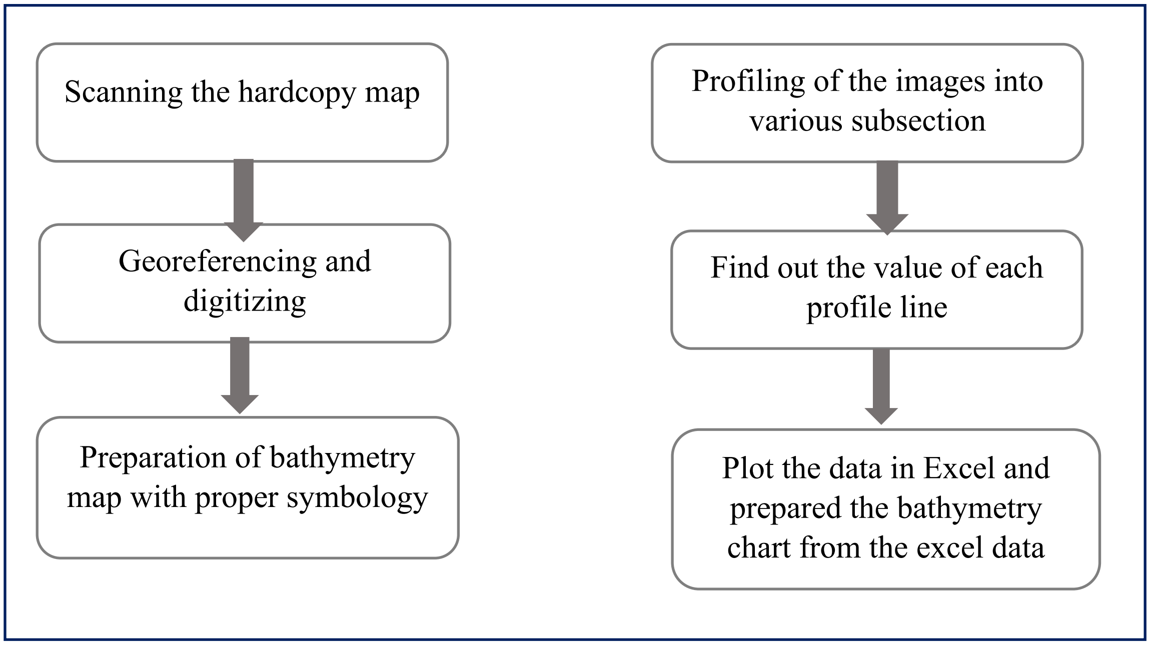


Figure 4.3: Procedure for Bathymetry Data Processing

4.6 Preparation of Graph and Chart

For both the Primary and Secondary data, a sufficient number of graphs and charts need to be prepared. To prepare the charts of Particle Size of Borehole data, the programming language was used using ‘R Studio’. Charts for Bathymetry data and landcover data were created using MS Excel.

Chapter-5: Data Presentation

5.1 Introduction

Physical geography lab work is essential to comprehending the intricate processes that shape our natural world. The area of geography known as physical geography is concerned with the investigation of the planet's physical characteristics, such as its landforms, climate, hydrology, vegetation, and ecosystems. While laboratory work complements and deepens the understanding of these processes through controlled experiments, simulations, and analysis of collected materials, fieldwork allows researchers to witness these phenomena in their natural surroundings. The laboratory provides a controlled setting where scientists can more thoroughly and methodically explore particular parts of the natural world. In the unpredictable and dynamic settings of the field, it may be challenging for researchers to reproduce and identify factors. Physical geographers can validate theories, do precise data analysis, and reach reliable findings regarding a variety of natural phenomena through laboratory experiments.

5.2 Changing Bathymetry due to Sand Mining: Tetulia River

River bathymetry has been changing due to unplanned sand mining. Tetulia river. And this change in bathymetry has a direct link with river erosion. When a particular area of riverbed becomes deeper than usual, the water flow becomes unusual, and bank erosion occurs when sediment particles move to the lower riverbed. And again, the bathymetry changes of the riverbed occur. The riverbank area turns into a riverbed.

To assess the bathymetry changes of a certain portion over the years, three profiles have been considered in the riverbed. The following bathymetry map shows the bathymetry of the Tetulia River and its selected 3 profiles to show the bathymetry changes.

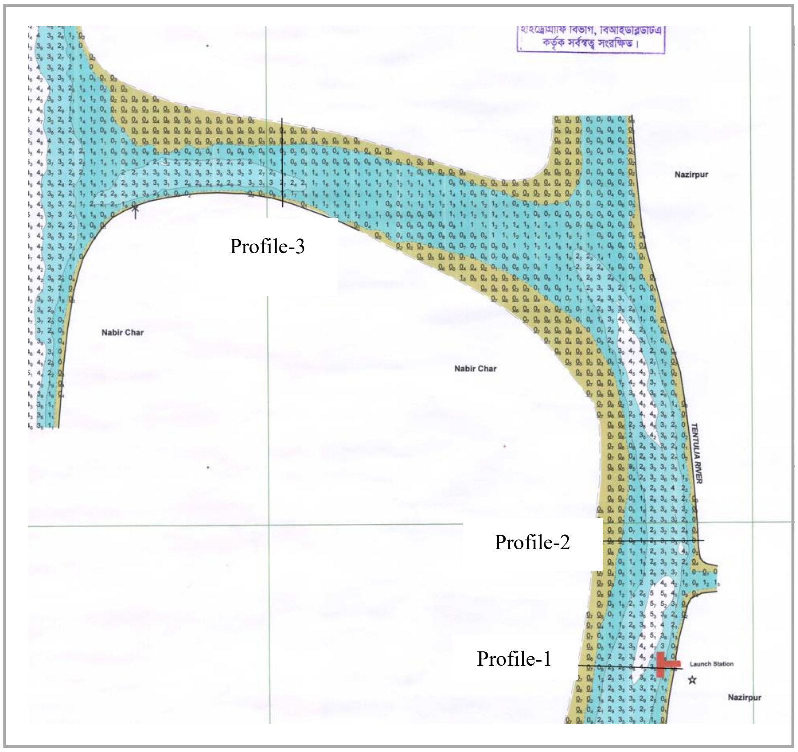


Figure 5.1: Bathymetry Profile from Bathymetry Map of Tetulia River

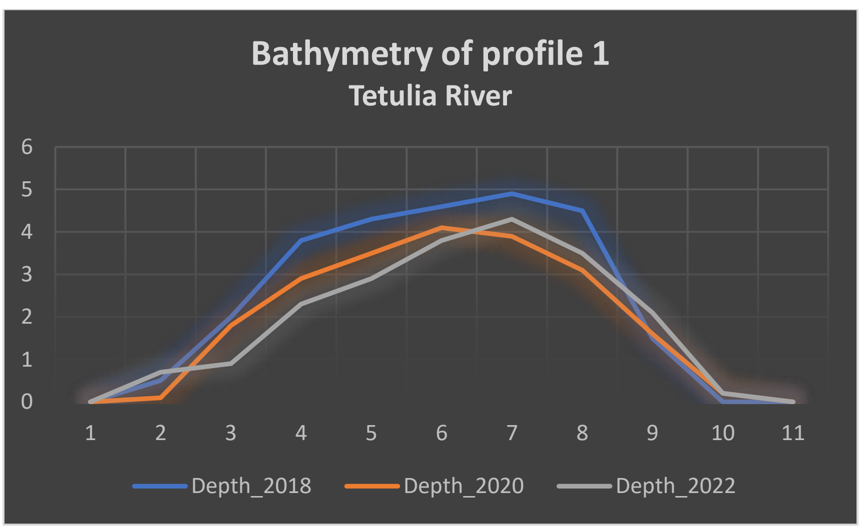


Figure 5.2: Bathymetry Profile 1 of Tetulia River

The above chart (Fig 5.2) shows the bathymetry of profile 1 for the years 2018, 2020, and 2022, which is located in parallel with Nazirpur Launch Ghat.

During the year 2018, the depth was higher than in any other year. In the middle of the riverbed, profile 1 has the highest depth of all the years. The highest depth is 4.9.

During the year 2022, the riverbank areas had the highest depth compared to other years.

The Bathymetry patterns of 2018 and 2020 were almost similar, unlike the bathymetry of 2022. It has a very different pattern, which could be because of sand mining and riverbed erosion. Another important parameter is that regular dredging has been conducted here by BIWTA to maintain the navigation of the launch ghat.

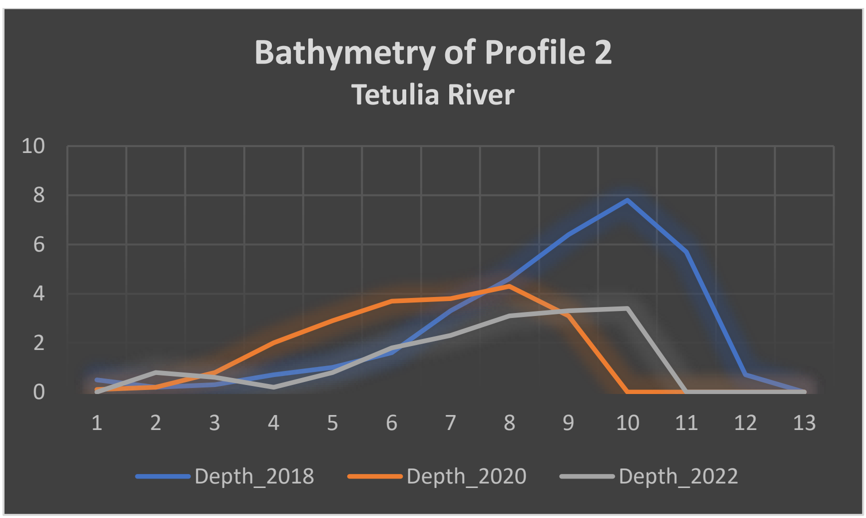


Figure 5.3: Bathymetry Profile 2 of Tetulia River

The bathymetry of Profile 2 (Fig 5.3) shows that the highest depth of the river lies in this area. The depth reached 7.8m in 2018. Depth decreases in 2022. The western side of the river that is bounded by Nabir Char faces erosion now. This erosion is decreasing the depth of the river near the bank area temporarily.

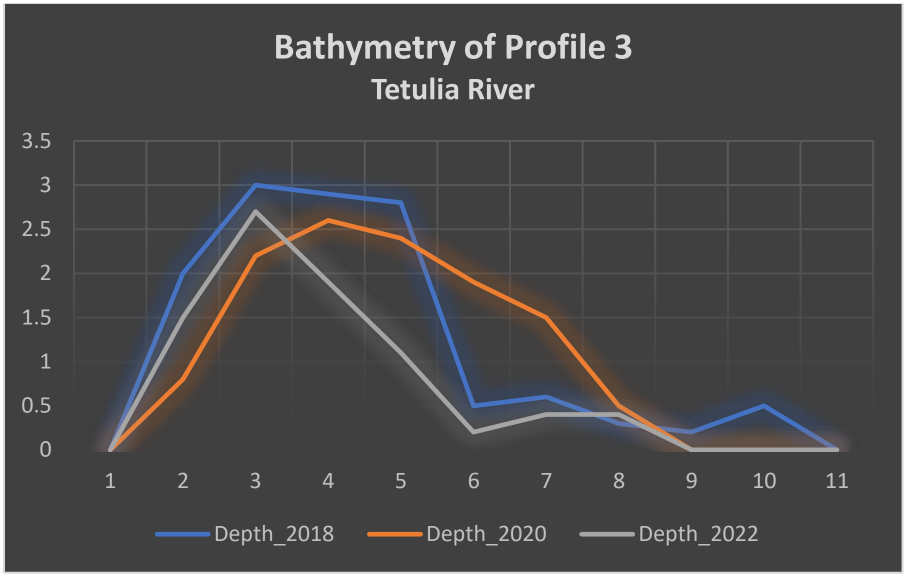


Figure 5.4: Bathymetry Profile 3 of Tetulia River

The above figure (Fig 5.4) shows that the southern part of profile 3 is much deeper than the northern part. The line of 2020 shows a symmetrical pattern of depth, while the lines representing the years 2018 and 2022 have a very asymmetrical pattern in the middle of the riverbed. The depth of the northern part is gradually decreasing because of the huge sedimentation in this area.

It is assumed that the eroded particles from the southern part get deposited in the northern part of Nabirchar.

Changes in 2018:

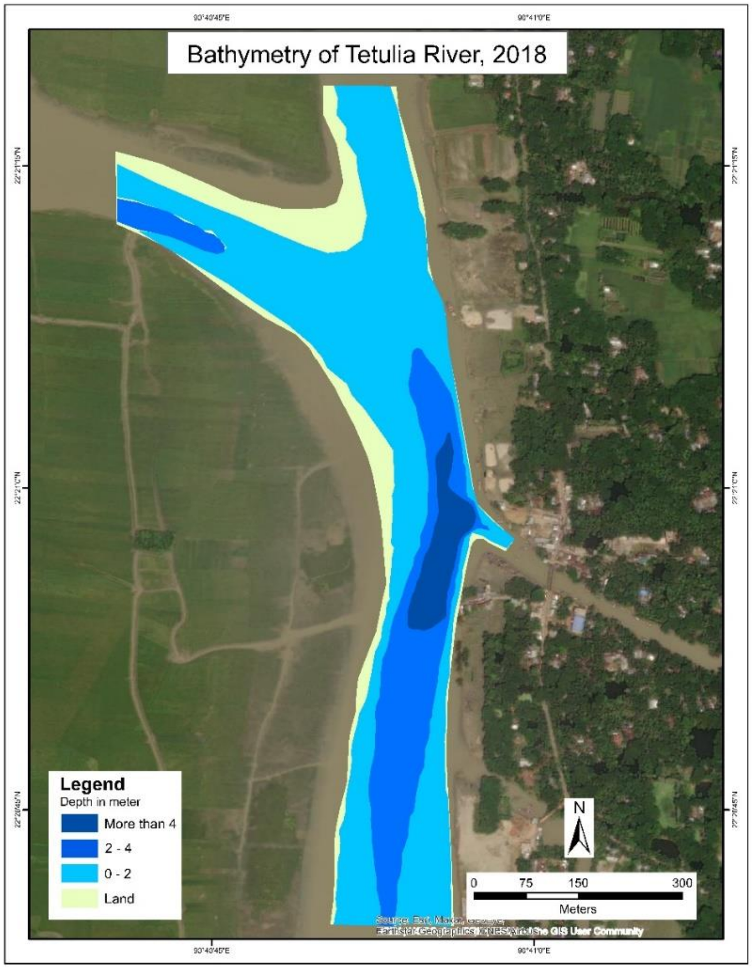


Figure 5.5: Bathymetry Map of Tetulia River, 2018

The above map (Fig 5.5) represents the bathymetry of the Tetulia River during the year 2018. It is considered the LLW (Lowest Level of Water) datum, which shows the actual depth of water all year, all the time (to reduce the value of high tide and low tide).

The northern portion of the river faces accretion. The highest depth of water prevailing near the launch ghat This area remains under constant monitoring by BIWTA to maintain the navigation system.

Changes in 2020:

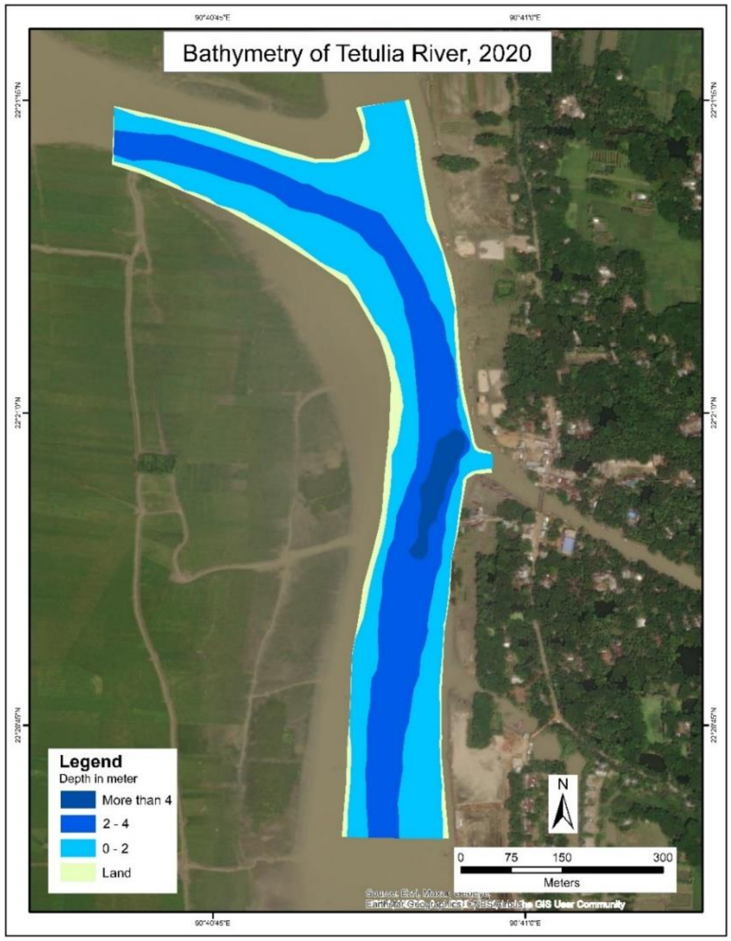


Figure 5.6: Bathymetry Map of Tetulia River, 2020

This map (Fig 5.6) shows a complete path of depth between 2-4 meter. The new landform has reduced during this time. This indicates the newly formed land has been eroded. During this time the new land of northern and eastern part of Nabir char faced much erosion.

The riverbed area which the depth is ranging from 2-4m has increased. Unlike the bathymetry of 2018 it extended much towards North south direction for all the riverbed area.

Changes in 2022:

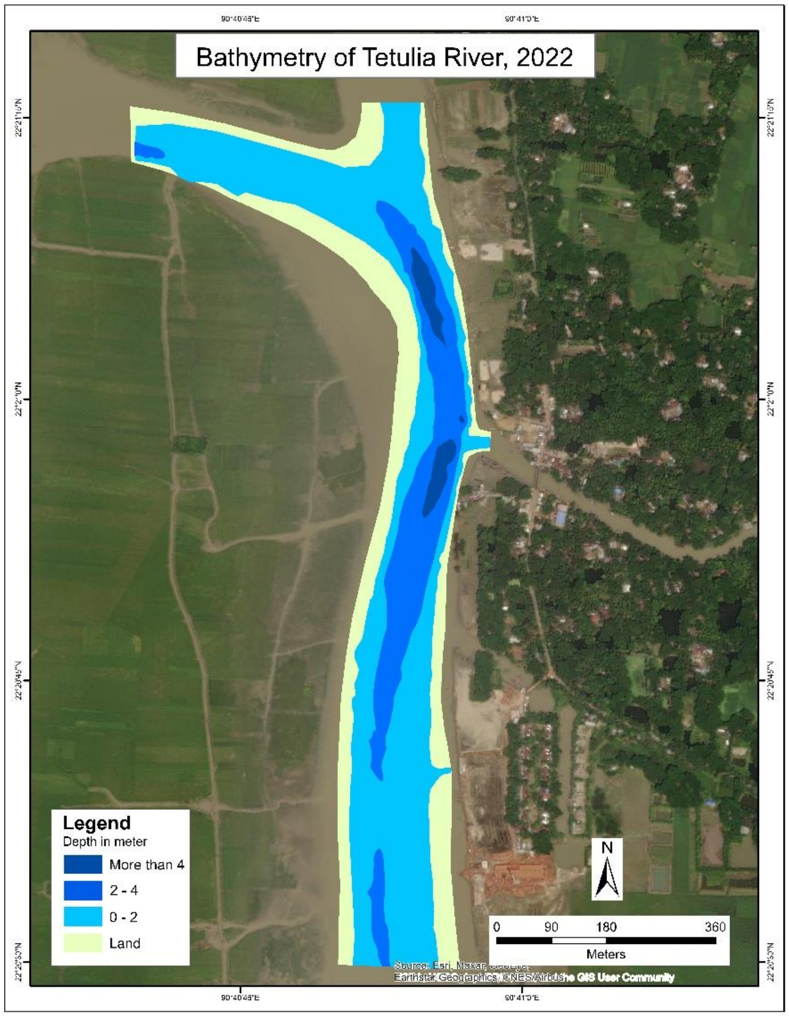


Figure 5.7: Bathymetry Map of Tetulia River, 2022

During 2022, The riverbed shrank, and the acquisition of new land is much higher all around the riverbed. The highest depth near Launch Ghat was slightly reduced, and the depth increased in the northern part of the river (Fig 5.7). The new land filling is occurring. The sand mining that is occurring for the project of Nabirchar may cause the bathymetry of the river to change in the middle of the river bed.

5.3 Changing Bathymetry due to Sand Mining: Meghna River

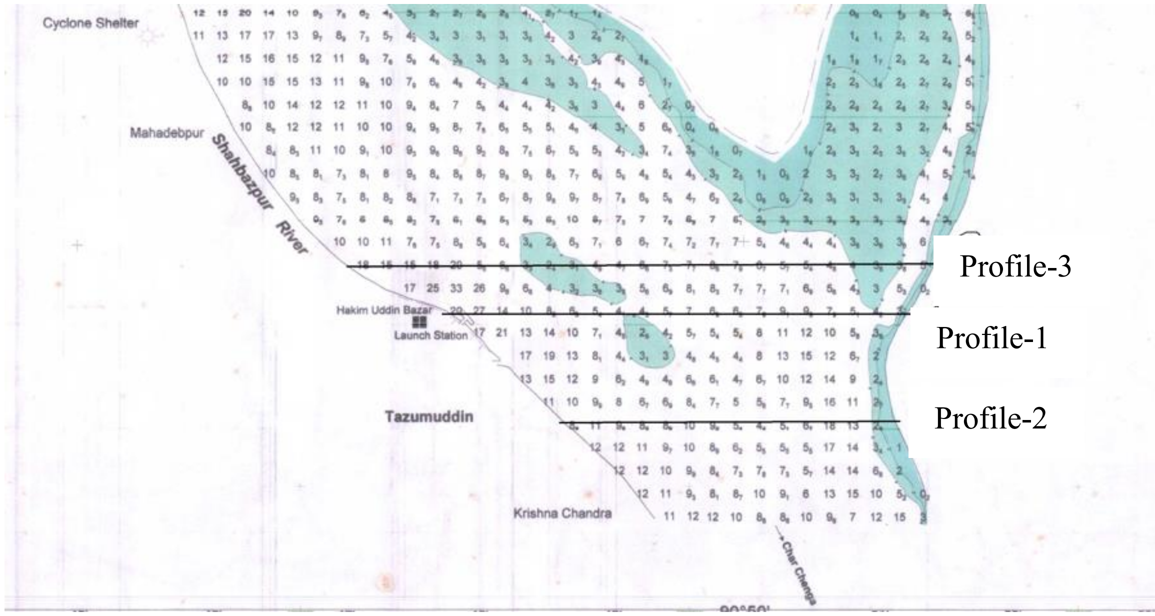


Figure 5.8: Bathymetry Profile of Meghna River from Bathymetry Map

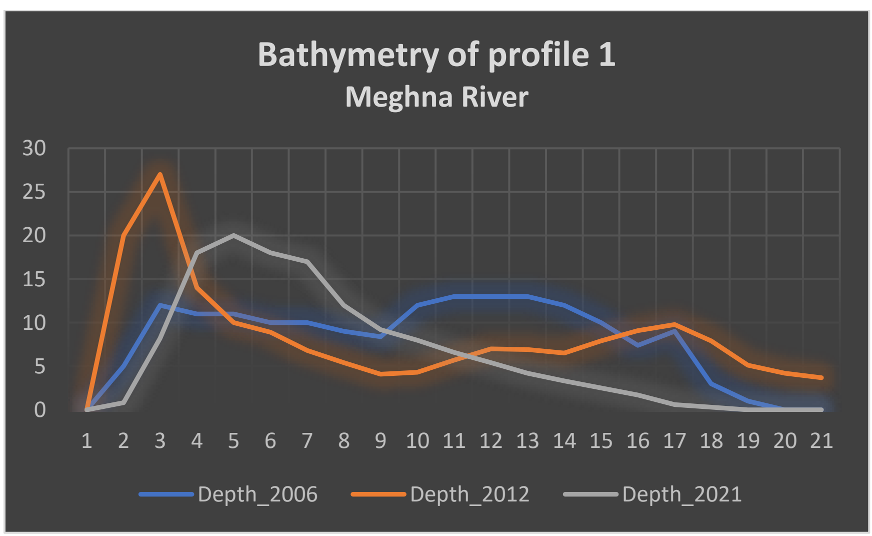


Figure 5.9: Bathymetry Profile 1 of Meghna River

The Meghna River is one of the hotspots for sand mining in Bangladesh. The above chart (Fig 5.9) shows that during the year 2006, when there was little or no sand mining in that area, the symmetrical pattern of bathymetry was profile 1. But during the year 2012, the bathymetry near the Launch Ghat area increased. Due to higher erosion in this area, the launch ghat also shifted throughout the year as the riverbed shifted rapidly. Due to higher erosion, the depth near the riverbank is reduced compared to 2012. Both riverbank sides have the lowest depth during 2021.

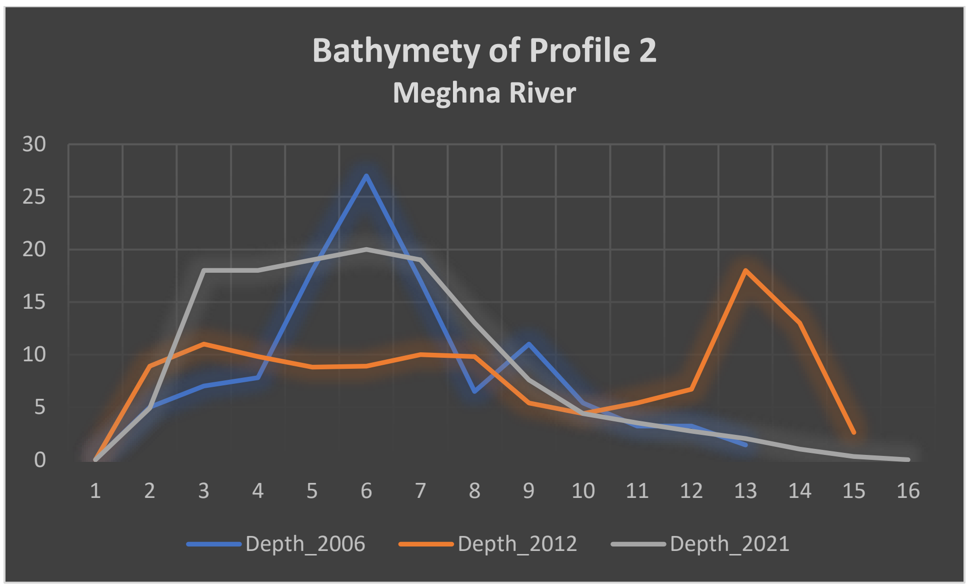


Figure 5.10: Bathymetry Profile 2 of Meghna River

The bathymetry profile 2 (Fig 5.10) is in the southern portion of Mirza Kalu Launch Ghat, which is towards Tazumuddin Launch Ghat. Though the graph of the year 2006 shows the highest depth in the middle of the riverbed suddenly, here the depth is always higher during the year 2021 because of the sandmining activities in that area in this year. The river depth in the eastern part of this profile has fallen because of the accretion of the new char land.

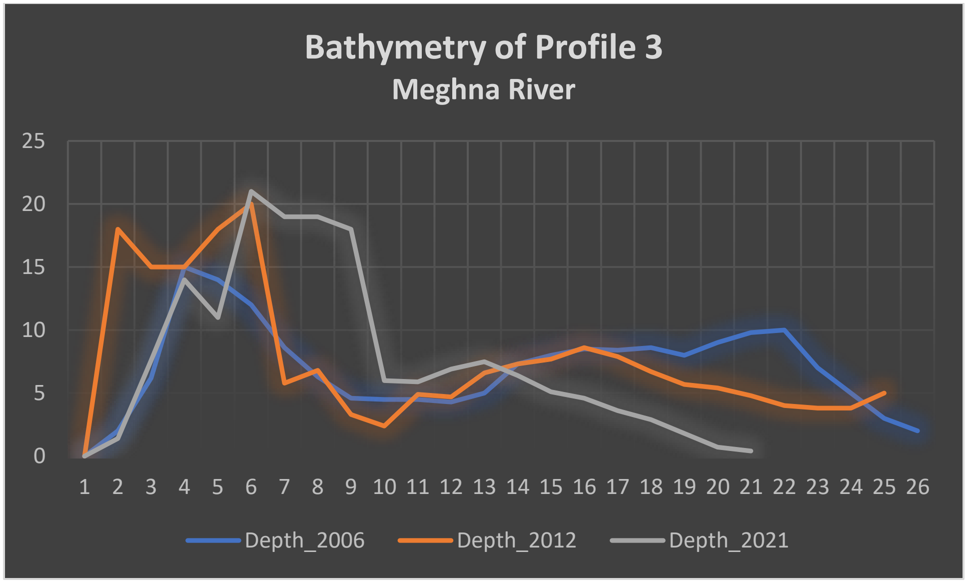


Figure 5.11: Bathymetry Profile 3 of Meghna River

Profile 3 represents (Fig 5.11) the northern part of the river. This graph reveals that the lines of 2012 and 2021 have a similar pattern. The uneven bathymetry of the graph has a direct link to human intervention. It seems like the sand mining spot just moved slightly east from the spot during 2012. The depth decreases in the western part of profile 3 much faster in 2021. In this portion, the accretion is occurring rapidly and creating new land forms.

Changes in 2006:

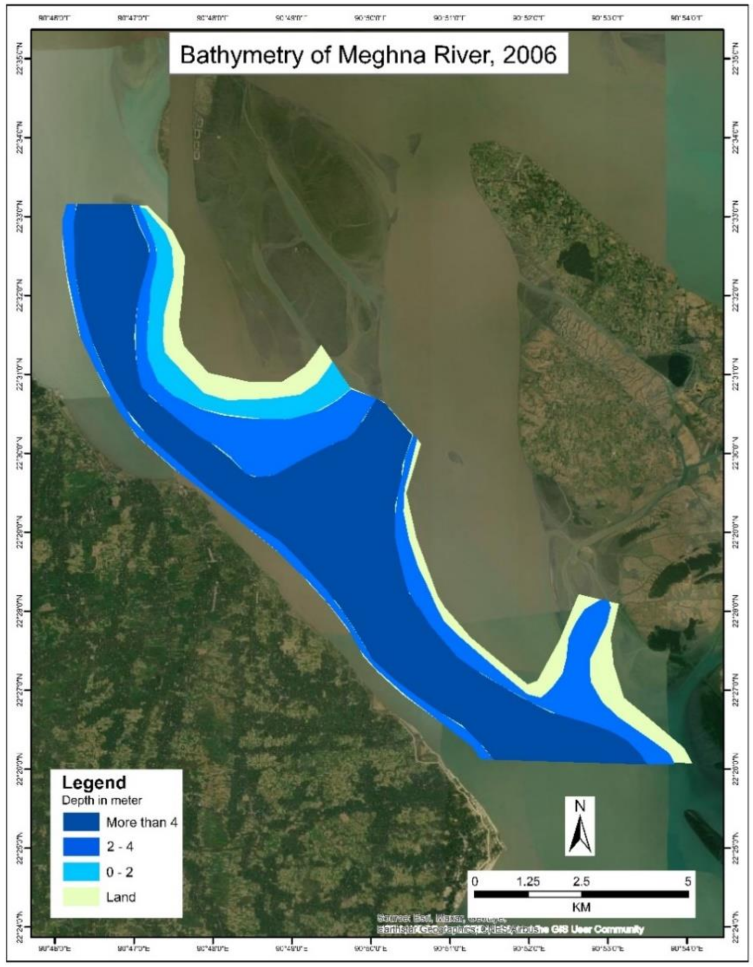


Figure 5.12: Bathymetry Map of Meghna River, 2006

The above map shows the bathymetry of the Meghna River during 2006. The depth of more than 4 meters, which BIWTA defines as the first rank of depth, dominated almost the whole area of the river (Fig 5.12). The comparison of the recent basemap reveals that the riverbed was shorter than it is today. The charland formation was higher in the eastern part of the river.

Changes in 2012:

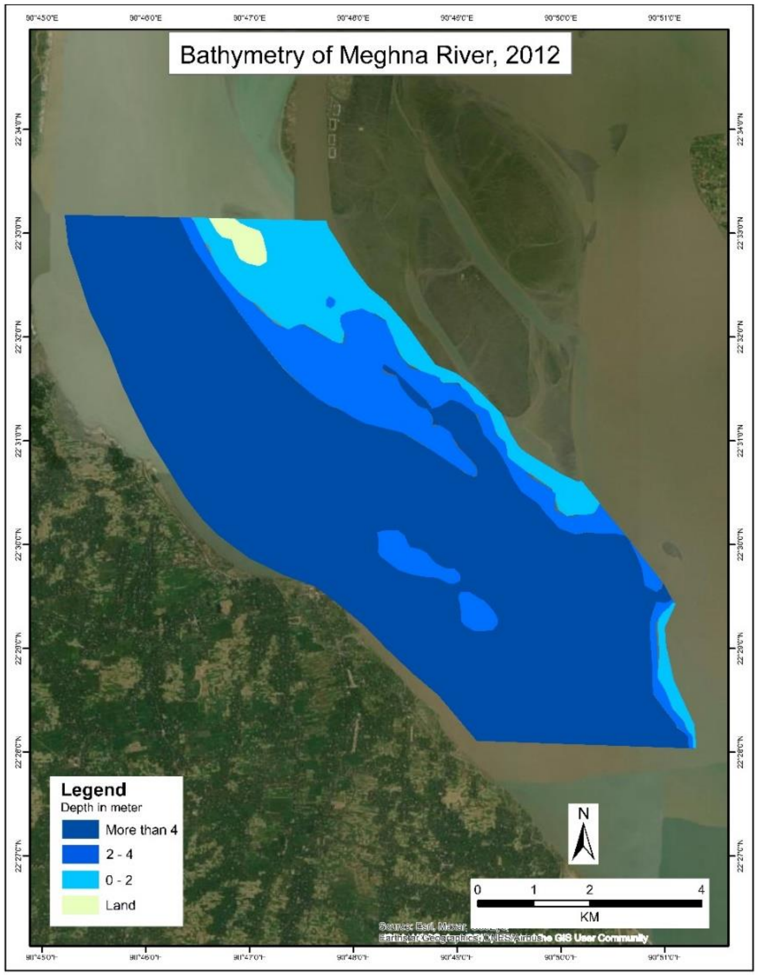


Figure 5.13: Bathymetry Map of Meghna River, 2012

The riverbed increased more than in 2006 during 2012 (Fig 5.13). It shows a much higher riverbed with a little bit of new land. But the basemap shows that the riverbank on the western side again had to erode. The highest depth prevails in all areas of the river. The depth is only slightly less in the eastern part, which represents the irregular pattern of deposition.

Changes in 2021:

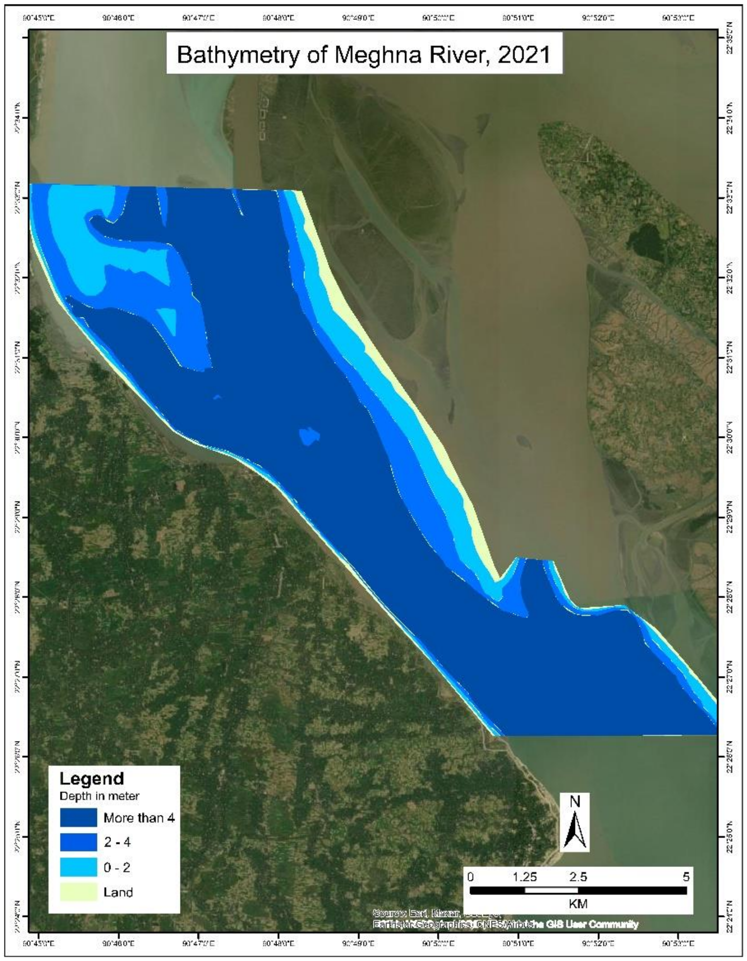


Figure 5.14: Bathymetry Map of Meghna River, 2021

The bathymetry map of 2021 (Fig 5.14) shows that the riverbank has been shifted westward. The basemap represents that the riverbank has moved to the eastern side compared to other years. The riverbed decreased due to the accretion in the eastern portion.

5.4 Physical Changes of Tetulia River

With the changing of bathymetry of river the physical changes of riverbank areas also occur with time. It is necessary to analyse that how much changes have been occurred during this time. The landcover classification of study area can describe the changes of the area over time.

Changes in 2006:

Figure 5.15: Land Cover Map of Tetulia River, 2006

Table 5.1: Total Area of Different Landcover of Tetulia River, 2006

Types	Area sq km	Area Percentage
Vegetation	0.653275	49.04007
Bare Land	0.194229	14.58039
Waterbodies	0.484621	36.37954

To determine the physical changes of the Tetulia River, the landsat image of 2006 is considered the baseline. With this landcover, the changes in river morphology of the Tetulia River will be determined over different years.

The above map (Fig 5.15) shows the landcover of the Tetulia River, and above that, a basemap is added as a reference. From the map, it can be seen that the new landform is occurring all around the river. This time is actually the development stage of Nabir Char.With the reference to the basemap, it can be seen that the riverbed was larger than previous times on the northern and western sides of the river. But the eastern portion was covered by land compared to the present-day basemap.

Changes in 2014:

Figure 5.16: Land Cover Map of Tetulia River, 2014

Table 5.2: Total Area of Different Landcover of Tetulia River, 2014

Types	Area sq km	Area Percentage
Vegetation	0.602353	45.276
Bare Land	0.311404	23.4068
Waterbodies	0.416645	31.3172

The above map (Fig 5.16) shows the landcover of the Tetulia River in 2014. This shows a great change in river area from 2006. The western side of the river turns mostly into charland. The Nabir char developed throughout a large area. The river area changed from 0.48 sq km in 2006 to 0.42 sq km in 2014, whereas the land area increased from 0.19 sq km in 2006 to 0.31 sq km in 2014.

Changes in 2016:

Figure 5.17: Land Cover Map of Tetulia River, 2016

Table 5.3: Total Area of Different Landcover of Tetulia River, 2016

Types	Area sq km	Area Percentage
Vegetation	0.6063	45.46
Bare Land	0.342324	25.6672
Waterbodies	0.385076	28.8728

The above map represents the landcover of the Tetulia River in 2016. There were very few changes from 2014 to 2016 (Fig 5.17). The river area also has a trend of decreasing, and the bare land has been increasing from 2014 to 2016.

Changes in 2018:

Figure 5.18: Land Cover Map of Tetulia River, 2018

Table 5.4: Total area of different landcover of Tetulia River, 2018

Types	Area sq km	Area Peercentage
Vegetation	0.407593	30.61941
Bare Land	0.443283	33.30053
Waterbodies	0.480283	36.08006

The landcover map of 2018 shows that both the bareland and river areas have increased, but the vegetation cover has decreased at this stage. The river area is equal to the area of 2006 (Fig 5.18). The vegetation cover of Nabir Char decreased, and the amount of bare land increased.The southern part of Nabir Char faces erosion.

Changes in 2020:

Figure 5.19: Land Cover Map of Tetulia River, 2020

Table 5.5: Total Area of Different Landcover of Tetulia River, 2020

Types	Area sq km	Area Percentage
Vegetation	0.454985	34.0989
Bare Land	0.574578	43.0618
Waterbodies	0.304746	22.8392

From 2018 to 2020, the river area decreased from 0.48 sq km to 0.30 sq km. This map (Fig 5.19) shows that the development of Nabirchar followed a westerly direction. Here, the vegetation cover started to increase. Riverbed shrank from the eastern part of Nabirchar. The amount of barren land increased because it was contributed from the eastern part of the river, which is the Nazirpur area. In this area, the vegetation cover decreased significantly.

Changes in 2021:

Figure 5.20: Land Cover Map of Tetulia River, 2021

Table 5.6: Total Area of Different Landcover of Tetulia River, 2021

Types	Area sq km	Area Percentage
Vegetation	0.229004	17.1654
Bare Land	0.730082	54.7247
Waterbodies	0.375014	28.1099

The map (Fig 5.20) represents the land cover of the Tetulia River in the year 2021. In the interval of 1 year, the river area increased from 0.3 sq km to 0.37 sq km. The erosion occurred significantly at this time. The vegetation cover of Nabirchar almost disappeared, so the amount of bare land increased significantly.

Changes in 2023:

Figure 5.21: Land Cover Map of Tetulia River, 2023

Table 5.7: Total Area of Different Landcover of Tetulia River, 2023

Types	Area sq km	Area Percentage
Vegetation	0.488666	36.611
Bare Land	0.499009	37.3859
Waterbodies	0.347077	26.0031

The above map (Fig 5.21) shows that the vegetation cover of Nabir Char again increased, but the river area decreased due to the formation of new land.

5.5 Physical changes of Meghna River

Changes in 2006

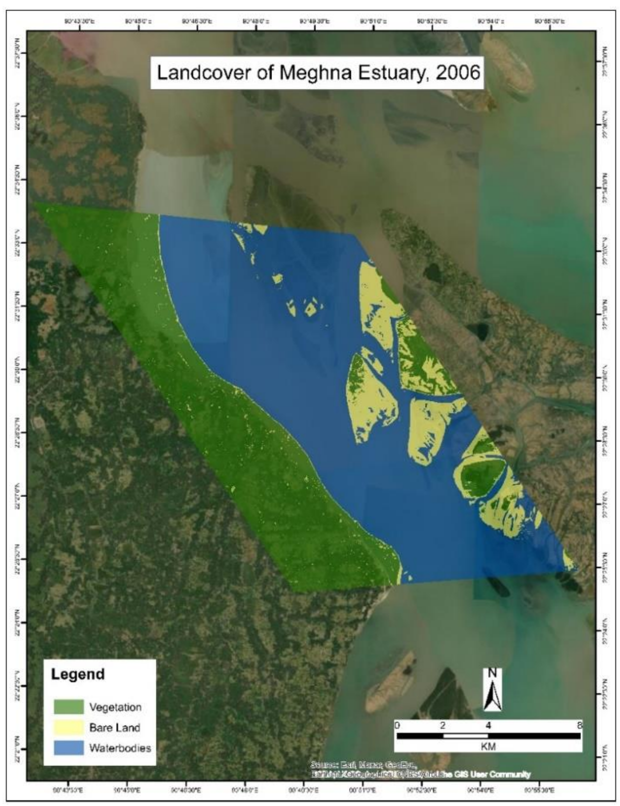


Figure 5.22: Land Cover Map of Meghna River, 2006

Table 5.8: Total Area of Different Landcover of Meghna River, 2006

Types	Area sq km	Area Percentage
Vegetation	73.8884	35.4919
Bare Land	22.11385	10.6223
Waterbodies	112.1813	53.8858

The above map (Fig 5.22) represents the Landcover changes of the part of the Meghna Estuary nearby Bhola district during 2006. To assess the landcover changes in this particular area, the 2006 image is considered a base to determine the actual changes throughout the years.

The landcover classification shows that the river area was 112.18 sq km in 2006.

Changes in 2014:

Figure 5.23: Land Cover Map of Meghna River, 2014

Table 5.9: Total Area of Different Landcover of Meghna River, 2014

Types	Area sq km	Area Percentage
Vegetation	57.79876	27.7623
Bare Land	36.32228	17.4466
Waterbodies	114.0706	54.7911

From the map of 2014 (Fig 5.23), it can be seen that new land areas have been created in the north-eastern and south-eastern directions from 2006 to 2014. Whereas the river area has also increased with the erosion of previous land in the western part of the river. The river area changed from 112.18 sq km in 2006 to 114.07 sq km in 2014.

Changes in 2016:

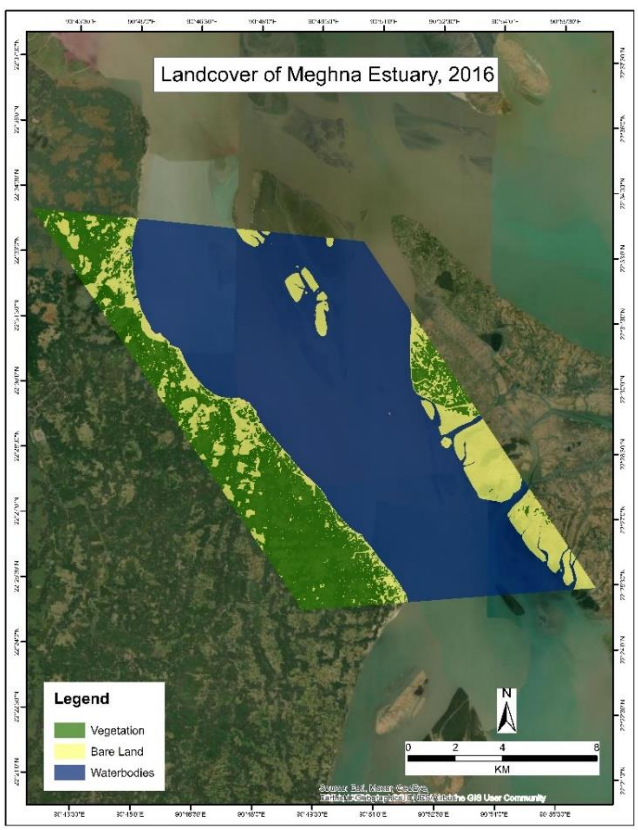


Figure 5.24: Land Cover Map of Meghna River, 2016

Table 5.10: Total Area of Different Landcover of Meghna River, 2016

Types	Area sq km	Area Percentage
Vegetation	46.23532	22.2116
Bare Land	30.74718	14.771
Waterbodies	131.1761	63.0174

The above map of 2016 (Fig 5.24) shows a significant change in land cover in just 2 years. The area faced a huge rate of erosion, causing an increase in river area. The river area increased by about 17.1 sq km from 2014 to 2016, which is huge compared to the changes from 2006 to 2014.From the land use classification data, it can be seen that the river eroded both the existing and new land at this stage.

Changes in 2018:

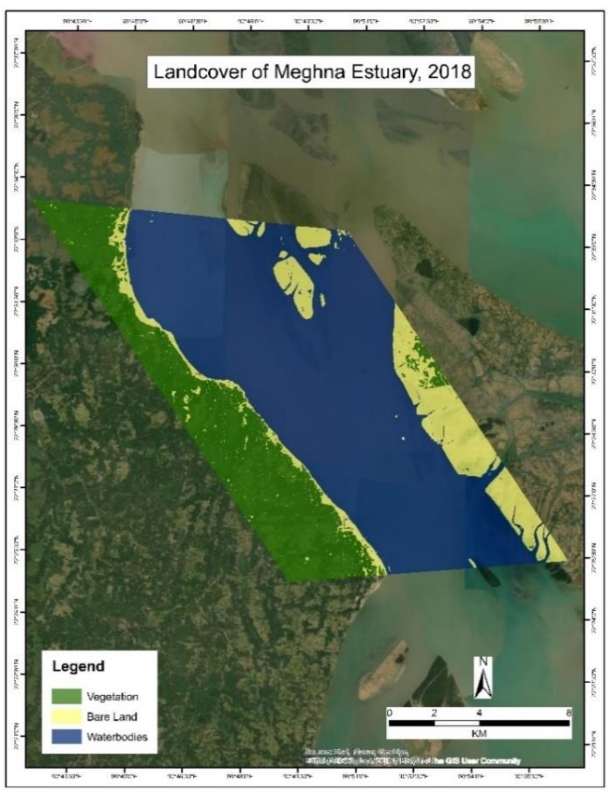


Figure 5.25: Land Cover Map of Meghna River, 2018

Table 5.11: Total Area of Different Landcover of Meghna River, 2018

Types	Area sq km	Area Percentage
Vegetation	51.14101	24.5653
Bare Land	28.5253	13.702
Waterbodies	128.5174	61.7327

The above map (Fig 5.25) represents the morphological features of a part of the Meghna estuary in 2018. It can be seen that the emerging of new charland in the north-eastern part caused a decrease in river area, but the western part faced erosion as well.

Changes in 2020:

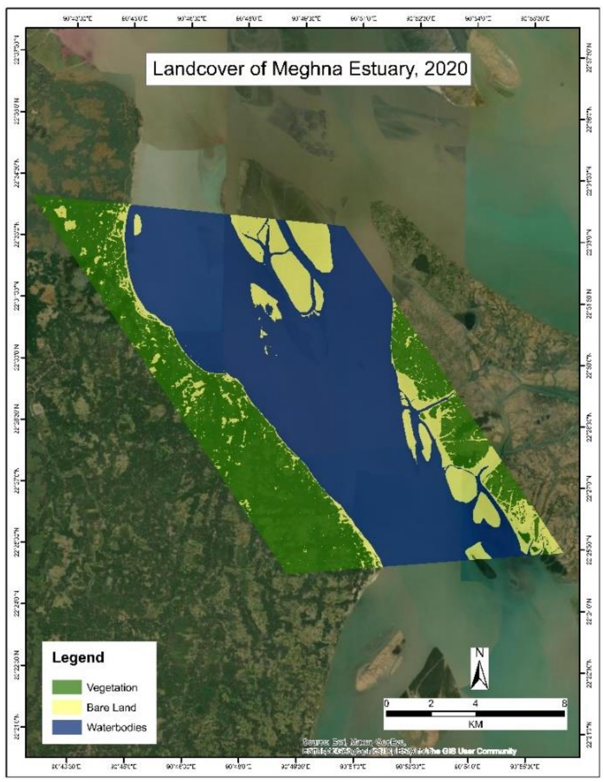


Figure 5.26: Land Cover Map of Meghna River, 2020

Table 5.12: Total Area of Different Landcover of Meghna River, 2020

Types	Area sq km	Area Percentage
Vegetation	62.06149	29.8122
Bare Land	29.31198	14.0805
Waterbodies	116.8013	56.1073

The above map (Fig 5.26) shows the landcover changes of Part of the Meghna Estuary during 2020. The map (Fig 5.26) shows the river area has shrunk due to the accretion of new landforms in the north-east and south-east directions. The area of the western part faces erosion because the riverbed has shifted in this direction.

Changes in 2021:

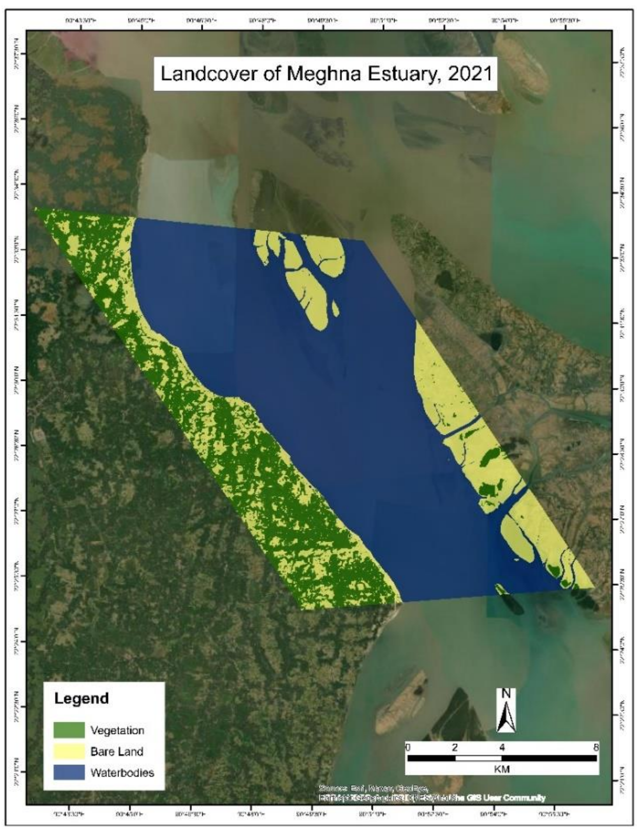


Figure 5.27: Land Cover Map of Meghna River, 2016

Table 5.13: Total Area of Different Landcover of Meghna River, 2016

Types	Area sq km	Area Percentage
Vegetation	38.34915	18.4219
Bare Land	43.28053	20.7908
Waterbodies	126.5419	60.7873

It can be seen that the river area changed from 116 sq km to 126 sq km in just one year. The map of 2021(Fig 5.27) shows the western part of the riverbank turning into a river area. That means it faced a high rate of erosion in just one year.

Changes in 2023:

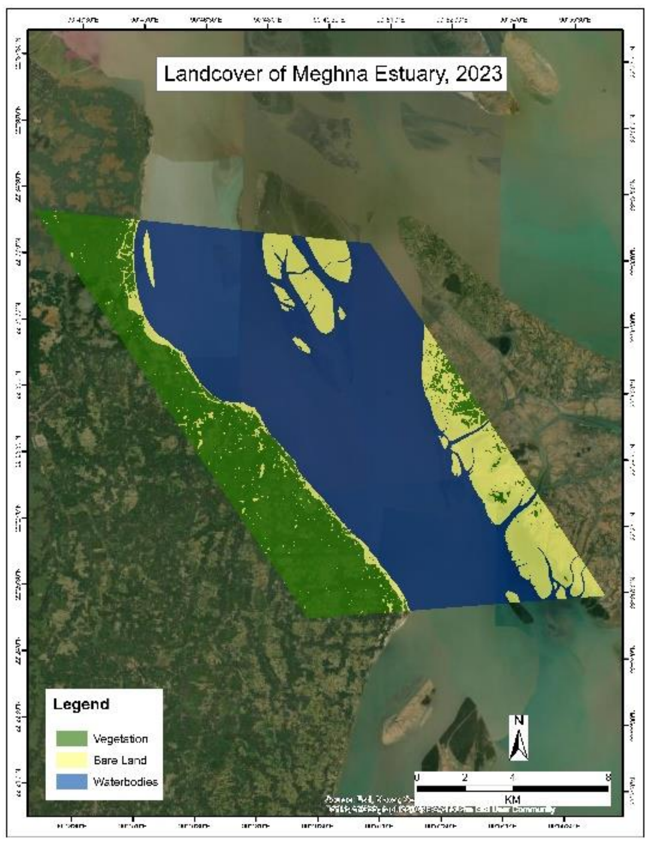


Figure 5.28: Land Cover Map of Meghna River, 2023

Table 5.14: Total Area of Different Landcover of Meghna River, 2023

Types	Area sq km	Area Percentage
Vegetation	52.67758	25.304
Bare Land	34.24069	16.4477
Waterbodies	121.261	58.2483

The above map (Fig 5.28) represents the present scenario of the study area. It shows the land cover of 2023. From this map, it can be seen that the river erosion is basically occurring on the west side of the river, which comprises the area of Tazumuddin and Burhanuddin Upazila. The river area has been shifting from east to west.

Particle size analysis:

A fundamental method utilized in many scientific fields, including physical geography, is particle size analysis. In order to comprehend the physical characteristics of field data, it includes estimating the size distribution of particles in a sample. The collected borehole data from the riverbed and riverbank was use for particle size determination.

Table 5.15: Soil Particle Sizes

Name of soil separate	Diameter limit (mm)
Very coarse sand	2.00-1.00
Coarse sand	1.00-0.5
Medium sand	0.5-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	Less than 0.002

Source: USDA soil classification system

5.6 Sediment Properties of Riverbank: Tetulia River

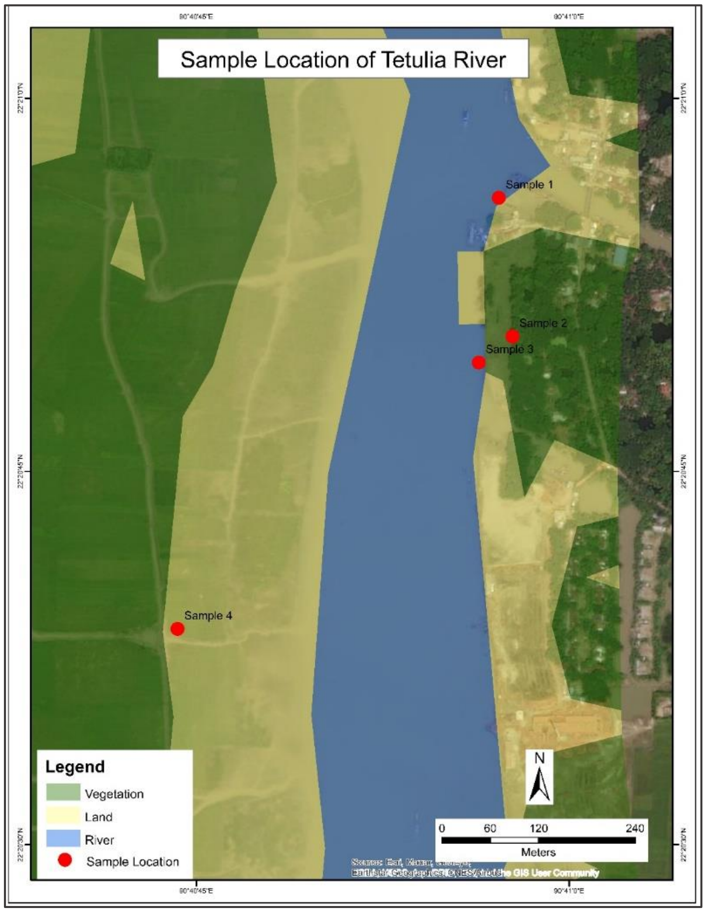
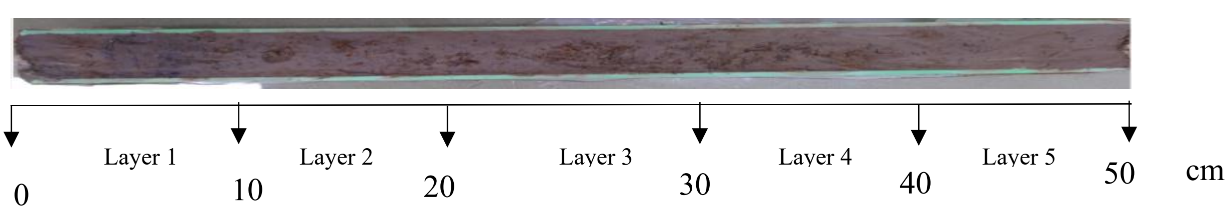


Figure 5.29: Borehole Sample Location of Tetulia River, 2023

Sample from Tetulia river was collected from the riverbed and riverbank near Nazirpur launch ghat and Nabirchar (Fig 5.29). The map shows the sample location of Tetulia River.

From the particle size, the particle size distribution curve has been prepared using ggplot2 in R studio. The graphs shows that the sediment is mostly shorter in diameter, that means the soil sample consists of fine particles.



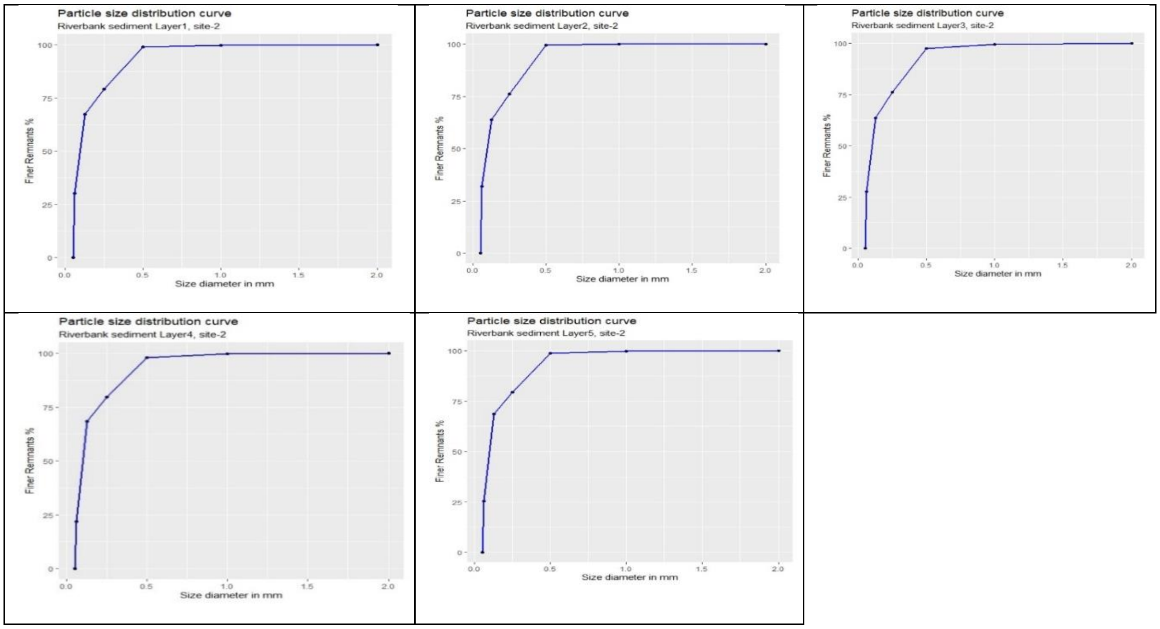
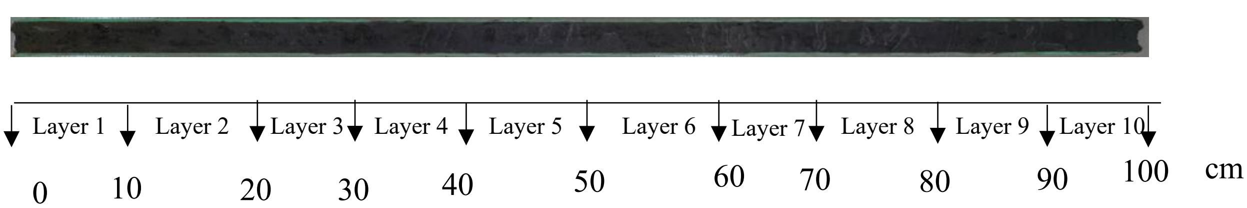


Figure 5.30: Particle Size Distribution Curve for Riverbank Sediment of Tetulia River

The x axis of the graphs represents the particle size and y axis represents the amount of passing the particlesThe sieve 1-3 shows almost all the sediments pass through it. On the other hand, the sieve with diameter 0.125 mm to less than 0.0063mm passes the less sample. The 5 layers of Riverbank borehole sediment Tetulia river shows almost same type of characteristics. That means the particle is comprised mostly very fine sand to silt and little amount of clay.

5.7 Sediment Properties of Riverbed: Tetulia River

The graphs of riverbed sediments of Nazirpur of 10 different boreholes layer shows a variation among the particle size among the layer unlike the riverbank sediment. Layer 1 shows almost uniform distribution of particles from 0.5 to less than 0.063mm sized particles. The uniform distribution of particles decreased gradually from layer 3 to10. From layer 3 the dominated particles are silt and clay.



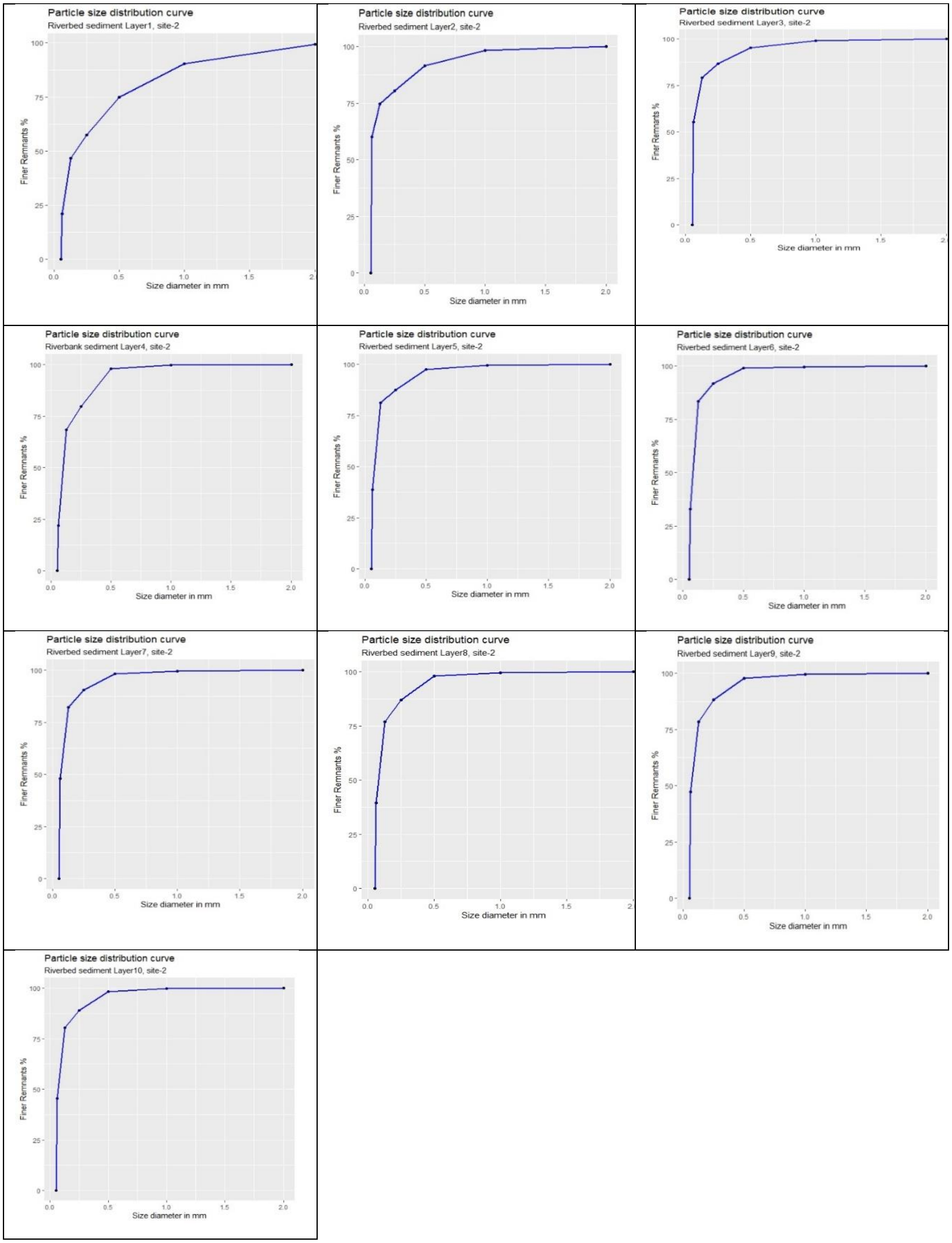


Figure 5.31: Particle Size Distribution Curve for Riverbed Sediment of Tetulia River

5.8 Sediment Properties of Riverbank: Meghna River

Borehole sample was collected from the Riverbed and Riverbank area in the southern portion of Mirza Kalu launch ghat (Fig 5.32). Near Mirza Khalu launch ghat around 1 km area is protected by polder.

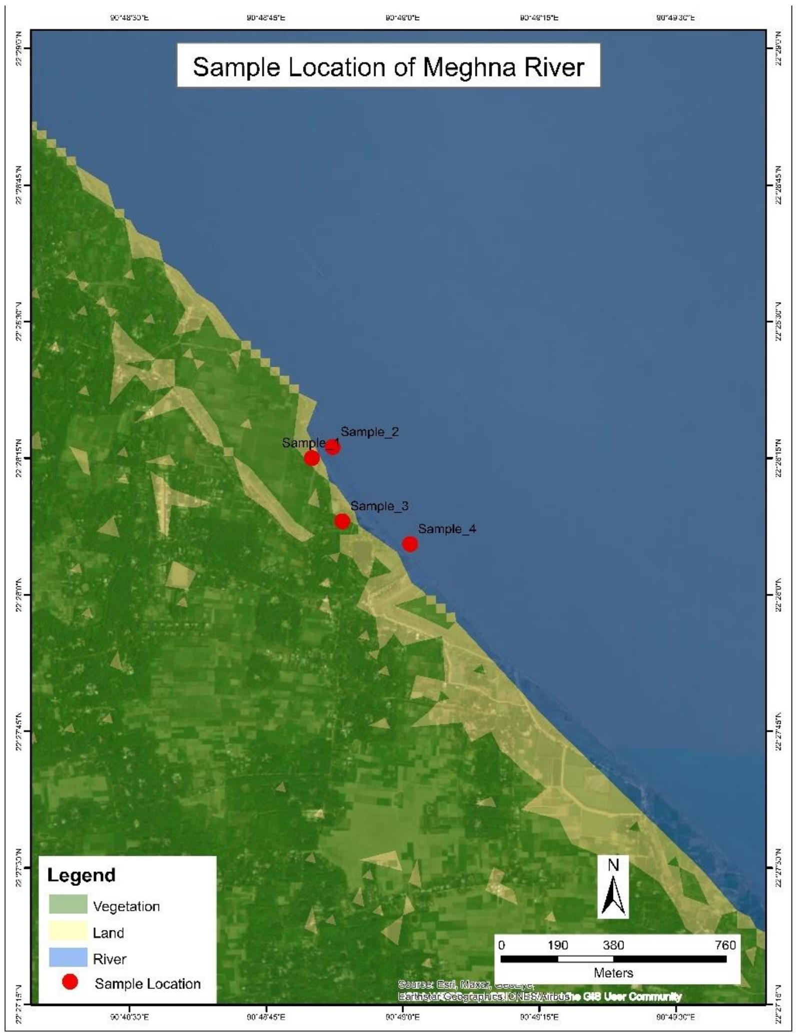
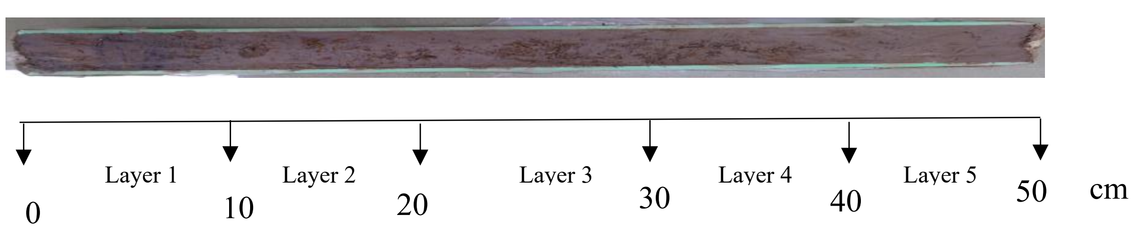


Figure 5.32: Borehole Sample Location of Meghna River, 2023

Paricle size distribution curve of Meghna river are in the following:The graph of particle size distribution of Meghna riverbank shows that in Layer 1 the silt and clay particle is dominating. Other layer shows the particle is ranging from very fine sand to silt and clay.



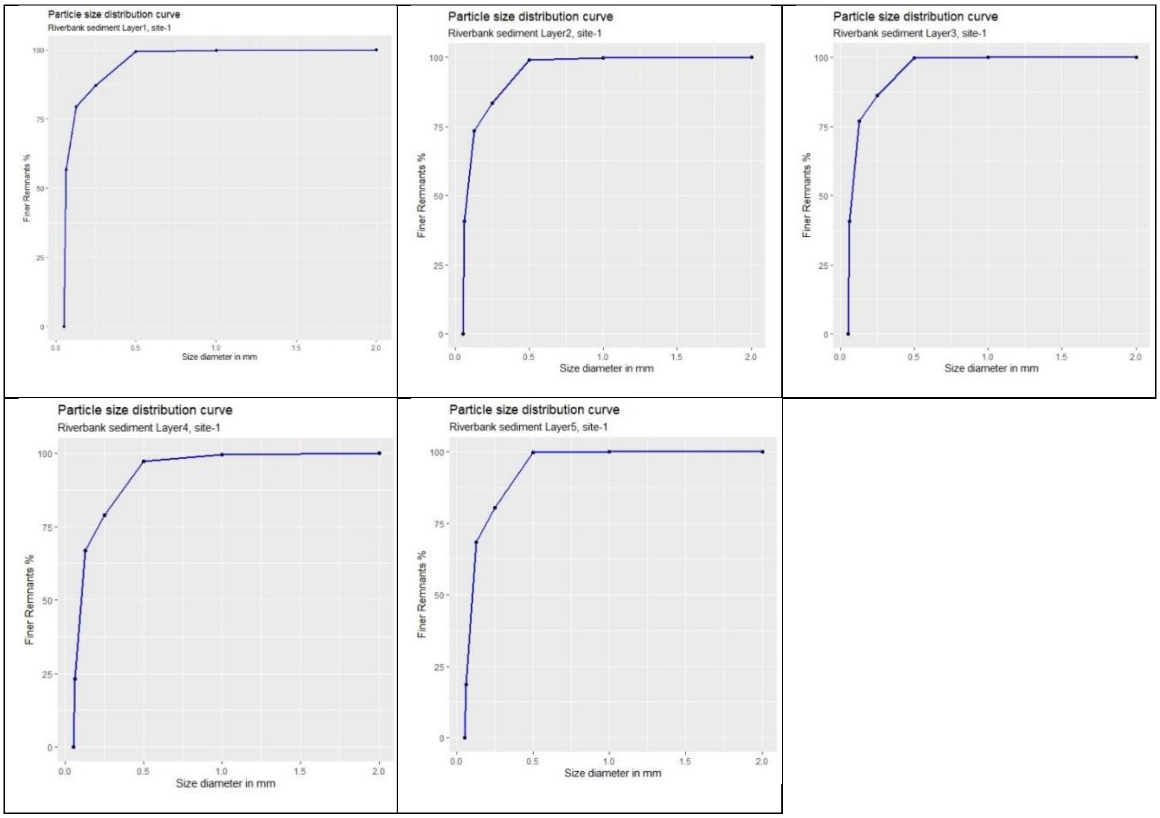
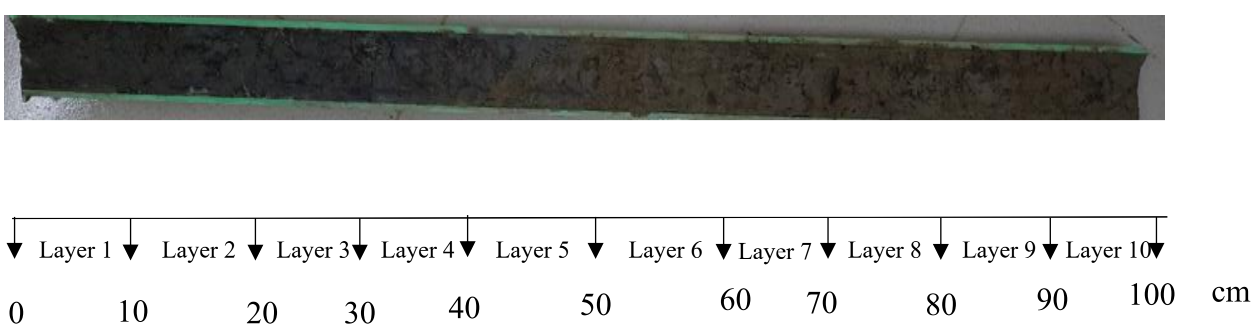


Figure 5.33: Particle Size Distribution Curve for Riverbank Sediment of Meghna River

5.9 Sediment Properties of Riverbed: Meghna River

In layer 1 and 2 the dominated particles is fine sand to very fine sand, whereas in layer 3-5 the sit and clay particles is dominating. Layer 6 and 7 containing the silt and clay particles mostly. Layer 8 consist of medium sand in greater proportion. The layer 9 is mostly consists of very fine sand whereas the layer 10 is highly aggregated with silt and clay particles.



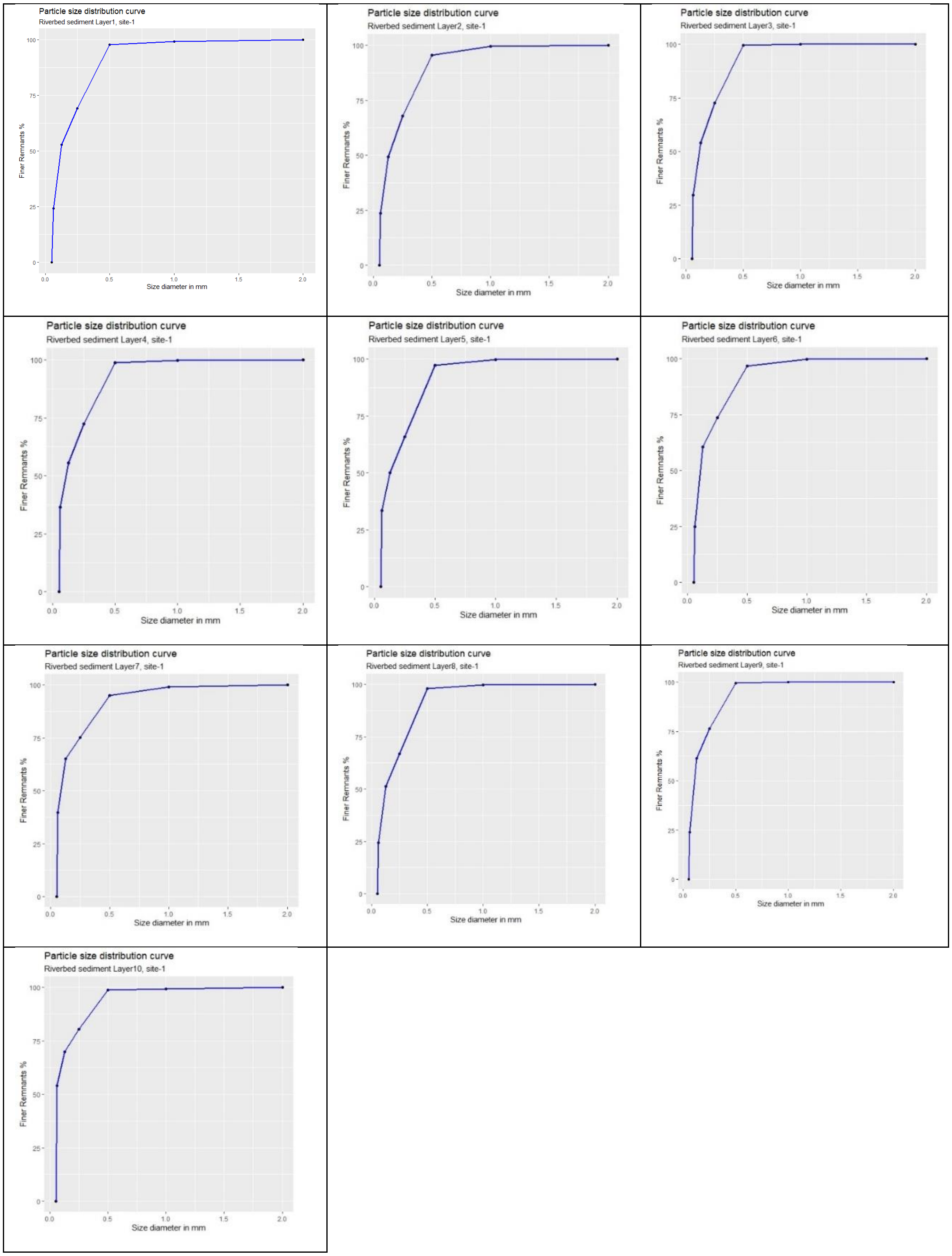


Figure 5.34: Particle Size Distribution Curve for Riverbed Sediment of Meghna River

5.10 Peoples' Perception About Sand Mining: Case of Tetulia River

A project to construct a park on the northern part of Nabir Char is going on. For these purposes, the current sand mining is occurring for the landfilling of this area. The local people said that the sand mining in that area was causing the erosion of other parts of Nabir Char as well as the riverbed of Tetulia near the launch ghat. The area was once the same level as other parts of the castle. For this project, the dam construction all around the area caused the river bathymetry to change because the soil for the dam was collected from the riverbed. The filling of this particular area required a large amount of sand that was mined from the Tetulia River. The height of the newly filled landform is about 3 meters above the associated land. And the area is about 0.5*0.5 sq km.

It is also planned that the launch ghat will be shifted in this char, and it will be connected to the main bazaar of Nazirpur. That means there will be more extraction of sand in the future.

Local people said that before the beginning of the project, the total area of char land was much bigger, and the erosion rate of nearby areas was also lower. At the beginning of the project, the unplanned mining of riverbed sand caused a higher rate of erosion in Nabir Char and associated areas.Though local people are aware of the consequences of unplanned sand mining, due to local political issues, they remain quite against it. Nabir Char is free from human settlement now, but it is a great place for cattle grassing. The local people keep their cattle in this char before the high tide. As high tide began to begin, the cattle moved to the main land. The loss of land in Nabirchar already has an impact on local cattle grassing. People are afraid that if the erosion of the lower part of Nabir Char continues to occur, it will cause all the land to disappear. The southern area of Launch Ghat, which is locally known as Chairman Bari and Molla Bari, is also facing erosion now. The residents of these areas are to lose their land very soon as this process continues.

5.11 Peoples' Perception About Sand Mining: Case of Meghna River

The people living next to Meghna always face erosion in their lifetime. But according to them, the rate of erosion is much higher than in previous decades. They said the higher rate of erosion is due to the unplanned sand mining from the Meghna River bed. The actual amount is unknown to them because all the processes of sand mining are controlled by local power companies. So, the local people had to remain quiet.

One of the respondents, who is 55 years old, said almost all of the inhabitants near the Meghna River in that area have lost their land and houses more than seven times. All the people who lost land had to migrate to the upper area or any other administrative region. Due to the sudden and unexpected rate of erosion, they lost their agricultural land and houses all of a sudden, without any scope to do any planning. As the people had to move occasionally because of the erosion, they could not afford to buy any new land. Rather, they had to stay on Khas land.

Another respondent, 25 years old, said that during his lifetime he lost eight times the value of his household due to erosion. He is a fisherman by profession. Before the erosion, his family had a good amount of agricultural land near the riverbank. But this erosion took away all their land. Their socioeconomic condition got worse day by day with the erosion.

People who have good financial conditions can move to another Upazilas after buying new land. But the people who do not have access to a good livelihood in this area anymore had to move to urban areas as slum dwellers.The people of this area said that unplanned sand mining is the only cause of the extensive rate of erosion these days.

Though they are well aware of the effects of unplanned sand mining on erosion patterns and their livelihood patterns, they are helpless in front of the power holders. All the processes of sand mining were controlled by local power holders.

But soon after the erosion started at a higher rate, the government took action to stop the sand mining in a portion of the Meghna River. The area nearby Tazumuddin Launch Ghat started to face a lot of erosion soon after the sand mining. Though the sand mining activities have been stopped currently in this area, the changing bathymetry of the riverbed is causing continuous erosion. The people of this area said that unplanned sand mining is the only cause of the extensive rate of erosion these days. Though they are well aware of the effects of unplanned sand mining on erosion patterns and their livelihood patterns, they are helpless in front of the power holders. All the processes of sand mining were controlled by local power holders.

Though some of the site has been banned for sand mining recently, according to locals, the mining operation in other areas of Meghna is still occurring. Due to the bathymetry changes, during high tide the water enters more inland areas and, with greater intensity, causes erosion in areas that are free from permanent water cover. The households nearby the Mirza Kalu Launch Ghat Bazaar area are facing erosion now, though this area is free from permanent water cover and only has water during high tide. The people of this area said that unplanned sand mining is the only cause of the extensive rate of erosion these days. Though they are well aware of the effects of unplanned sand mining on erosion patterns and their livelihood patterns, they are helpless in front of the power holders. All the processes of sand mining were controlled by local power holders.

Another respondent, 27 years old, who is a caretaker of a residential hotel near Mirza Kali Launch Ghat, said he also lost his household due to erosion and moved to this upazila for better livelihood. He has been staying in this area for five years. Since then, he has also faced a lot of changes in the riverbed. The location of the riverbank has been shifted in just 5 years.

5.12 Conclusion

The chapter is the representation of all the data including the primary and secondary. This chapter presents all the data of the research. Using the data, the maps and graphs are presented here. This chapter will give a quick review regarding the processing of all the data.

Chapter-6: Results and Discussion

6.1 Causes of Sand Mining

Sand is called raw gold, as this natural resource does not need to go through any processing. In 2022, urban population for Bangladesh was **39.7 %**. Urban population of Bangladesh increased from 8.6 % in 1973 to 39.7 % in 2022 growing at an average annual rate of 3.21% (knoema, 2023). Due to this rapid urbanization, it needs a lot of sand for construction and land filling. In the Meghna basin, the deposit of thin sand is found to be higher than that of thick sand (Bari and Haque, 2022). The lab analysis of mined sand also showed that the sediment was finer in the Meghna River.

The following chart of the particle size distribution curve shows that the sand sample contributed about 80% of the total sample(Fig 6.1). So, this sand is good for land filling because it holds more moisture, and the compaction is good. So, this type of sand is good for land filling.

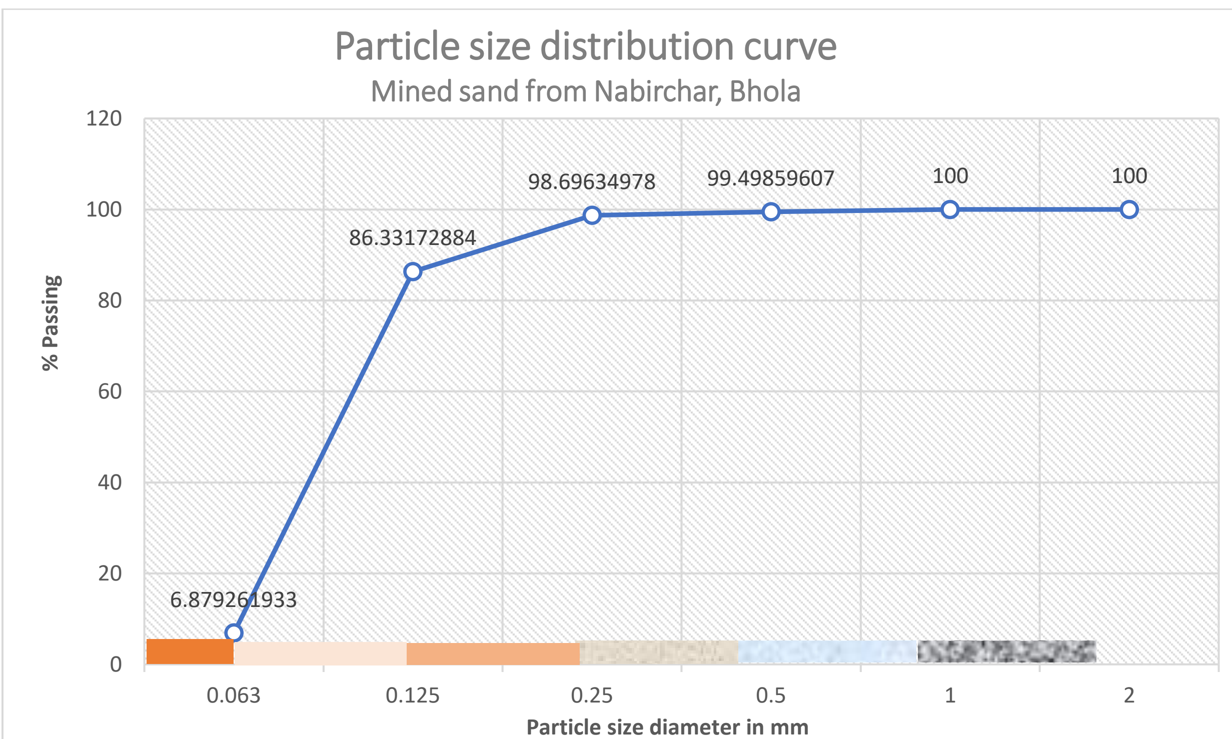


Figure 6.1: Particle Size Distribution Curve of Mined Sand, Tetulia river

According to estimates, 60–70% of the nation's mined sand is collected illegally from rivers around the country without taking any environmental or hydrological considerations. (Siddique, 2022)

According to several national news reports, Meghna is subject to a great deal of sand extraction by local leaders. Despite being against the law, they can still happen because of political influence. Although the precise amount of sand extracted is unknown from this study, a different study by Bari and Haque (2022) suggests that only one site of the Meghna basin may be able to collect roughly 3.7 million cft of sand per day. Locals claimed that the supply is limitless. The sand is extracted illegally from the Meghna River. According to local administrations, there is no legal permission for sand mining. In 2021, The administration body of Bhola took action against the authority of illegal sand mining. But all the laws and actions are typically ignored by local powerholders. According to a news report published in June 2023 by Dainik Janakantha, sand extraction has been going on in Lalmohon Upazila, Bhola, for the past six months. Local officials and their family are in control of all of these unlawful activities. According to this news article, the approximate volume of Balu Mahal at the Mangal Sikder Launch Ghat area would be more than a few thousand cubic feet. Some of the primary reasons for sand mining activities include a lack of oversight of sand extractions, breaking the law, and mainly the enormous demand for sand.

6.2 Morphological Impact

The river morphology is changing due to sand mining without any consideration. A huge amount of sand is extracted regularly from the river bed. A sudden change in the depth of the riverbed changes the bathymetry of the river. It increases the depth, causing changes in river flow, water discharge, and the deposition of sediment. With this unusual depth and water flow, the riverbank gets eroded into the river bed. On the other hand, the other portion of the river gets much sedimentation, which causes the formation of new char land in other areas. Thus, it caused the shifting of the riverbank.

6.2.1 Tetulia River

This study focused on the Two Rivers area of Bhola district. The study result for the Tetulia River shows less erosion than the Meghna. The sand mining project in the Tetulia River started recently, as per the information. A new project in Nabirchar that was started in late 2022 caused the extraction of sand for this project.

The river area is also much smaller than the Meghna River, and the flow is also lower there. The highest depth of the Tetulia River channel is about 5 meters.The linear distance in the east-west direction from Nazirpur Launch Ghat to Nabir Char is only about 157m.

Though the intensity of sand extractions and erosion was lower at that moment, the local people said that after the Nabir Char project they faced more erosion than before.

The bathymetry data also showed that the depth of the Tetulia River varied over time. The depth of the river near the Launch Ghat area decreased due to sedimentation. But all the time it shows a similar pattern, which means it faces less human intervention according to the available data from the bathymetry.

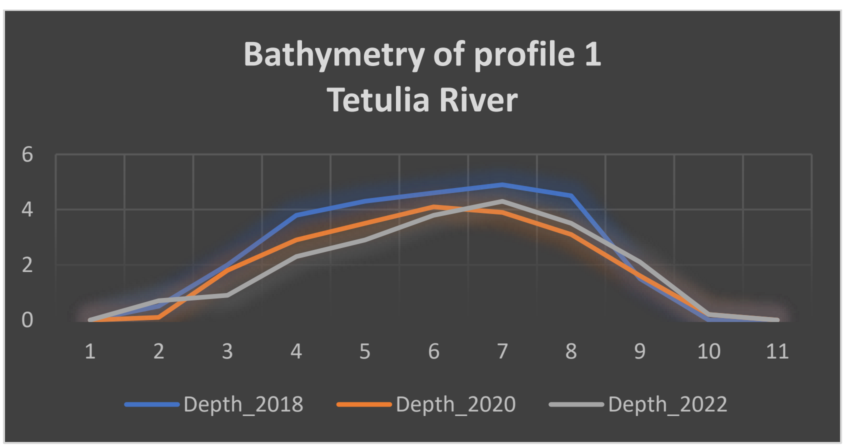


Figure 6.2: Bathymetry Profile of Tetulia River

The following map shows that the river area decreases and the land area increases from 2006 to 2023 (Fig 6.3).

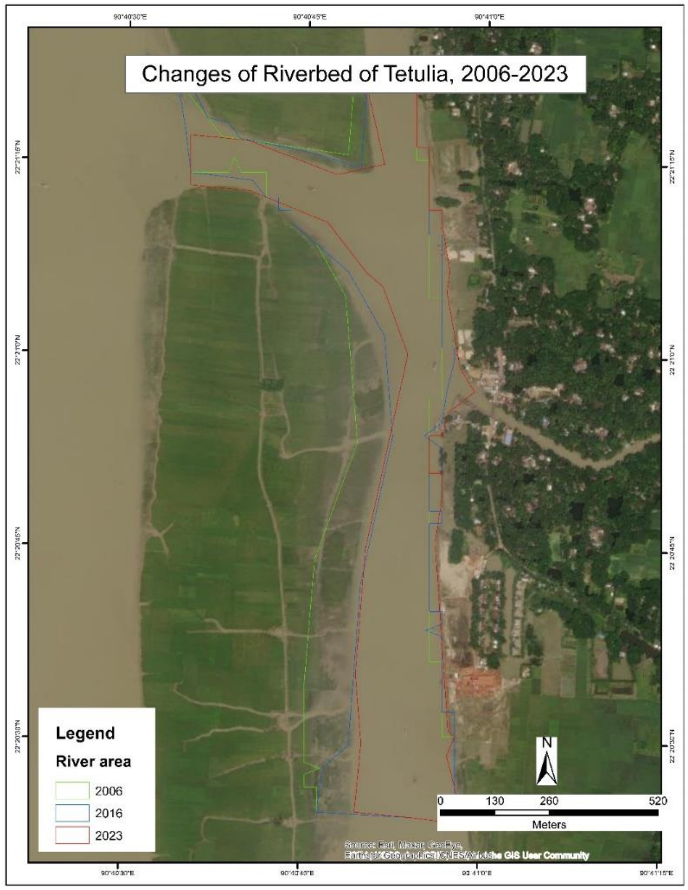


Figure 6.3: Changing Riverbed of Tetulia River

As this area has faced sand mining and erosion in recent years, further investigation on this site can reveal the actual impact of sand mining on bathymetry changes in this area.

6.2.2 Meghna River

Meghna is one of the Mighty rivers of Bangladesh. The river is very dynamic by nature. The depth of this river at some points is more than 30 meters in the study area. The minimum linear distance in the east-west direction from one side of the river to another side of the river is about 6km. The wider and deeper characteristics of this river have a great impact on the riverbank people. According to various news reports, literature, and perceptions of local people, the morphology of this river is changing rapidly due to excessive sand mining, which is illegal. From the available bathymetry data, it can be seen that during 2006, the pattern of bathymetry was in regular form, which means the natural erosion and sedimentation of the riverbed in that area. But 2012 and 2021 show an irregular pattern of river bathymetry (Fig 6.4). It seems there are a lot of human interventions that change the pattern of bathymetry drastically at some points of the river. According to the data, the rate of riverbed extension from 2006 to 2014 was 0.21 percent per year, which indicates a decreased rate of erosion of the riverbed. But from 2014 to 2016, it began to rise. The rate at the time was 7.45% annually. However, from 2020 to 2021, the river bed significantly increased. The rate of riverbed expansion at that time was 8.37% annually.

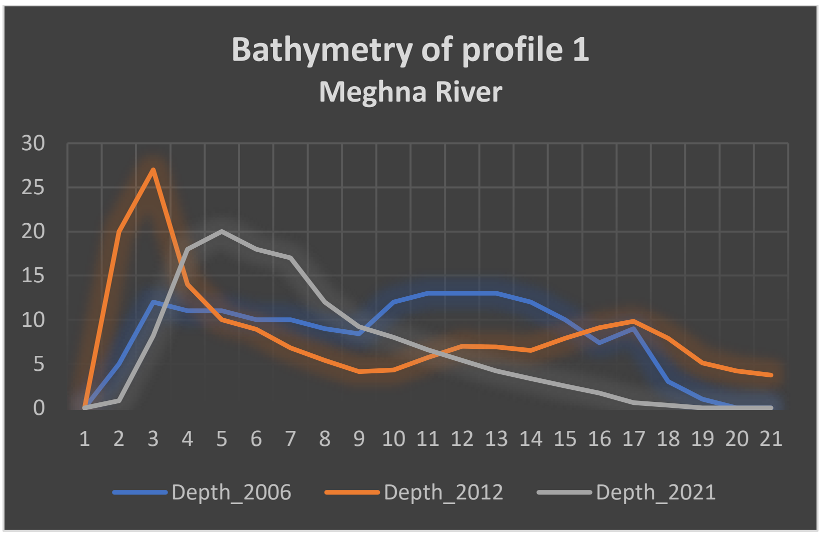


Figure 6.4: Bathymetry Profile of Meghna River

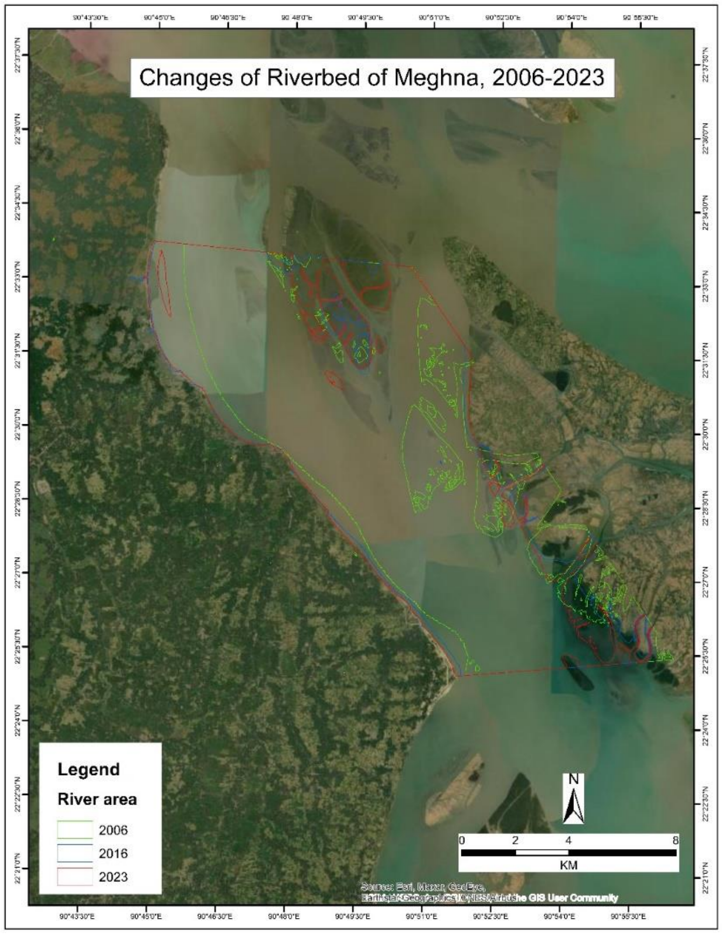


Figure 6.5: Changing Bathymetry of Meghna Riverbed

From the above map, it can be seen that the riverbank of Meghna has shifted from 2006 to 2023. The riverbank was more on the western side, and new charland was also visible on the map during 2006 (Fig 6.5). Whereas the riverbank eroded from the western side and also the new land on the eastern side in later years. During 2016 and 2021, new land will form on the north-eastern side of the river and be eroded in the western direction (Fig 6.5).

6.3 Ecology and Environmental Impact

The changing nature of the riverbed has a profound effect on the ecology and environment of the area. The erosion causes the loss of vegetation cover in the riverbank area, causing great ecological damage and degrading the environment.

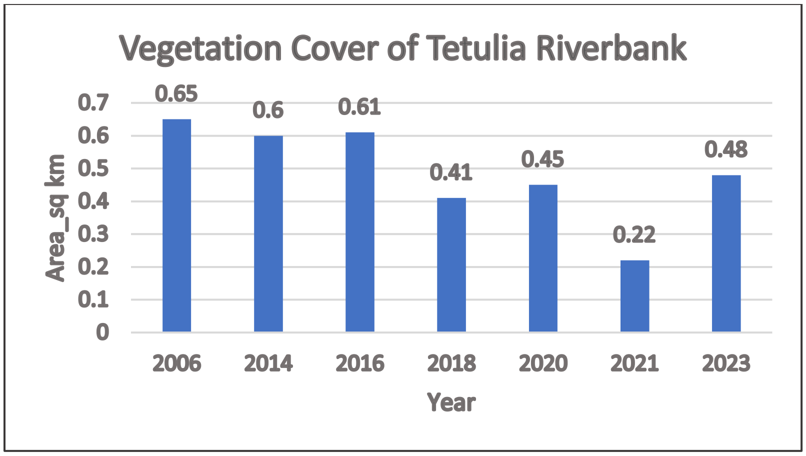


Figure 6.6: Vegetation Cover of Tetulia Riverbank

The graph of vegetation cover along the Tetulia Riverbank shows slight changes in vegetation cover in that area from 2006 to 2023(Fig 6.6) . But the new project on Nabirchar may change this scenario rapidly. Already, most of the area of Nabirchar has lost its natural vegetation cover due to landfilling. The local people said that the area, which is grassland for the cattle, may not be able to remain the same due to the development of a new project on this site.

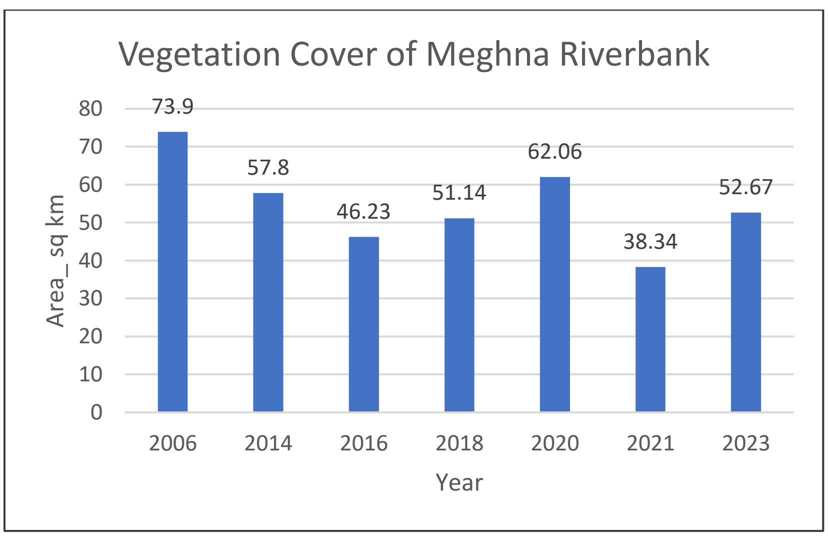


Figure 6.7: vegetation Cover of Meghna Riverbank

On the other hand, the graph of vegetation cover of the Meghna riverbank(Fig 6.7) shows that the riverbank lost about 21.23 sq km, which is 28.73% of vegetation cover, from 2006 to 2023, and most of these losses are because of riverbank erosion. According to the local people, the fish species in the Meghna River have also decreased. The heavy instrument that is used for sand extraction causes the loss of the organisms' natural ecosystems. The Balu Mahal (where the sand is aggregated for transport) causes the loss of vegetation or agricultural area. The local people of Mirzakalu said that during the sand extraction, a huge amount of land near Riverbank was occupied by the sand. This area was used for agriculture. It destroyed the natural environment in that area.

6.4 Socioeconomic Impact

Sand mining, whether legal or illegal, is closely related to the socioeconomic standing of the community. Numerous academics believe that sand mining operations can provide marginalized locals with economic prospects, however in Bangladesh, the situation is entirely the contrary. The local power brokers in this area are the ones that benefit the most from sand extraction. There is statistical evidence, according to a study by Bari and Haque from 2022, that local communities did not see any improvement or diversification in their economic situation, nor did they see any jobs being created or income being generated (Bari and Haque, 2022). This scenario is for legal sand mining issues; if there are illegal issues, the scenario can easily be assumed. This type of illegal sand mining can cause social conflict. About 90% of locals in the Brahmaputra basin reported that sand mining activities led to noticeably more social disputes (such as instances of verbal threats, physical altercations, etc.) among supply chain participants (Haque and Bari, 2022). River erosion causes the loss of agricultural land and households of local people, which creates more homeless people. These people, losing their livelihoods, migrate to different urban areas, especially slum areas, which eventually make them burdens for the urban areas. The people who stay there have to find a new place to live. Building a new home, finding a new job, or finding a new livelihood means making their lives miserable. The result of this study finds that the displaced people live worse than before. According to a report by the Daily Star, 2021, because of sand extraction in Bhola, the Meghna River has seen massive damage, displacing at least 20,000 people (Abbas, 2021). The overuse of sand is causing this situation to become more prevalent day by day.

6.5 Sand Mining and Policy Issues in Bangladesh

The entire sand mining is supposed to be regulated by law. Illegal sand mining is an offence under the Sand Quarry and Soil Management Act, 2010. According to the law, the government forbade sand quarrying within a kilometer of key buildings like bridges, culverts, dams, barrages, embankments, highways, rail tracks, and residential areas. For the purpose of sand mining, a specific miner is given access to a certain section of the river. However, what actually occurs is that they frequently go well beyond the area that has been leased out and take sand from areas of the river that have not been leased out. According to a report by Dhaka Tribune, this law forbids the lifting of sand without the appropriate authorization. It's shocking to learn that there is so little local oversight. As a result, unrestricted sand mining is having a negative impact on the entire river environment (Akhter, 2022). The government of Bangladesh permits legal sand mining largely to enhance river water navigation rather than to earn income, according to the Balu Mohal O Mati Babosthapona Bidhimala, 2011 (Ministry of Land 2011). In actuality, however, the goal of permitting sand mining at river basins can go beyond enhancing water transportation. One could argue that the goal of sand mining operations may be multifaceted since "Jalmohol Babosthapotha Niteemala 2009" (Water Bodies Management Policy 2009) essentially talks about "efficient management of water bodies to benefit the poor fishermen and women for the improvement of income generation and livelihood." (Ministry of Land 2009). Deciphering the sand mining supply chain in the various river basins of Bangladesh is crucial for policymakers given the texts under the 2009 Policy and 2010 Act for the following reasons: Understanding the value addition at each supply chain segment, identifying the actors involved and their roles in the process, and understanding the involvement of local communities in the sand mining supply chain (company) are all important (Bari and Haque, 2022). The most crucial legal tenet was that sediments taken from riverbeds are public property. On the basis of this premise, the BWDB rule was developed. But the study by khan and Sugie, 2015 explored that In the context of this study, neither the legislation nor the BWDB rule on the extraction of sediments were adhered (Khan and Sugie, 2015).

Chapter-7: Conclusions

7.1 Summary

The study is an evaluation of river bathymetry changes due to human interventions and its impact on local community. The data and analysis of this study suggest that there is direct link between river bathymetry changes and riverbank erosion. The changes of bathymetry occurred due the excessive sand mining from the riverbed. This practice changes the riverbed suddenly and in an unusual way. To compensate the deficiency of the sediment in riverbed the sediment from river bank eroded. Another situation creates when the flow of river changes due the misbalancing the depth of river. The erosion rate is increasing day by day in Meghna riverbank because of illegal sand mining of river bed.

Though local communities are aware of the impact of illegal sand mining but they area less likely to protest the situation against the authority of sand mining as this process all over Bangladesh mostly controlled by local political power holder. They simply can ignore the act and law. The comparative analysis of the two riverbeds shows relatively different situation from each other. As sand mining activities in Meghna River bed is much higher than Tetulia river in terms of both duration and amount.

7.2 Major Findings

The study focusing on sand mining and coastal morphology changes finds some relevant findings. It reveals how the sand mining is changing the river bathymetry changes and how this impacted the livelihood of local people. Here are some of the major findings of the study.

- River bathymetry changes due to sand mining: The study result shows that the excessive sand mining causes the river bathymetry changes. Due to the sand mining from riverbed the sediment from riverbed displaced and the dept of certain point get increases. To compensate the deficiency of that area the sediment from other part especially near riverbed washed away. This cause the erosion in riverbed.
- Most of the sand mining in Bangladesh is illegal: After reviewing the different literature and newspaper article it could be concluded that most of the sand mining of Bangladesh occurring illegally. There are strict laws regulations related sand

mining in developed country. Despite having proper laws in Bangladesh there are little or no implementation of law.

- There is no legal permit to extract sand in the Meghna River, even though the extraction process is going on: The local authority of Bhola confirm that there is no legal permit of sand mining from Meghna at that time. But the scenario in field level is very different. Sand mining from Meghna riverbed occurring regularly without any local permit.
- In the Meghna River basin in the study area, the highest rate of riverbed expansion was in 2021. This year, the rate of riverbed expansion was 8.37% per year. That means a higher rate of erosion. The bathymetry data of Meghna river showed the pattern of bathymetry is different during 2020. This indicates the human intervention particularly sand mining of that area. Due to the sand mining and bathymetry differences the statistics of erosion show the highest at rate.
- The erosion is lower on the Tetulia river bank as sand mining has recently occurred in this area: Comparative to Meghna river the area of Tetulia river is very short. The flow velocity and depth both is lower in Tetulia river. Sand mining is also occurring recently in that area, that’s why the erosion is still in lower in rate.
- The erosion in the Meghna River is occurring greatly in the westward direction near Tazumuddin and Hakimuddin launch ghat areas: The erosion is significance in nearby launch ghat area. Due to the higher flow velocity and excessive erosion nearby the areas, it faces a higher rate of erosion every year now a days
- The erosion in the Tetulia River is higher in the northern part of Nabirchar, where a new project is going on: Due to this new project the human intervention has been increased in that area causing the erosion increasing the northern part of that char rather than near local areas.
- Though sand mining activities in study area is illegal, the actual amount of sand is unknown.

7.3 Recommendations

- The law should be properly implemented at the field level. Should take immediate action against illegal sand mining.
- A local-level monitoring system should be developed to properly monitor the amount of extracted sand where there is a legal permit.
- The fine should be applied if any illegal sand mining occurs.
- The local people who have suffered due to the sand extraction process should take measures to provide the financial benefits.
- Proper relief should be provided to the displaced people.

7.4 Conclusions

Due to the paucity of studies on the subject, it is unclear how sand mining affects the geomorphology of different regions. This study is a pioneering attempt to link sand mining activities and changes in river bathymetry. This study also makes an effort to explore the relationship between riverbank erosion and changes in bathymetry. All of these variables have a significant impact on human livelihood, which is under-addressed in Bangladesh. Numerous news websites routinely published articles about this subject, but it is still an issue today. Finding the true situation with regard to the quantity of collected sand is difficult and virtually impossible. Since most sand mining sites are illegal, it was impossible to determine the precise quantity. However, the amount might be guessed from the secondary literature. There are various restrictions on physical environment research. For the researchers, it presents numerous difficulties and barriers. It is thought that there were additional difficulties because this study is focused on illegal sand mining issues. Finding reliable secondary information was difficult because not much information about river bathymetry for all years and regions is readily available. But there was always an effort to make the study significant in order to address these new difficulties in later research projects, as it takes more study to accurately assess the real situation, particularly in the most dynamic regions like Meghan Estuary.

References

Abbas, M. (2021, October 6). Sand extraction from Meghna river causes erosion in Bhola. The Daily Star. https://www.thedailystar.net/environment/climate-crisis/natural-disaster/news/sand-extraction-meghna-rivercauses-erosion-bhola-2191486

Adedeji, O. H., Adebayo, H. O., & Sotayo, E. I. (2014). Assessing environmental impacts of inland sand mining in parts of Ogun State, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *7*(5), 478. https://doi.org/10.4314/ejesm.v7i5.2

Ahmad, O. (2017, December 27). *Top 2017 stories: Sandmining is destroying Asia's rivers*. The Third Pole. https://www.thethirdpole.net/en/energy/top-2017-stories-sandmining-is-destroying-asias-rivers/

Ahameed, K. K. B, and Pandey, A. C. (2020). Impact of marine sand mining on coastal morphology: A case study on alappad coast, Kerala. In Earth and Space Science Open Archive. https://doi.org/10.1002/essoar.10503653.1

Ahammed, K. K. B., and Pandey, A. C. (2021). Geospatial application for coastal morphology changes along the sand mining coast: A case study on alappad, Kerala. In Earth and Environmental Sciences Library (pp. 465– 479). Springer International Publishing.

Akhter, F. (2022, August 1). *The untold environmental catastrophe that is being caused by continuous sand mining*. Dhaka Tribune. https://www.dhakatribune.com/epaper/291488/the-untold-environmental-catastrophe-that-is-being

Ali, N. S. (2022, March 22). Special report: Wasteland foretold. *Dawn*. https://www.dawn.com/news/1681131

Bangladesh -201205. Jaxa.Jp. Retrieved August 21, 2022, from https://www.eorc.jaxa.jp/SAFE/prototyping/lineup/bgd/201205/index.html

Bari, E., and Haque, S. E. (2022). Legal and illicit sand mining practice in Bangladesh: Exploring supply chain and its value. *Journal of Illicit Economies and Development*, *4*(1), 44–57. https://doi.org/10.31389/jied.149

Beiser, V. (2017, February 27). Sand mining: the global environmental crisis you've probably never heard of. *The Guardian*.

https://www.theguardian.com/cities/2017/feb/27/sand-mining-global-environmental-crisis-never-heard

Books, L. L. C. (2010). *Bhola District: Upazilas of Bhola District, Burhanuddin Upazila, Bhola Sadar Upazila, Tazumuddin Upazila, Daulatkhan Upazila* (L. L. C. Books, Ed.). Books.

China cracks 368 illegal sand mining cases along Yangtze. (n.d.). News.Cn. Retrieved July 17, 2023, from http://www.news.cn/english/2021-12/03/c_1310348058.htm

de Leeuw, J., Shankman, D., Wu, G., de Boer, W. F., Burnham, J., He, Q., Yesou, H., & Xiao, J. (2010). Strategic assessment of the magnitude and impacts of sand mining in Poyang Lake, China. *Regional Environmental Change, 10*(2), 95–102. https://doi.org/10.1007/s10113-009-0096-6

Devoured: How China's Poyang lake was decimated by dredging and sand mining. (2021, July 19). *Reuters*. https://www.reuters.com/graphics/GLOBAL-ENVIRONMENT/SAND-POYANG/qzjpqxxabvx/

Dishman, K. L. (2000). Sieving in particle size analysis. In *Encyclopedia of Analytical Chemistry*. John Wiley & Sons, Ltd.

Gavriletea, M. (2017). Environmental impacts of sand exploitation. Analysis of sand market. *Sustainability, 9*(7), 1118. https://doi.org/10.3390/su9071118

Gruel, C.-R., Park, E., Switzer, A. D., Kumar, S., Loc Ho, H., Kantoush, S., Van Binh, D., & Feng, L. (2022). New systematically measured sand mining budget for the Mekong Delta reveals rising trends and significant volume underestimations. International Journal of Applied Earth Observation and Geoinformation: ITC Journal, 108(102736), 102736. https://doi.org/10.1016/j.jag.2022.102736

Hossain, M. S., Gopal Das, N., Sarker, S., & Rahaman, M. Z. (2012). Fish diversity and habitat relationship with environmental variables at Meghna river estuary, Bangladesh. *Egyptian Journal of Aquatic Research*, *38*(3), 213–226. https://doi.org/10.1016/j.ejar.2012.12.006

International Television Channel Ltd. (NTV). (2017, March 6). *Sand to be exported to Singapore, Maldives*. International Television Channel Ltd. (NTV). https://en.ntvbd.com/bangladesh/50949/Sand-to-be-exported-to-Singapore-Maldives

Jakobsen, F., Azam, M. H., & Mahboob-Ul-Kabir, M. (2002). Residual flow in the Meghna estuary on the coastline of Bangladesh. Estuarine, Coastal and Shelf Science, 55(4), 587–597. https://doi.org/10.1006/ecss.2001.0929

Khan, S., and Sugie, A. (2015). *Sand mining and its social impacts on local society in rural Bangladesh: A case study of a village in tangail district*. Core.ac.uk. Retrieved July 15, 2023, from https://core.ac.uk/download/pdf/222957973.pdf

Khatiwada, D. (2019). *Why sand mining is rampant and what's (not) being done to control it*. The Kathmandu Post. Retrieved August 5, 2023, from https://tkpo.st/2L1yyQJ

Knoema. (2023). *Bangladesh Urban population* [Data set].

Konert, M., and Vandenberghe, J. (1997). Comparison of laser grain size analysis with pipette and sieve analysis: a solution for the underestimation of the clay fraction. *Sedimentology*, *44*(3), 523–535. https://doi.org/10.1046/j.1365-3091.1997.d01-38.x

Lai, X., Shankman, D., Huber, C., Yesou, H., Huang, Q., & Jiang, J. (2014). Sand mining and increasing Poyang Lake's discharge ability: A reassessment of causes for lake decline in China. *Journal of Hydrology*, *519*, 1698–1706. https://doi.org/10.1016/j.jhydrol.2014.09.058

Lau, J. (2015, November 10). *China's construction sector forecast to slump to historic lows: no recovery expected until 2030*. South China Morning Post. https://www.scmp.com/property/hong-kong-china/article/1877354/construction-declines-china-shifts-industrial-sector

Mineral Commodity Summaries: 2012. (2012). Geological Survey.

Rentier, E. S., and Cammeraat, L. H. (2022). The environmental impacts of river sand mining. *The Science of the Total Environment*, *838*(Pt 1), 155877. https://doi.org/10.1016/j.scitotenv.2022.155877

Resilience. (2017, April 13). *Sand mining in America*. Resilience; Resilience.org. https://www.resilience.org/stories/2017-04-13/sand-mining-america/

The messy business of sand mining explained. (2021, February 18). *Reuters*. https://www.reuters.com/graphics/GLOBAL-ENVIRONMENT/SAND/ygdpzekyavw/

Williams, K. (2021, September 20). *Illegal sand mining is creating an ecological crisis in Bangladesh*. VICE. https://www.vice.com/en/article/4av9jm/illegal-sand-mining-is-creating-an-ecological-crisis-in-bangladesh

Worldbank.org. Retrieved August 21, 2022, from https://data.worldbank.org/indicator/SP.URB.GROW

(N.d.-a). Retrieved July 15, 2023, from http://(https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a9123a9a40f44e043a0ecc178bc0eee40cadca23#page=111))

(N.d.-b). Unep.org. Retrieved July 15, 2023, from https://www.unep.org/pdf/UNEP_GEAS_March_2014.pdf

Researchgate.net. Retrieved August 4, 2023, from https://www.researchgate.net/publication/354046413_Impact_of_sand_mining_on_the_changes_of_morphological_and_physical_dynamics_in_Sa%27dang_River_Pinrang_District_Indonesia

Zou, J., Huss, M., Abid, A., Mohammadi, P., Torkamani, A., & Telenti, A. (2019). A primer on deep learning in genomics. *Nature Genetics*, *51*(1), 12–18. https://doi.org/10.1038/s41588-018-0295-5

Appendix

Table: Sieve Analysis Result Riverbed Sediment of Layer 1 of Nazirpur

Site-2: Nazirpur, Riverbed sediment_Layer 1			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0.71	0.712494
6	1	8.9	8.931259
5	0.5	15.5	15.55444
4	0.25	17.4	17.46111
3	0.125	10.67	10.70748
2	0.063	25.5	25.58956
1	<0.063	20.97	21.04365
Total		99.65	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 2 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	1.75	1.759324
5	0.5	6.67	6.705539
4	0.25	11.12	11.17925
3	0.125	5.7	5.730371
2	0.063	14.55	14.62753
1	<0.063	59.68	59.99799
Total		99.47	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 3 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	1.03	0.89278
5	0.5	4.52	3.91783
4	0.25	9.75	8.45107
3	0.125	8.56	7.419606
2	0.063	27.68	23.99237
1	<0.063	63.83	55.32634
Total		115.37	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 4 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.4	0.36667
5	0.5	1.34	1.228344
4	0.25	7.68	7.040059
3	0.125	5.58	5.115043
2	0.063	33.84	31.02026
1	<0.063	60.25	55.22963
Total		109.09	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 5 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.4	0.379615
5	0.5	2.25	2.135333
4	0.25	10.4	9.869982
3	0.125	6.82	6.47243
2	0.063	44.75	42.46939
1	<0.063	40.75	38.67325
Total		105.37	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 6 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.5	0.428706
5	0.5	0.53	0.454429
4	0.25	8.5	7.288005
3	0.125	9.63	8.256881
2	0.063	59.02	50.60448
1	<0.063	38.45	32.9675
Total		116.63	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 7 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.5	0.460914
5	0.5	1.41	1.299779
4	0.25	8.37	7.715708
3	0.125	8.9	8.204277
2	0.063	37.14	34.23673
1	<0.063	52.16	48.0826
Total		108.48	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 8 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.34	0.377778
5	0.5	1.3	1.444444
4	0.25	10.02	11.13333
3	0.125	9.01	10.01111
2	0.063	33.86	37.62222
1	<0.063	35.47	39.41111
Total		90	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 9 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.35	0.393568
5	0.5	1.57	1.765433
4	0.25	8.52	9.580569
3	0.125	8.76	9.850444
2	0.063	27.72	31.17058
1	<0.063	42.01	47.2394
Total		88.93	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 10 of Nazirpur

Site-2: Nazirpur, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.16	0.182482
5	0.5	1.21	1.380018
4	0.25	8.16	9.306569
3	0.125	7.67	8.747719
2	0.063	30.55	34.84261
1	<0.063	39.93	45.5406
Total		87.68	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 1 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.8	0.798164
5	0.5	1.45	1.446673
4	0.25	28.53	28.46453

3	0.125	16.5	16.46214
2	0.063	28.76	28.694
1	<0.063	24.19	24.13449
Total		100.23	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 2 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.46	0.524336
5	0.5	3.47	3.955317
4	0.25	24.15	27.52764
3	0.125	16.31	18.59113
2	0.063	22.6	25.76086
1	<0.063	20.74	23.64072
Total		87.73	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 3 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0	0
5	0.5	0.32	0.309268
4	0.25	27.87	26.93534
3	0.125	19.23	18.5851
2	0.063	25.3	24.45153
1	<0.063	30.75	29.71876
Total		103.47	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 4 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.11	0.097882
5	0.5	1.33	1.183485
4	0.25	29.5	26.25022
3	0.125	19.07	16.96921
2	0.063	21.34	18.98914
1	<0.063	41.03	36.51006
Total		112.38	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 5 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.29	0.244499
5	0.5	2.92	2.46185
4	0.25	37.15	31.32114
3	0.125	18.89	15.92614
2	0.063	19.71	16.61749
1	<0.063	39.65	33.42888
Total		118.61	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 6 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.33	0.285789
5	0.5	3.44	2.979129
4	0.25	26.76	23.17485
3	0.125	14.86	12.86914
2	0.063	41.28	35.74955
1	<0.063	28.8	24.94154
Total		115.47	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 7 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	1.1	1.002004
5	0.5	4.22	3.844052
4	0.25	21.94	19.98543
3	0.125	10.95	9.974494
2	0.063	28.02	25.52377
1	<0.063	43.55	39.67025
Total		109.78	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 8 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.18	0.173712
5	0.5	1.9	1.833623
4	0.25	32.15	31.02683
3	0.125	16.18	15.61475
2	0.063	27.96	26.98321
1	<0.063	25.25	24.36788

Total		103.62	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 9 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0	0
5	0.5	0.5	0.534302
4	0.25	21.43	22.90019
3	0.125	14.32	15.30242
2	0.063	34.86	37.25155
1	<0.063	22.47	24.01154
Total		93.58	100

Table: Sieve Analysis Result Riverbed Sediment of Layer 10 of Mirza Kalu

Site-1: Hakimuddin, Riverbed sediment 1m			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.7	0.760787
5	0.5	0.33	0.358657
4	0.25	16.93	18.40017
3	0.125	9.82	10.67275
2	0.063	14.55	15.8135
1	<0.063	49.68	53.99413
Total		92.01	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 1 of Mirza Kalu

Site-1: Hakimuddin, Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.1	0.080652
5	0.5	0.71	0.572627
4	0.25	15.24	12.29131
3	0.125	9.51	7.669973
2	0.063	28.22	22.7599
1	<0.063	70.21	56.62553
Total		123.99	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 2 of Mirza Kalu

Site-1: Hakimuddin, Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.09	0.092726
5	0.5	0.72	0.741809
4	0.25	15.12	15.57799
3	0.125	9.81	10.10715

2	0.063	31.66	32.619
1	<0.063	39.66	40.86132
Total		97.06	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 3 of Mirza Kalu

Site-1: Hakimuddin, Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.01	0.008813
5	0.5	0.33	0.290826
4	0.25	15.12	13.32511
3	0.125	10.61	9.350489
2	0.063	41.26	36.36203
1	<0.063	46.14	40.66273
Total		113.47	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 4 of Mirza Kalu

Site-1: Hakimuddin, Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.54	0.42796
5	0.5	2.73	2.163576
4	0.25	23.29	18.45776
3	0.125	15.35	12.16516
2	0.063	55.18	43.73118
1	<0.063	29.09	23.05437
Total		126.18	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 5 of Mirza Kalu

Site-1: Hakimuddin, Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.01	0.009314
5	0.5	0.13	0.121077
4	0.25	20.82	19.39089
3	0.125	12.9	12.01453
2	0.063	53.41	49.74388
1	<0.063	20.1	18.72031
Total		107.37	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 1 of Nazirpur

Site-2: Nabir char, Nazirpur Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.2	0.159515
5	0.5	1.03	0.821503
4	0.25	24.8	19.77987
3	0.125	14.71	11.73233
2	0.063	46.84	37.35843
1	<0.063	37.8	30.14835
Total		125.38	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 2 of Nazirpur

Site-2: Nabir char, Nazirpur Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.02	0.017579
5	0.5	0.49	0.430694
4	0.25	26.67	23.44203
3	0.125	13.9	12.21763
2	0.063	36.3	31.90648
1	<0.063	36.39	31.98558
Total		113.77	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 3 of Nazirpur

Site-2: Nabir char, Nazirpur Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.39	0.325515
5	0.5	2.43	2.028211
4	0.25	25.6	21.36716
3	0.125	15.03	12.54486
2	0.063	43.18	36.0404
1	<0.063	33.18	27.69385
Total		119.81	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 4 of Nazirpur

Site-2: Nabir char, Nazirpur Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.14	0.13893
5	0.5	1.72	1.706857
4	0.25	18.6	18.45787
3	0.125	11.32	11.2335

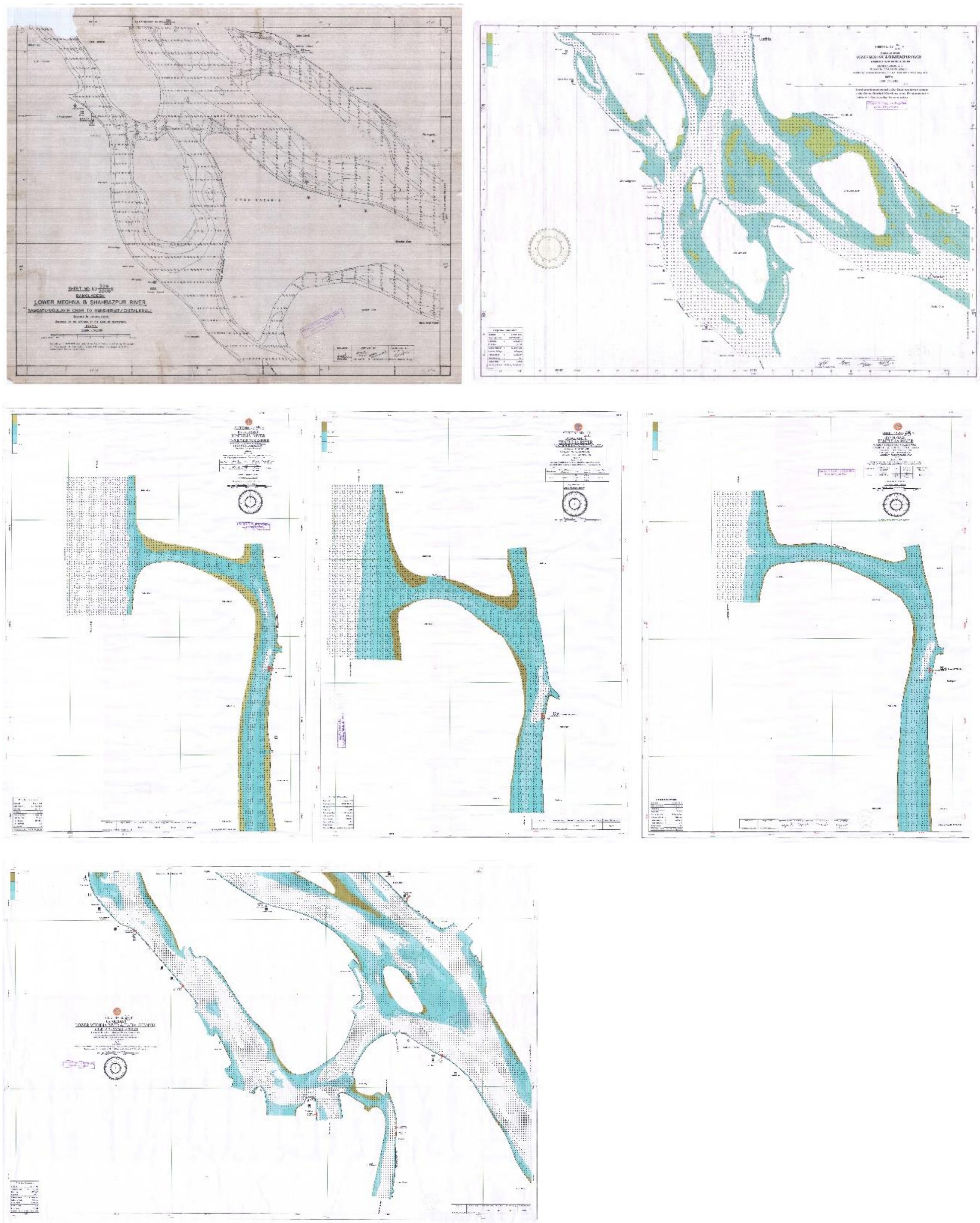
2	0.063	46.89	46.53171
1	<0.063	22.1	21.93113
Total		100.77	100

Table: Sieve Analysis Result Riverbank Sediment of Layer 5 of Nazirpur

Site-2: Nabir char, Nazirpur Riverbank sediment 50cm			
Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0.16	0.133556
5	0.5	1.4	1.168614
4	0.25	23.11	19.29048
3	0.125	12.95	10.80968
2	0.063	51.73	43.1803
1	<0.063	30.45	25.41736
Total		119.8	100

Table: Sieve analysis result of Mined sand Nazirpur

Sieve	Size (mm)	Sediment (g)	% amounts
7	2	0	0
6	1	0	0
5	0.5	0.5	0.501403931
4	0.25	0.8	0.80224629
3	0.125	12.33	12.36462094
2	0.063	79.23	79.45246691
1	0.05	6.86	6.879261933
Total		99.72	100

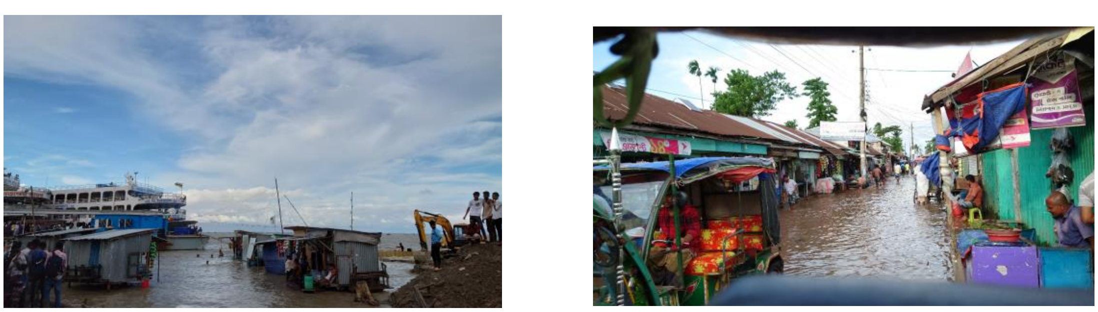


Collected Bathymetry map of Meghna and Tetulia river from BIWTA

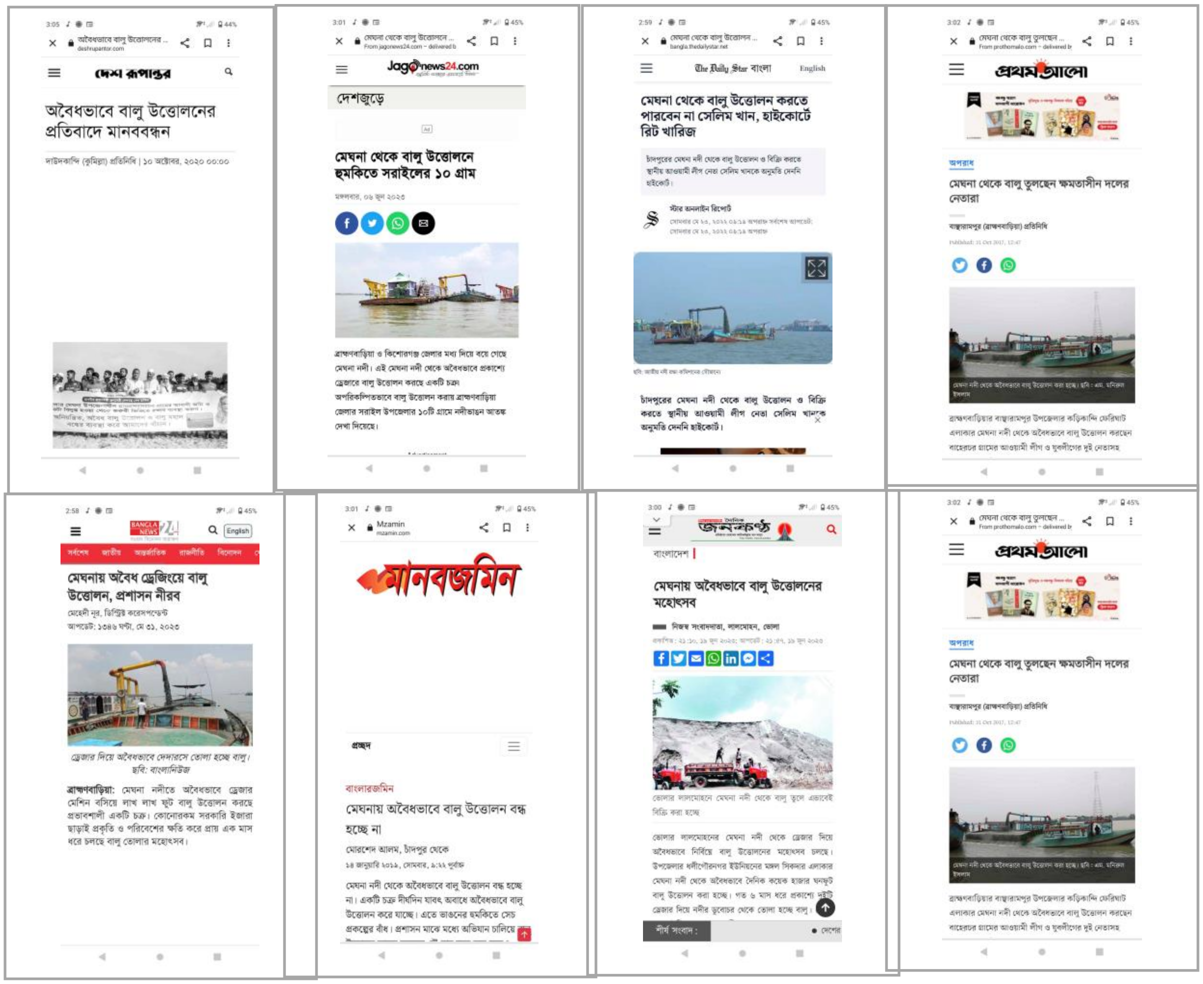
River Erosion in Meghna River (left) in Tetulia River (right)

Sand Mining in Tetulia River

Erosion in study area



Submerged condition during high tide in study area



Published Newspaper Related to Illegal Sand Mining In Bangladesh