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Decadal Dynamics of Jamuna Riverbank Erosion and Its Impact on Local Livelihoods in Shariakandi, Bangladesh

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Abstract: Over a thirty-year period (1990-2020), the spatiotemporal changes in riverbank erosion and accretion along the Jamuna River in Shariakandi Upazila, Bogura District, Bangladesh, were investigated using Landsat satellite imagery processed through ArcGIS 10.8 and Erdas Imagine 2015. The analysis delineated significant alterations in the riverbank, quantifying a decrease in the river area from 108 km^2 to 79.99 km^2, with a net erosion of 50.02 km^2 and an accretion of 78.03 km^2. Among the nine unions affected, Karnibari, Kazla, and Chaulabari were most impacted, with erosion accounting for $14.79\%, 25.98\%$, and 28.42% of the total, respectively. This study established a direct correlation between riverbank erosion and increased vulnerability for local populations, characterized by loss of homesteads and agricultural lands, displacement, income reduction, and a cycle of poverty. Environmental repercussions included deteriorated water quality and an increased prevalence of diseases. The effectiveness of various local adaptation strategies, such as financial reliance on external sources, migration, and occupational shifts, was also assessed, revealing a spectrum of success and underscoring the necessity for more sustainable, holistic approaches. This research emphasizes the imperative for integrated riverbank management strategies that concurrently address the geological and socio-economic ramifications of riverbank erosion.

Keywords: Riverbank erosion; Jamuna River; Decadal change; Geographic information systems; Environmental impact; Socioeconomic effects; Erosion measurement

1 Introduction

Riverbank erosion is a prevalent occurrence observed in both fluvial and coastal regions across numerous countries worldwide, albeit with varying impacts and characteristics depending on the specific location [1, 2]. This phenomenon entails the displacement of bank lines and the migration of bars inside a stream. Riverbanks undergo continuous shifts in location as a result of both natural and human-induced factors [3–6]. The pace and characteristics of channel change exhibit significant spatial and temporal variations [7, 8] influenced by multiple factors. The phenomenon of channel displacement is important for a number of geomorphological and river management issues [9, 10]. The mechanisms of fluvial sedimentation movement, watershed sediment yields, and the creation and modification of floodplains, or the overall development of river channels, are primarily influenced by the phenomena of bank erosion and accretion of a river [11]. The lives and property of those who live alongside rivers are seriously impacted by this local and recurring natural hazard [12].

Riverbank erosion and accretion statistics on a global scale have been studied by multiple researchers. The first global dataset of riverbank erosion for over 370,000 km of large rivers was created using up to 20 years of water classifications from Landsat imagery [13]. The study found that riverbank erosion for rivers wider than 150 m has an approximately log-normal distribution with a median value of 1.52 m/yr [14, 15]. Comparing this dataset to 25 similar estimates of riverbank migration, a normalized mean absolute error of 42% and a bias of 5.8% were found [16]. The relationship between river width and bank erosion was found to be different among global river basins, suggesting second-order influences of geology, hydrology, and human influence.

Bangladesh encounters numerous natural hazards on an annual basis due to its geographical positioning, topographical features, weather and climatic conditions [11]. The country is characterized by its deltaic landscape, which exhibits complex networks of rivers and streams [11, 17]. The Ganges-Brahmaputra-Meghna (GBM) river system, known for its substantial water and sediment load of about 1 billion tons per year [18], undergoes periodic planform changes resulting in the formation and relocation of sandbars, with channel abandonment [19] being the primary factor contributing to the recurring flood events and bank erosion across Bangladesh [20]. Riverbank erosion is widely recognized as a significant and prominent disaster in Bangladesh, mostly because of its detrimental impact on property loss [21]. Approximately 20 out of the total 64 districts in Bangladesh are susceptible to riverbank erosion, resulting in the annual loss of approximately 8,700 hectares of land which significantly affect the lives of approximately 200,000 individuals, as it leads to the destruction of their homesteads and/or land used for agriculture [22].

The Jamuna River, one of the world's largest braided rivers, experiences frequent and substantial erosion. This erosion leads to significant displacement of the river's bank line, resulting in the displacement of numerous families and substantial land loss on an annual basis [23]. According to Uddin Ahmed [24], the annual erosion of the Jamuna riverbank results in the displacement of a minimum of 20,000 households and the destruction of approximately 10,000 hectares of land. According to Sarkar et al. [25], the Jamuna River experienced erosion and accretion from 1973 to 2021, resulting in respective land area changes of 88,462 hectares and 16,315 hectares. However, the river has seen a spreading phenomenon over the past few decades, resulting in the displacement of individuals residing on both sides of the river during the period spanning 1973 to 2021. The cumulative erosion observed along the 220 kilometer stretch of the Jamuna River amounted to 88,462 hectares. Located at the bank of the Jamuna River, the Shariakandi Upazila of Bogura District in Bangladesh has a complex and evolving history of riverbank erosion, deeply intertwined with the region's environmental, social, and economic fabric [22].

However, numerous studies have been conducted since the 1960s, with a specific focus on morphological changes in the Jamuna River [26–33]. The utilization of satellite remote sensing (RS) techniques has proven to be highly effective in the analysis of fluvial channel dynamics at extensive spatial scales [34]. The advancements in RS and geographic information systems (GIS) have facilitated a convenient, cost-effective, and efficient platform for conducting thorough spatiotemporal analysis of bank erosion and accretion [35, 36]. Globally, numerous studies utilizing GIS have been conducted to assess the dynamics of riverbank migration [37–40]. The Landsat imagery is employed to determine the average annual bank migration and erosion/accretion conditions of the Ganges-Padma River system [33]. Additionally, an assessment was conducted to analyze the morphological alterations of the Jamuna-Padma-Lower Meghna River system following the disturbance caused by the Assam earthquake in 1950 [41]. These cases exemplify the utilization of this methodology within the specified region. Nevertheless, the majority of the previous studies primarily focused on geological aspects, with limited attention given to exploring the influence of gender, age, and other crucial socio-economic factors on the phenomenon of riverbank erosion. In addition, there exists a dearth of scholarly investigations examining the temporal fluctuations in riverbank erosion and accretion, as well as the impact of damage and displacement resulting from shifts in the river's bank line on the livelihoods of local communities. Therefore, this study aims to fill these gaps by investigating the temporal variations in bank erosion and accretion of the Jamuna River on Shariakandi Upazila of Bogura District and the impact of this hazard on the livelihoods of the local people and their adaptation strategies. The Shariakandi Upazila is one of the 29 areas in Bangladesh that are most susceptible to riverbank erosion [42]. The inhabitants of the Shariakandi Upazila confront a great deal of inland riverbank erosion primarily caused by annual flooding, and the intensity of erosion is exacerbated by disastrous floods that occur every three years or so [30]. The impact of riverbank erosion in Shariakandi and the broader Bogura District extends beyond the loss of land. It has profound implications for local livelihoods, particularly for communities dependent on agriculture and fishing. Given this context, this study emphasizes understanding erosion dynamics and the impact on local communities and exploring both modern and traditional mitigation approaches to enhance resilience and sustainability in the face of climate change.

This study aims to (a) delineate the spatiotemporal scenario of riverbank erosion in the Shariakandi Upazila of the Bogura District from 1990-2020; (b) assess the impact of riverbank erosion on the livelihoods of the local people; and (c) address the coping strategies of the people in the study area. ArcGIS 10.8 and Erdas Imagine 2015 were employed for the spatial analysis and visualization of changes in riverbank erosion and accretion, complemented by community-focused methodologies, including Focus Group Discussions (FGDs) and structured questionnaire surveys for insights into the socio-economic impact on local livelihoods. This approach allows for a comprehensive analysis of both physical alterations and their community implications, laying the groundwork for the subsequent detailed methodology section. The findings of this study can provide valuable insights for future endeavors aimed at establishing an erosion management strategy for the Brahmaputra River in Bangladesh.

2 Methodology

2.1 Study Area

Shariakandi Upazila, situated in the Bogura District, covers a total area of 408.45 km^2. It is geographically positioned between 24°44' and 25°04' north latitudes and 89°31' and 89°45' east longitudes. The region under consideration is geographically demarcated by Saghatta and Sonatala Upazilas to the north, Dhunat and Kazipur

Upazilas to the south, and Islampur, Madarganj, and Sarishabari Upazilas to the east (Figure 1). Gabtali Upazila encircles the region to the west [43]. It has about 85 km^2 of river area. The people and soil of Shariakandi have long been closely connected with the rivers Manas, Belai, Dakuria, Sukhdah, Bangali and Yamuna.

A significant proportion of the Shariakandi Upazila encounters riverbank erosion caused by the formidable Jamuna River. The Jamuna River experienced erosion and accretion from 1973 to 2015, resulting in the loss and gain of land areas measuring 88,462 hectares and 16,315 hectares, respectively [11] . Over the past few decades, the Jamuna River has been experiencing a spreading phenomenon, resulting in the displacement of individuals residing on both sides of the river. Riverbank erosion in Shariakandi Upazila has caused severe damage to several aspects of the local community, including residential properties, cultivable land, educational institutions, commercial establishments, and transportation infrastructure. Consequently, the erosion phenomenon has significantly influenced the overall economic landscape of the entire nation.

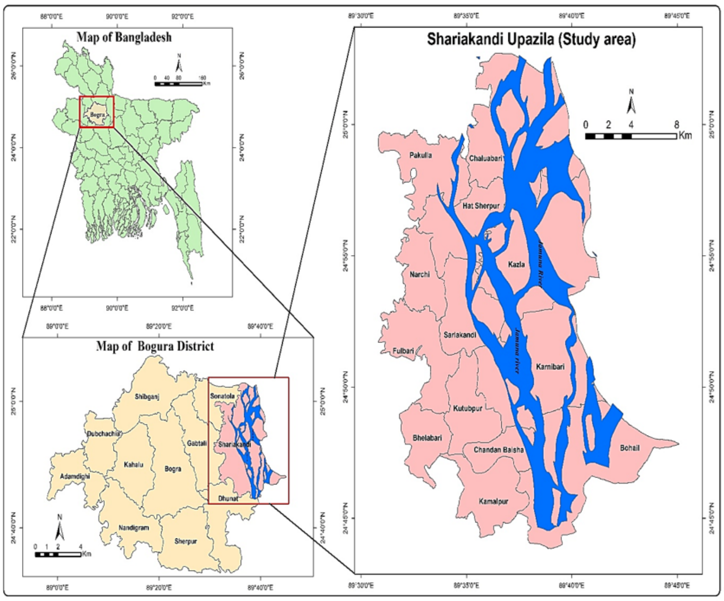

Figure 1. Study area

2.2 Data Collection

In this study, both primary and secondary data were taken into account. Primary data were mainly collected through questionnaires, FGDs and informal meetings with the local people. Secondary data include satellite images, books, newspapers, journals and the internet, etc. (Figure 2).

2.2.1 Landsat satellite images

Satellite images of Shariakandi Upazila of Bogura District were collected from USGS Earth Explorer Landsat Collection 2 Level-1 for the years 1990, 2000, 2010 and 2020 to delineate riverbank erosion (Table 1).

Table 1. Satellite data specifications

Satellite	Sensor	Path/Row	Acquisition Date	Resolution
Landsat 5	TM	138/43	1990/11/14	30 meters
Landsat 7			2000/11/17	
Landsat 7	ETM +	138/43	2010/12/15	
Landsat 8	OLI TIRS	138/43	2020/12/02	

Source: https://earthexplorer.usgs.gov

The images were collected from November to February, thereby ensuring that the data reflects the true morphological characteristics of the landscape, free from transient flood effects. These images have a spatial resolution of 30 meters.

2.2.2 Household survey and sampling

Purposive sampling was chosen for this study. It is employed in household surveys to opt for particular participants according to pre-established standards. Purposive sampling possesses an extensive evolutionary trajectory and is perceived as both straightforward and intricate from diverse perspectives [44]. The study area covers a total of 12 unions (Bhelabari, Bohail, Chaluabari, Chandan Baisha, Fulbari, Hat Sherpur, Kamalpur, Karnibari, Kazla, Kutubpur, Narchi, and Shariakandi), one municipality and 122 mouzas. Nine of the 12 unions have experienced riverbank erosion. A total of 220 respondents were selected from the most eroded Karnibari (14.79% of total erosion), Kazla (25.98% of total erosion) and Chaulabari (28.42% of total erosion) Unions who live on the banks of the mighty Jamuna River.

2.2.3 FGDs

FGDs are a research methodology in which data is derived by engaging a limited number of participants in deliberation on a specific subject or matter [45]. Focus groups are designed to provide a deeper understanding of the perspectives held by the participants regarding the topic being discussed [46]. For the purpose of this study, FGDs were conducted to collect information and understand the impact of riverbank erosion on livelihoods and the coping strategies of the local people. In Shariakandi Upazila, the majority of people are farmers and day laborers. The vulnerable farmers and day laborers of Kazla, Chaulabari and Karnibari Unions who live adjacent to the riverbank were chosen for FGDs. Eight member groups of vulnerable male farmers of young, middle and old ages were selected for two FGDs and seven member groups of day laborers were selected for another FGD.

2.3 Analysis of the Riverbank Erosion

As the study area is encircled by the water body, the approach known as the Modified Normalized Difference Water Index (MNDWI) was employed to distinguish between land and water. The MNDWI utilizes the green band and the Mid Infrared (MIR) band of the satellite images to enhance the characteristics of water bodies while simultaneously eliminating any interference from the surrounding land areas [47]. The threshold value for MNDWI analysis in GIS depends on several factors, including the characteristics of the satellite imagery, the specific environmental and geographical context of the study area, and the nature of the water bodies being analyzed [47]. According to Liu [47], researchers might start with commonly used threshold values which range from 0 to 1, with positive values indicating water. This was also used in this study. The threshold value was determined by the reclassified land and water, and was then identified with the help of GIS. Conditions were used to determine the MNDWI value for the class separation and the threshold determination. However, this value is not universally fixed and must often be determined empirically through analysis and validation. The outcome demonstrates heightened differentiation between the regions, thus facilitating the delineation of the coastlines for a specific year. In the instance of Landsat 5 images, bands 2 and 5 were used to denote the green and MIR bands, respectively. However, in the case of Landsat 8 images, bands 3 and 6 were utilized for the same purpose. Utilizing ArcMap 10.8, the MNDWI values were computed for the chosen Landsat images. The MNDWI values, obtained using the Raster Calculator tool, range from a negative value to a positive one, with the positive values characterizing the water bodies.

2.4 Processing of the Primary Data

After completion of the field survey, all the interview schedules were set for its data tabulation for coding and recording. All data collected from primary and secondary sources was analyzed using SPSS 25 and Microsoft Excel 2021. Finally, the analyzed data were integrated and presented accordingly.

3 Results

3.1 Riverbank Erosion in the Study Area

The morphology of the Jamuna River has changed over time, and erosion continues to occur along the riverbanks in Shariakandi Upazila. A considerable portion of land in the upazila is devoured by the mighty Jamuna every year. The main channel of the river in the upazila shifts from east to west, eroding a large portion of the area, including agricultural land, settlements, wetlands, and char lands.

3.1.1 Temporal changes in riverbank erosion and accretion

From 1990 to 2020, the total river area declined from 108 km^2 to 79.99 km^2. Furthermore, a segment of the river exhibited a consistent state across certain periods of time. In the given time frame of 1990-2000, the river area exhibited consistent stability, measuring approximately 41.27 km^2 (Table 2). Subsequently, the following decades witnessed a lack of significant alterations in smaller portions of the river.

The region experienced a significant erosion of 50.72 km^2 and an accretion of 66.72 km^2 from 1990 to 2000. This pattern continued with varying degrees of erosion and accretion in the subsequent decades. Although the erosion and accretion rates of the Jamuna River area in the Shariakandi decreased by 9.37 km^2 and 14.42 km^2, respectively, during 2000-2010, both rates increased again during 2010-2020. The erosion rate was 42.48 km^2, which was 1.13 km^2 more than that of the previous decade. The accretion rate showed a continuous decreasing pattern, which was 43.80 km^2 and 8.23 km^2 less than that of the previous decade (Table 3).

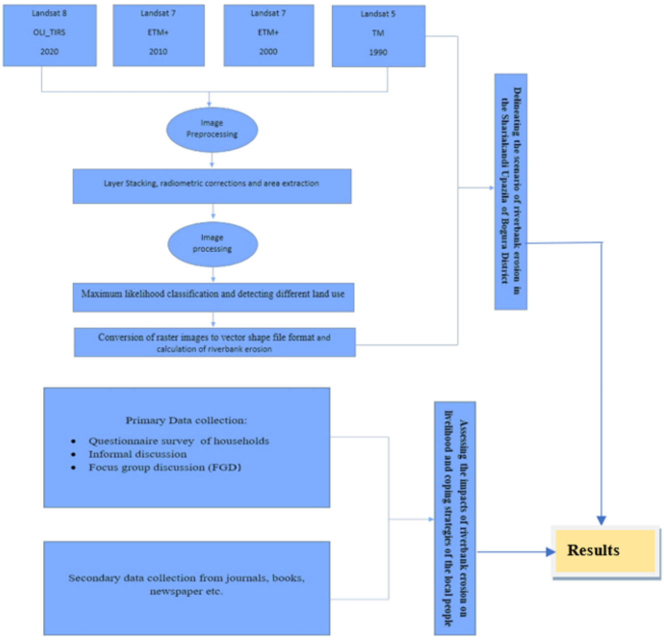

Figure 2. Methodological workflows

Table 2. Temporal changes in the Jamuna River area of Shariakandi Upazila

Year	River Area (km^2)	Year	Unchanged Area (km^2)
1990	108	1990 – 2000	41.27
2000	92	2000 – 2010	39.96
2010	81.31	2010 – 2020	37.51
2020	79.99	1990 – 2020	29.6

Table 3. Riverbank erosion and accretion rates in Shariakandi Upazila

Year	Erosion (km^2)	Accretion (km^2)
1990 – 2000	50.72	66.72
2000 – 2010	41.35	52.03
2010 – 2020	42.48	43.80
1990 – 2020	50.02	78.03

Overall, over the entire three-decade period, there was a net erosion of 50.02 km^2 and a net accretion of 78.03 km^2 (Figure 4). These figures highlight the ongoing and dynamic nature of the riverbank in this area, with both erosion and accretion processes playing a significant role in shaping the landscape (Table 3).

3.1.2 Union-wise riverbank erosion in Shariakandi Upazila

The research covers 12 unions, one municipality and 122 mouzas. Out of those unions within the Shariakandi Upazila, namely, Shariakandi, Kutubpur, Kazla, Karnibari, Kamalpur, Hat Sherpur, Chandan Baisha, Chaluabari, and Bohail, a total of nine unions are affected by the phenomenon of riverbank erosion. Among those nine unions, Karnibari, Kazla, and Chaulabari Unions have experienced the highest proportions of erosion, accounting for 14.79%, 25.98%, and 28.42% of the total erosion, respectively.

The union-wise comparative analysis of erosion rates indicates a cumulative erosion extent of 56.55 km^2 across all assessed unions, with an average erosion rate of 6.28 km^2 per union. Bohail exhibits the most substantial erosion, amounting to 14.27 km^2, which constitutes 25.23% of the total erosion and is 7.99 km^2 higher than the average. It is followed by Kazla, which has an erosion of 13.00 km^2, accounting for 22.99% of the total and exceeding the average by 6.72 km^2. Karnibari ranks third with 7.40 km^2 of erosion, representing 13.09% of the total and surpassing the average by 1.12 km^2. Conversely, unions, such as Kutubpur, Kamalpur, Chaluaubari, Chandan Baisha, Hat Sherpur, and Shariakandi, register erosion rates below the average, with corresponding erosion extents ranging from 5.33 to 2.20 km^2 and deviations from the average ranging from -0.95 to -4.08 km^2. This delineation highlights a significant disparity in the erosion impact across the unions (Figure 5).

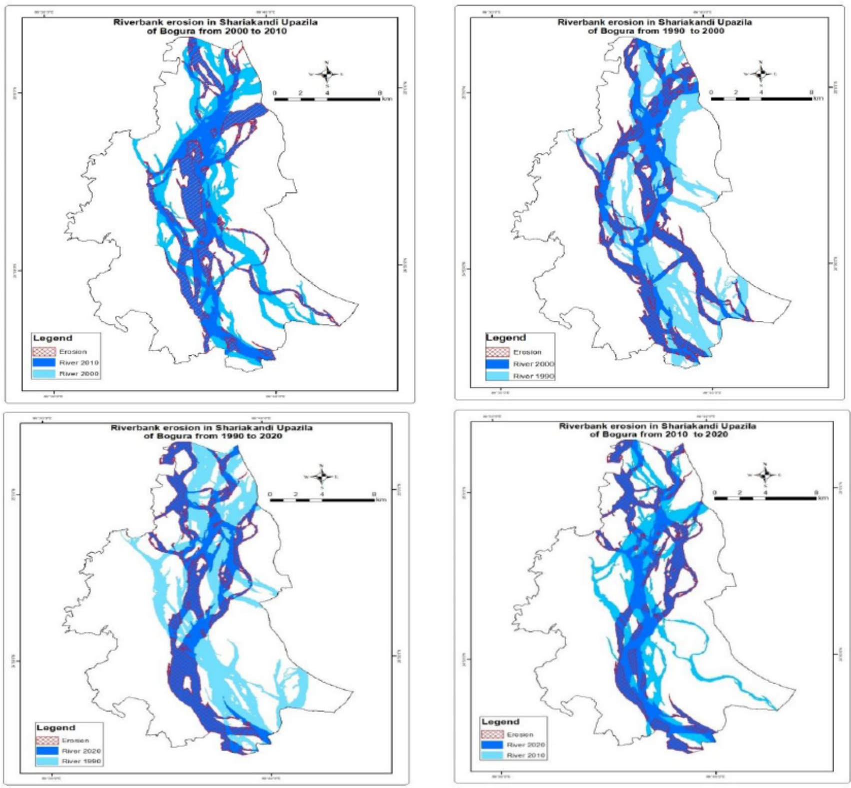

Figure 3. Riverbank erosion and accretion scenarios in Shariakandi Upazila from 1990 to 2020

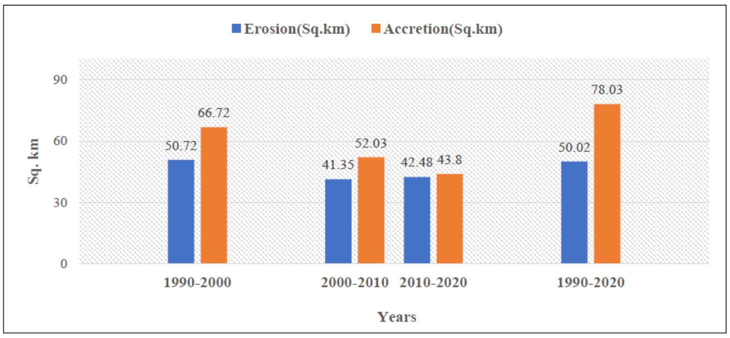

Figure 4. Erosion and accretion rates of the riverbank in Shariakandi Upazila (1990–2020)

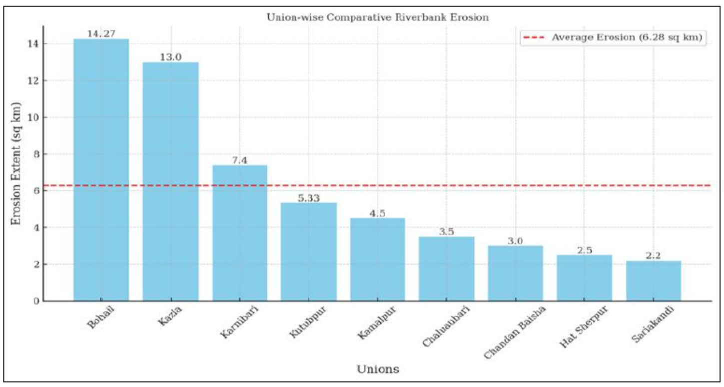

Figure 5. Union-wise comparative riverbank erosion

3.1.3 Causes of riverbank erosion

20% of the respondents said that excessive rainfall was responsible for erosion incidents, with heavy and protracted rain causing increased water flow and bank erosion. 13% of the respondents believed that dam failures, resulting in the release of massive amounts of water downstream, exacerbated the problem. A significant 23% of them blamed the absence of river embankments, which are essential protective barriers. On the other side, 8% of respondents said they thought poor planning was to blame for the incidents, highlighting the significance of taking preventative action. Notably, 36% of them thought that both too much rain and too few embankments contributed to erosion (Figure 6).

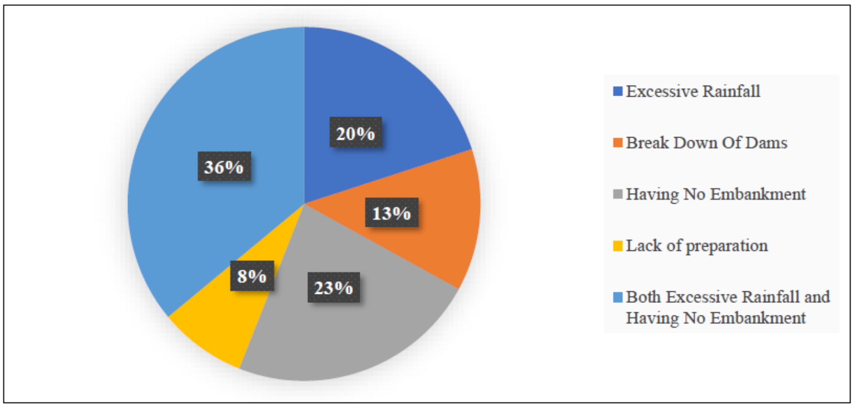

Figure 6. Causes of riverbank erosion

3.2 Impact of Riverbank Erosion on Local Livelihoods

In this study, the impact of riverbank erosion on local livelihoods was classified into three categories, namely, socio-economic impact, environmental impact, and the other impact. The socio-economic impact includes loss of homestead area and its economic value, loss of agricultural and productive land, displacement, loss of income, risk of poverty, etc. The environmental impact encompasses the degradation of drinking water quality, inadequate sanitation, and poor management of soil and agricultural land, among other issues. The other impact is a lack of health facilities, educational attainment, crime involvement, and so on.

3.2.1 Losses of homestead areas and their economic value

The findings of the field survey indicate that the respondents lost a sizable portion of their original homesteads. The majority of respondents acknowledged that they had frequently repaired their homes using the majority of their savings. According to the findings, 49% of respondents in the study area said they had lost less than an acre of land. 31% of the respondents stated that they had lost 1-3 acres of their property. In the three to five acres around their properties, just 20% of those polled reported having lost anything (Figure 7).

This study also considers the economic loss incurred by the sample respondents due to the loss of homestead areas. 47% of respondents reported an economic loss of less than 5 lakhs. Meanwhile, 40% reported losses ranging from 5 to 10 lakhs, and 13% faced losses between 10 and 15 lakhs, as detailed in Figure 8.

3.2.2 Losses of agricultural lands

Less than 1.00 acre of land was lost for nearly half of the affected homestead areas (49%), indicating relatively minor losses. A significant portion (31%) experienced a moderate land loss between 1.00 and 3.00 acres, while a minority (20%) encountered more substantial losses ranging from 3.00 to 5.00 acres. This breakdown allows for a clear understanding of the distribution of land loss severity among the homestead areas, highlighting the varying degrees of impact within this context (Figure 9).

3.2.3 Population displacement

31% of respondents experienced internal displacement once, while the majority (55%) experienced it twice. Only a small percentage of respondents experienced displacement three (8%), four (4%), or more than five (2%) times (Figure 10).

3.2.4 Losses of income

Empirical data reveals that 9% of respondents in the pre-erosion state, which has now dropped to 7%, had a monthly income of less than 30,000 takas. The respondents stated that they earned between 25,000 and 30,000 takas per month, showing no significant change in this income bracket. Before the onset of riverbank erosion, 17% of respondents reported monthly incomes ranging from 20,000 to 25,000 takas. Post-erosion, this percentage increased to 44%, indicating a shift toward lower income brackets, specifically between 15,000 and 20,000 takas. Moreover, the proportion of respondents earning more than 5,000 takas monthly decreased from 16% before erosion to 5% thereafter. Clearly, the majority of the local people have been struggling to make ends meet. A new income category, less than 5,000 takas per month, emerged post-erosion (Figure 11).

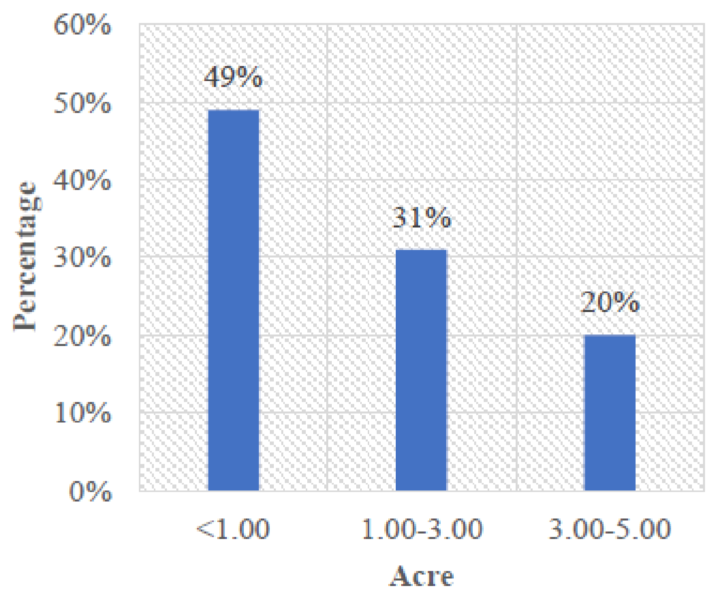

Figure 7. Homestead areas lost due to erosion

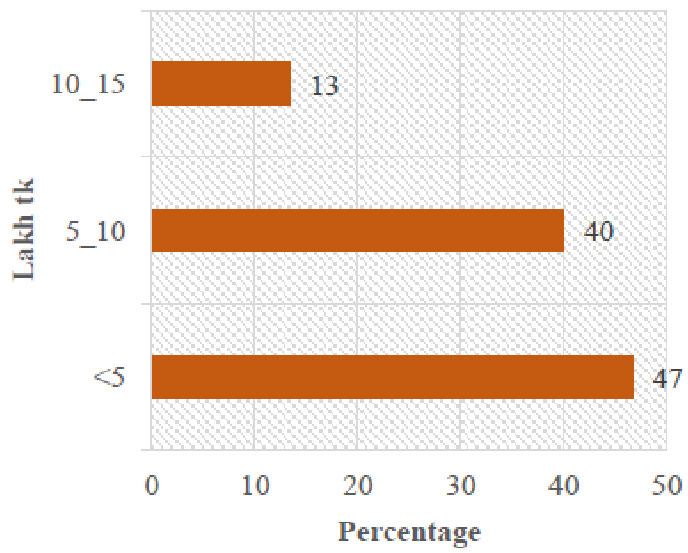

Figure 8. Economic losses in the homestead areas

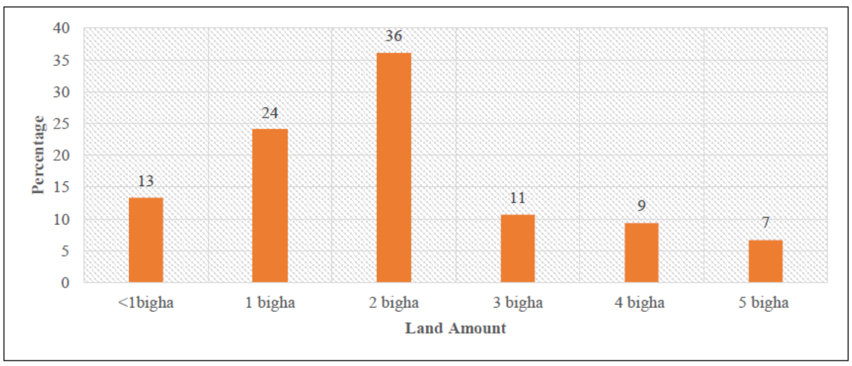

Figure 9. Amount of agricultural land lost

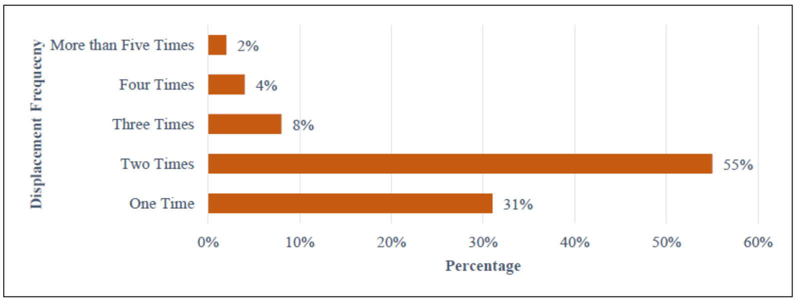

Figure 10. Displacement frequency of the population

This analysis reveals a clear decline in income stability among the local population, exacerbated by the impacts of riverbank erosion. The shift towards lower income brackets underscores the increasing economic vulnerability within the affected communities.

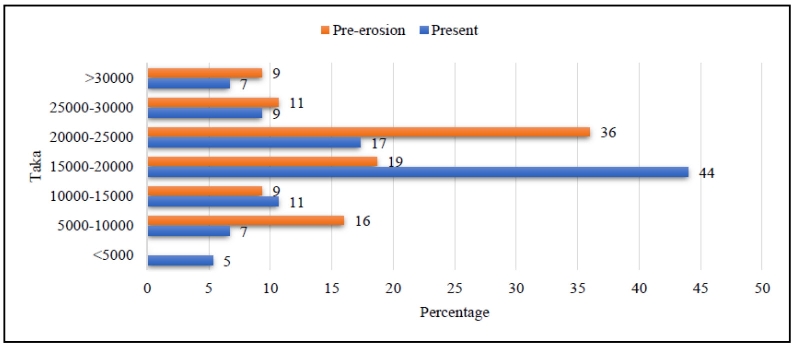

Figure 11. Monthly incomes of the respondents before and after the erosion

3.2.5 Impact on physical and mental wellbeing

The erosion of riverbanks has increased the number of threats to people's health. Due to riverbank erosion, respondents reported contracting new diseases they had never encountered before evacuation. The study reveals that diarrhoea was prevalent in more than 80% of the assessed homes. Skin disorders and malnutrition were reported by 71% and 87% of families, respectively. According to the majority of respondents, a lack of access to drinking water and a scarcity of freshwater contribute to a rise in skin disorders and diarrhoea.

Riverbanks have a severe impact on not only socioeconomic standing and physical wellness but also psychological wellbeing. Experiencing internal displacement is an identifiable cause of depression, anxiety, and distress. Because of riverbank erosion, the majority of respondents suffered from worry, stress, and sadness. To deal with their mental health difficulties, many of them turn to drugs. Furthermore, over 62% of respondents suffered from sleeplessness as a result of discontent with their jobs, homes, property and worries about their future. 75% of respondents reported significant social estrangement and loneliness (Table 4). Since they moved a significant distance from their previous places, they felt socially isolated and lonely.

3.3 Adaptation Techniques of the Local People to Cope with the Losses

3.3.1 Adaptation techniques to cope with the loss of cultivable land

It is evident that 48% of respondents turned to money lenders for financial assistance, indicating a significant reliance on external financial resources. Additionally, 16% sought support from neighbors and relatives, emphasizing the importance of social networks in mitigating land loss challenges. Moreover, 31% utilized a combination of both relatives and money lenders, suggesting a multifaceted approach to addressing the issue. A smaller 5% employed personal means for adaptation (Figure 12).

3.3.2 Strategies for reducing displacement loss during riverbank erosion

As riverbanks eroded, people attempted to mitigate the losses with their own adaptive strategies. Along with other community programmes, they tested their own indigenous approaches. Both governmental bodies and non-governmental organizations (NGOs) have taken responsibility to minimize the damages. The majority (48%) of the respondents used piled sand bags to protect themselves and reduce losses. To cut down on losses, approximately 24% and 19% of them used zeo soil bags and occasionally brick pieces, respectively (Figure 13).

Table 4. Impact of riverbank erosion on the physical and mental wellbeing of the respondents

Physical Wellbeing of the Respondents	
Diseases	**Percentage** (%)
Skin diseases	71
Diarrohea	86
Malnutrition	88
Chronic diseases	48
Water-related diseases	81
Neonatal and child health problems	78
High blood pressure	38
Mental Health and Wellbeing of the Respondents	
Diseases	**Percentage** (%)
Social isolation or loneliness	94
Depression	75
Family quarrel	50

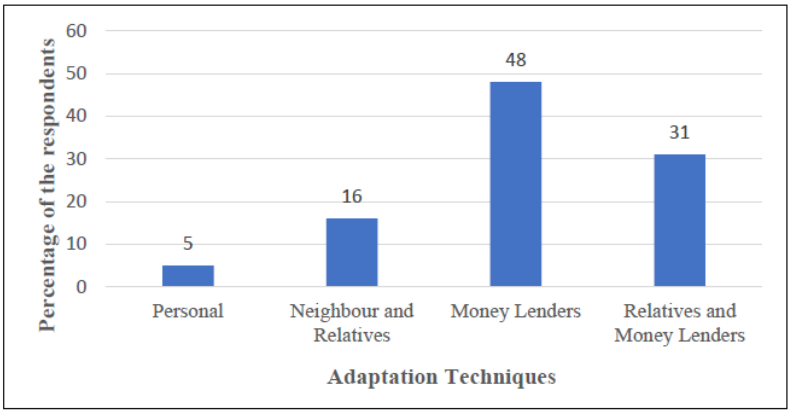

Figure 12. Different adaptation techniques adopted by the respondents to cope with losses of cultivable lands

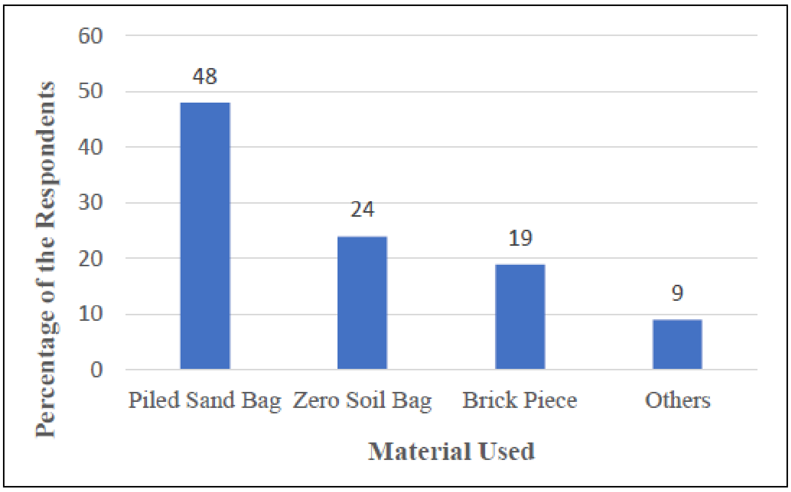

Figure 13. Different displacement loss reduction strategies

3.3.3 Internal migration for riverbank erosion

People migrated to new areas in search of fresh homes and employment opportunities. According to the field survey, 49% of people came to Shariakandi town to look for new jobs. Almost 24% of them relocated to Bogura. For this reason, only 16% of them relocated to Dhaka. The remaining 11% relocated to Sonatola town in pursuit of better opportunities (Figure 14).

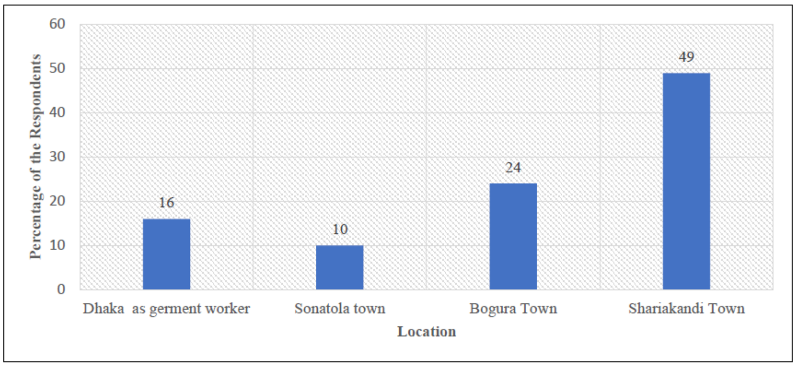

Figure 14. Destinations of the major internal migration

3.3.4 Changes in occupations

Changes in occupations are an important component of the adaptation strategies employed by affected communities. They might adopt certain lifestyle choices to maintain their traditional way of life and lessen the impact of the tragedies in their home region. The figure below shows that, due to agricultural land loss, higher spending rates, and lower agricultural revenue, the percentage of farmers has decreased from 47% to only 16% before and after the erosion. Day laborers now account for roughly 13% of the workforce, down from 20% before the erosion. Before and after the erosion, fishermen made up 13% and 9% of the workforce, respectively. Small-company entrepreneurs, on the other hand, are the same in all situations. The migration to Dhaka and other cities led to an increase in rickshaw pulling, which rose from 9% before the erosion to 36% afterward. The number of garment workers is higher than it was previously.

3.3.5 The government's infrastructural strategies for adapting to riverbank erosion

About 69.36% of respondents thought that repairing dams at government expense was an essential component of adaptation to river erosion since the majority of the roads, dams, or embankments in the region are of poor quality. About 12.67% thought that cyclone shelter was a government infrastructure strategy for adaptation (Figure 15). Only 6.22% believed that setting up a sluice gate was an adaptation strategy.

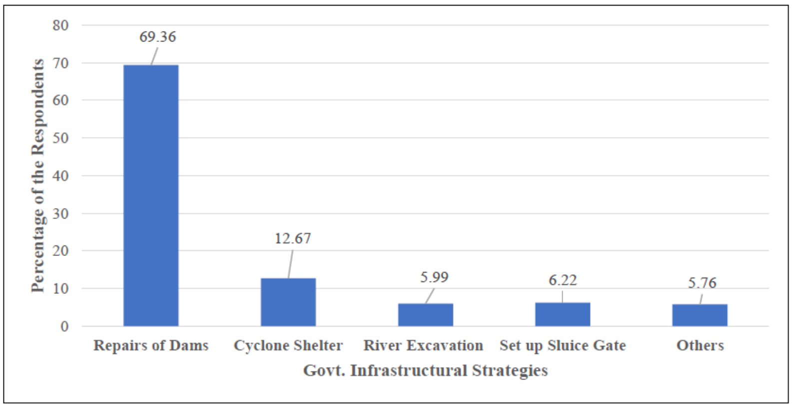

Figure 15. The government's infrastructural measures for adapting to riverbank erosion

4 Discussion

The study reveals obvious links between riverbank erosion, loss of land, job insecurity, food shortages, and health difficulties. The erosion of riverbanks in the northern region of Bangladesh persists in a continuous state of augmentatio [48]. Many communities in that region have been displaced due to riverbank erosion. The impact of the erosion has resulted in the deprivation of affluent households, extending beyond the mere loss of residences, properties, employment opportunities, bodies of water, and agricultural activities [33]. The primary reason behind the displacement and descent into destitution of middle- and upper-middle-class households stems from a paucity of incomes caused by property and cultivable land demolitions. This study reveals that the river has destroyed most of the population's homes, leaving them unable to afford their repair.

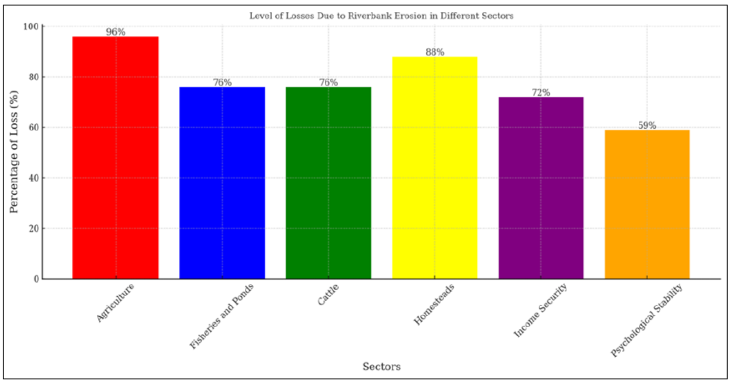

Figure 16. Level of losses due to riverbank erosion in different sectors

In this study, several types of losses were found and categorized into high, medium and low levels. As a result of these natural calamities, the local community suffered tremendously. Agriculture and homesteading were particularly hard hit. 96% of the respondents said they had lost their agricultural crops, while 4% perceived a moderate impact. Riverbank erosion significantly impacts agricultural and residential land, accounting for the stronger responses. Erosion, with an average rate of more than 76%, also has an impact on fisheries and ponds. Cattle losses as a result of erosion are small (76%). 88% of homesteads were seriously damaged. In the research area, the prevalence of income insecurity is 72%, psychological stability is 59%, and high, medium, and low-impacted circumstances are 11%, 31%, and 11%, respectively (Figure 16). This study reveals that numerous individuals sought shelter in the embankments of rivers and along the edges of roadways in the proximate urban area. Furthermore, a subset of individuals dwelt on leased open terrain, upon which they constructed substandard impermanent dwellings. In the aftermath of the erosion of their domiciles by the river, none of them were able to erect a durable edifice. The respondents often relocated to the residences of their neighbors, relatives, or government-provided Khas land or leased land. Residents living near rivers or roads were found to be particularly vulnerable to social exclusion and related adversities.

According to the findings, riverbank erosion has a significant influence on the economic and physical setting, rendering them subject to prolonged destitution, a lack of electrical access, inadequate sanitation facilities, disaster catastrophes, and exorbitant food prices. Ahmad et al. [49] discovered a similar finding about riverbank erosion harming the cultural, mental, financial, and social wellbeing of Pakistan. Islam et al. [50] conducted a study on the effects of riverbank erosion hazards in the floodplain regions of Mymensingh, Bangladesh and asserted that riverbank erosion led to a multitude of outcomes, encompassing social, economic, health, and educational consequences. Furthermore, in some cases, it can lead to political ramifications. The most notable socioeconomic consequence resulting from land erosion is the displacement of individuals, necessitating their relocation.

During periods of flooding, riverbank erosion leads to the displacement of a significant number of individuals. Residents living along the riverbank lose their homes, agricultural land, livestock, and other valuable natural resources. Consequently, those rendered homeless due to riverbank erosion are compelled to establish new settlements in remote or secluded areas known as chars, where they struggle with symptoms of depression, destitution, and malnutrition. The profound ramifications of flooding and erosion encompass homelessness and the loss of a person's primary means of sustenance. The data reflects a significant relationship between erosion and socio-economic disruption. High displacement frequencies suggest continuous instability, with a striking 55% of the population being displaced twice and others facing displacement up to more than five times. Economically, post-erosion income distribution has shifted, indicating a surge in both lower (<5,000 takas) and higher income (15,000-20,000 takas) brackets and a decrease in middle-income earners (20,000-25,000 takas). This points to increased economic disparity following the erosive events.

Following the devastating loss of everything to the river, the vast majority of those affected find themselves trapped in a cycle of impoverishment and unable to secure gainful employment, resulting in difficulties in acquiring proper nourishment. A substandard diet and health issues pose significant obstacles to attaining and maintaining employment. Once unemployed, these individuals invariably regress into poverty. Iqbal [51] further posited that the majority of individuals affected by riverbank erosion experienced severe economic adversity due to forced displacement, including the relinquishment of job opportunities and possessions. Consequently, they encountered the risk of descending into destitution and, in certain instances, engaging in illicit activities. Riverbank erosion leads to economic instability and destroys material wealth for underprivileged and marginalized people in afflicted areas [52].

People residing near rivers had greater access to river-based livelihoods, including dry-season cultivation in riverbeds, according to the findings of this study. The overall financial stability and asset holdings, including housing, generally deteriorated. Furthermore, there was a negative impact on the ability to repay loans. Support from NGOs and government agencies were found to play a crucial role in aiding individuals to mitigate the effects of their precarious situations. Furthermore, this study reveals considerable relocation costs and even greater household medical costs following the relocation.

It was found in this study that feelings of anxiousness, tension, and despair were influenced by a variety of factors, such as holdings of property, the number of kids, schooling, dwelling region, earnings, and people's adapting methods. The majority of parents with multiple children or additional family obligations were depressed since they're unable to satisfy their essential demands. However, fewer parents with higher-educated and richer households were less affected by riverbank erosion as they possessed more options to deal with the shock.

The psychological effects of riverbank erosion on the community are undoubtedly complex, including ongoing tension, anxiety, and a generalized feeling of powerlessness, which may even lead to depression. Social networks were upset by frequent relocations, which weakened links to the community and increased feelings of loneliness. A generational trauma cycle may result from such environmental instability, which may disproportionately impact children and interfere with their social and academic development. A thorough strategy for mental health therapies in these areas is necessary since the stress of moving to lower-income groups after the erosion may exacerbate these problems and increase the likelihood of substance addiction and domestic problems.

Housewives were particularly despondent, while daily earners remained most concerned. Older people expressed more sadness and anxiety than those who were younger. Landless individuals faced more economic and physical challenges compared to landowners. Low-level interpersonal relationships contributed to the households' lack of resilience capability. Their interaction with others, which is the cornerstone of the creation of social capital, also turned out to be constrained owing to poor socioeconomic situations and insufficient road transit options. Risks can shift over individuals and periods, making communities with robust implicit dividing risk connections more resilient to distinctive disruptions [53, 54]. However, well-educated displaced people were capable of dealing with their situations, whether they were impoverished or not.

In accordance with this study, approximately a third of the respondents relocated at least twice. Several of the interviewees relocated more than five times. Char dwellers, in particular, relocated with greater regularity than other inhabitants. Several participants said they originally relocated to a town. But within a few days, they found themselves unable to get used to the sociocultural milieu and reverted to a nearer rural location where they'd originally resided. For subsistence and financial stability, impoverished riverine communities depended significantly on animals. The imminent demise of livestock as a result of river erosion generated triple the anguish and strain.

This study reveals that riverine populations in Bangladesh depended on agriculture and fishing to make a living. Nevertheless, riverbank erosion destroyed or forced residents to abandon their houses, destroying their belongings, jeopardizing their sustenance and ways of life, and driving communities to seek alternative livelihoods. Furthermore, the erosion hindered their children's schooling and prevented them from accessing safe drinking water and adequate sanitation. Shockingly, despite the horrific impact of erosion, most people suffering from it wanted to stay in their localities, regardless of the limited employment possibilities. According to the report, displacement victims had no means of receiving organizational assistance and could not participate in a recovery programme. Riverbank erosion is the primary driver of displacement. Therefore, government agencies and NGOs should collaborate to implement adequate and long-term restoration plans for riverbanks.

5 Conclusions

The extensive study of riverbank erosion in the Shariakandi Upazila of the Bogura District, Bangladesh over the period of 1990-2020 highlights the profound and multi-dimensional impact of this environmental phenomenon. This study illuminates the dynamic nature of the Jamuna River's bankline, revealing significant temporal changes in the river's morphology characterized by both erosion and accretion. This continuous reshaping of the riverbank has far-reaching implications for the local population, severely affecting their livelihoods and leading to substantial socio-economic and environmental challenges.

The study emphasizes the importance of riverbank erosion as a recurrent natural hazard, particularly in a deltaic landscape like Bangladesh. The annual erosion along the Jamuna River not only resulted in substantial land loss and displacement of thousands of households but also disrupted agricultural practices, leading to economic instability and increased vulnerability among the local communities. The loss of homestead areas, agricultural land, and subsequent income reduction pushed many people into a cycle of poverty and destitution, with some resorting to migration and occupational changes as coping strategies.

Environmental impact, including water quality deterioration and increased disease prevalence, further compounds the difficulties faced by the local populace. The psychological toll of this natural hazard is evident in the increased instances of mental health issues like depression, anxiety, stress, and social isolation among the affected communities. Moreover, this study brings to light the adaptation strategies employed by the local people, ranging from financial dependence on external resources to self-initiated protective measures like using sandbags or relocating to safer areas. The effectiveness of these strategies, however, varies widely, reflecting the need for more comprehensive and sustainable solutions.

In conclusion, this study not only contributes significantly to the understanding of riverbank erosion and its impact on local livelihoods in Bangladesh but also emphasizes the urgent need for integrated management approaches. These approaches should encompass not just geological and environmental aspects but also socio-economic, psychological, and cultural dimensions. In addition, emerging technologies, such as RS, GIS, drones, Internet of Things (IoT) sensors, and machine learning, can significantly enhance the monitoring and management of riverbank erosion. These tools provide detailed real-time data, enable precise mapping and analysis, offer predictive insights into future erosion patterns, and improve strategic planning and community resilience, especially in vulnerable areas like Shariakandi Upazila in Bangladesh. There is a clear imperative for policy interventions that address the immediate needs of the affected populations and implement long-term strategies to mitigate the impact of riverbank erosion. Collaborative efforts involving the government, NGOs, and local communities are essential in developing resilient and adaptive mechanisms to cope with the challenges posed by riverbank erosion in Bangladesh.

Future research on riverbank erosion in Shariakandi Upazila could include long-term trend analysis, comparative studies with similar river systems, detailed socio-economic impact, and the effectiveness of technological solutions like GIS and IoT. Additionally, exploring the psychological and cultural impact on affected communities, assessing policy effectiveness, and investigating health and climate change implications would address the limitations of this study and enhance erosion management strategies in regions like Bangladesh.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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