



Impact of River Erosion on Agricultural Practices in Bangladesh: Review of Secondary Data

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Abstract: River erosion is a significant environmental challenge in Bangladesh, leading to substantial land loss, reduced crop yields, and socio-economic instability, particularly for populations who depend on agriculture. This study analyzes the multifaceted impacts of river erosion on agricultural productivity, focusing on crop yield variability, land use changes, and socio-economic consequences. Data from governmental and non-governmental sources were analyzed using R programming to identify patterns, causes, and effects of river erosion on agricultural land and crop production. The findings show that erosion-induced land loss threatens food security by reducing arable land, particularly for crops like rice and jute, and displacing communities, which exacerbates poverty and migration. The study also highlights the role of both natural processes, including seasonal monsoon variations, and anthropogenic activities, such as unplanned embankment construction, in worsening river erosion. Mitigation strategies, including vegetative stabilization and crop diversification, have shown promise in reducing erosion impacts, with vegetative stabilization identified as the most effective for long-term resilience. The study highlights the need for integrated river management strategies and sustainable agricultural practices. It suggests the adoption of policy frameworks that combine effective erosion control measures with community-based resilience approaches to safeguard agricultural productivity and livelihoods in erosion-prone areas.

Keywords: River, Erosion, Agriculture, Socio-economic, Bangladesh

Bangladesh riverbank erosion presents a multifaceted challenge, significantly impacting agricultural land, displacing communities and disrupting agricultural activities (Billah et al., 2023). The dynamic nature of the Bengal Delta, characterized by shifting river channels and the formation and erosion of char lands, exacerbates these issues (Haque and Jakariya 2023). This instability leads to the displacement of settlers and a decline in their socioeconomic status, highlighting the need for adaptive management and planning approaches (Haque and Jakariya 2023, Islam et al., 2023). The geographical location of Bangladesh, bordered by the Ganges, Brahmaputra and Meghna River systems, indeed makes it highly susceptible to changing river courses and increased sedimentation, leading to significant land loss (Paszkowski et al., 2021). This susceptibility is exacerbated by the dynamic nature of these river systems, which are prone to frequent erosion and accretion processes (Saleem et al., 2019). The impacts of these changes are profound, affecting land use, agriculture, and the livelihoods of millions of people in the region (Smith and Dawson 2020). The following sections delve into the specific aspects of this issue.

The lower Meghna River has experienced significant erosion, with an average land loss rate of 124.18 ha/year, affecting 43.88% of households as severely vulnerable (Chowdhury et al., 2021). The Jamuna River has also shown

substantial erosion, with 3356 ha lost between 1972 and 2013, leading to settlement displacement and increased poverty (Gazi et al., 2020, Alam and Ahamed 2022, Haque et al. 2022). In the Malda district of West Bengal, the Ganga River's erosion has resulted in an average annual land loss of 4.5 km², affecting nearly a million people (Das and Samanta 2022, Haque et al., 2022). Land use and land cover (LULC) changes in Bangladesh have shown a significant decrease in agricultural land by 11.68% due to inundation risks from river systems (Dey et al., 2022). Vulnerability maps indicate that more than 50% of areas in Khulna and Dhaka divisions are highly vulnerable to agricultural land use changes due to potential inundation (Dey et al., 2022). Riverbank erosion in the Meghna River has led to severe impacts on livelihoods, with 91% of affected households losing their homes and 87% borrowing money to cope with the disaster (Gazi et al., 2020, Halima and Maria 2021). The socio-economic scenarios predict increased flood potential and reduced water availability, which could exacerbate the impacts on agriculture and livelihoods (Khan et al., 2022, Gupta and Chembolu 2024). While the geographical location of Bangladesh makes it vulnerable to these natural processes, it is important to consider the role of human activities and climate change in exacerbating these issues (Bandh et al., 2021).

The construction of upstream water transfers and socio-economic changes could further impact water availability and quality, affecting the delta region's ecosystems and livelihoods (Khan et al., 2022). Addressing these challenges requires comprehensive riverbank erosion management policies and sustainable land use planning to mitigate the adverse effects on the population and environment. The goal of this study is to analyze secondary data to quantify the impact of river erosion on agricultural land and crop production in Bangladesh, with the aim of providing actionable insights for policy development and erosion mitigation. This study employs a secondary data analysis approach to explore the complex relationships between river erosion, land-use changes, crop yields and socio-economic consequences, thereby offering a comprehensive assessment of the impacts on agriculture in Bangladesh.

MATERIAL AND METHODS

The study in question utilizes a secondary data analysis approach, integrating datasets from various sources like the Bangladesh Water Development Board (BWDB) and Bangladesh Bureau of Statistics (BBS), along with academic and NGOs reports, provides a robust framework for analyzing these impacts to understand the socio-economic impacts of river erosion in Bangladesh Figure 1. The data were analyzed using descriptive statistics to identify patterns in river erosion, land loss, and agricultural yield variability. Correlation analyses were performed to examine the relationship between erosion intensity and agricultural productivity. R's data manipulation and visualization libraries (e.g., ggplot2, dplyr) were used to create visual representations of erosion trends, land-use changes and socio-economic impacts, facilitating a clearer understanding of the data.

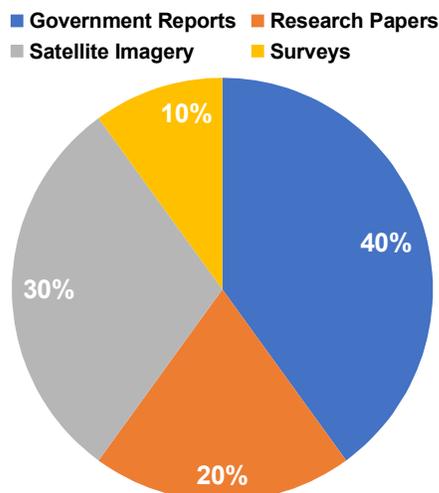


Fig. 1. Distribution of data sources used in the study

Study area: Bangladesh, situated in South Asia, spans a geographic region of 20°34' to 26°38' North Latitude and 88°01' to 92°41' East Longitude (Fig. 2). It is a delta plain created by the Ganges, Brahmaputra, and Meghna rivers, bordered by the Bay of Bengal. The nation shares its borders with India to the west, north, and northeast, and with Myanmar to the southeast (Uddin et al. 2024). This area covers regions most affected by river erosion, particularly in the Ganges-Brahmaputra Delta, where agriculture is integral to the livelihoods of rural communities (Khan and Rahman 2022). The research aims to assess the extent of damage caused by erosion and its ripple effects on agriculture, crop yield, and socio-economic conditions of the affected populations.

RESULTS AND DISCUSSION

River erosion in Bangladesh: Context and causes: Bangladesh's vulnerability to river erosion is significantly influenced by both natural and anthropogenic factors. The country's geographical position at the confluence of the Ganges, Brahmaputra, and Meghna rivers makes it susceptible to natural processes like sediment deposition, river migration, and flooding (Chowdhury et al., 2021, Haque et al., 2022). However, human activities such as

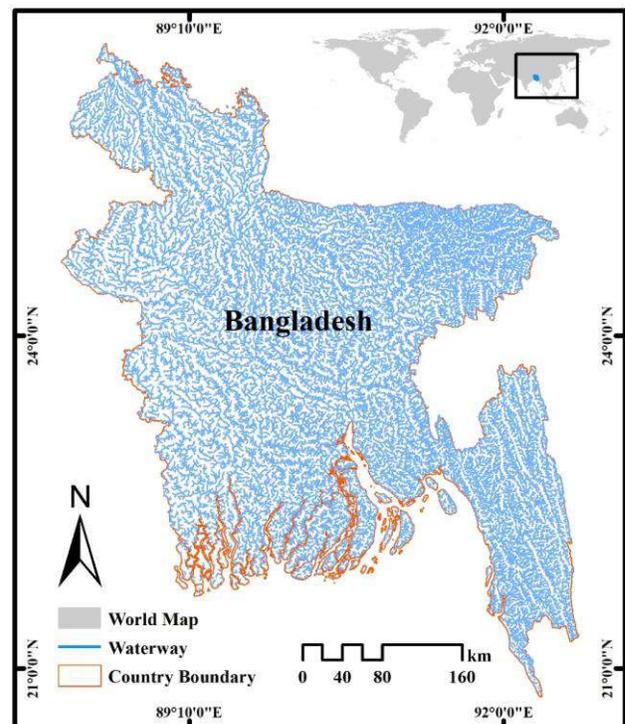


Fig. 2. Map of Bangladesh showing the country's waterways in blue and the national boundary in orange. The inset map provides a global context for the location of Bangladesh

deforestation, unplanned embankment construction, and unsustainable river management practices have exacerbated these natural processes, leading to increased erosion and its associated impacts (Grabowski et al. 2022).

Natural and anthropogenic factors: Bangladesh's location in the deltaic region of the Ganges-Brahmaputra-Meghna River system makes it prone to natural erosion processes due to sediment transport and deposition dynamics (Anzum et al., 2023). Natural drivers of river erosion include seasonal variations in water flow, sediment transport, and hydrological patterns. The annual monsoon rains increase river flow, which in turn accelerates erosion, particularly during flood events. The natural fluvial processes, including riverbank shifting and sediment flux, contribute to the erosion and accretion patterns observed in the region (Anzum et al., 2023). Additionally, the erosion-prone nature of the riverbanks, due to a high sediment load and fluctuating river currents, contributes to the shifting of river channels, further destabilizing the landscape.

In contrast, human activities have compounded the natural causes of river erosion. Unplanned construction of embankments, as well as illegal sand mining, have disrupted the natural sediment flow and weakened riverbanks (Dey et al., 2022, Haque et al., 2022). Furthermore, the rapid urbanization and expansion of infrastructure in floodplain areas have led to the destruction of natural buffer zones, such as wetlands, which play a crucial role in stabilizing riverbanks (Ali and Ferdos, 2024). Construction activities such as embankments and bridges have been identified as significant contributors to river ecosystem changes. For instance, cross embankments and bridge construction over the Bhairab River have been major factors in altering the river's ecosystem (Islam et al., 2023). Industrial growth has led to increased pollution, which affects river water quality and exacerbates erosion by disrupting the natural aquatic ecosystem (Freihardt and Frey 2023). High-speed water vehicles generate waves that intensify riverbank erosion, as observed in the Kirtankhola River.

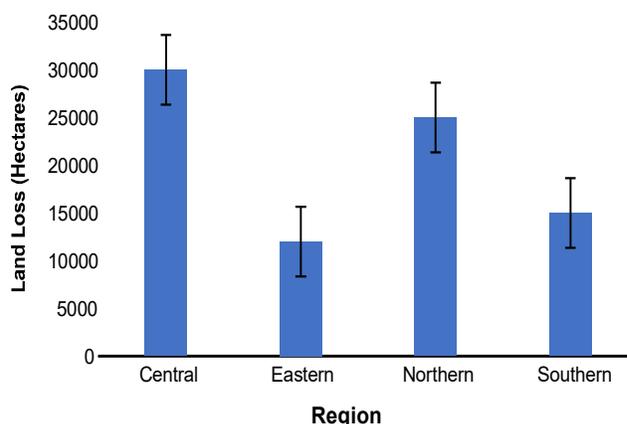
While Bangladesh has made strides in disaster risk reduction and anticipatory action, challenges remain in securing livelihoods and properties from erosion-induced damage (Naz et al. 2024). The country's proactive disaster management approach has reduced human casualties, but adaptation failures and the need for improved policies persist (Faisal and Hayakawa 2022). Addressing these issues requires a comprehensive understanding of both natural and human-induced factors contributing to river erosion.

Extent of River erosion and land loss: The Central region experiences the highest erosion, with 30,000 hectares of land lost annually, followed by the Northern region with

25,000 hectares (Fig. 3). The Southern region faces a moderate loss of 15,000 hectares per year, while the Eastern Region has the lowest land loss, at 12,000 hectares annually (Gazi et al., 2020, Chowdhury et al., 2021, Alam and Ahamed 2022, Dey et al., 2022, Haque et al., 2022, Mamun et al., 2022). These figures highlight the significant regional disparities in the impact of river erosion, with the Central region being the most severely affected. The variation in land loss across regions likely reflects differences in river dynamics, sedimentation patterns and geographical factors, which contribute to the extent of erosion.

River erosion significantly impacts agricultural land, particularly in regions like the Brahmaputra and Jamuna rivers, where frequent river course changes and high sediment loads exacerbate the problem. This erosion leads to substantial land loss, affecting the cultivation of essential crops such as rice, jute, and vegetables, thereby threatening food security. The loss of approximately 87,000 hectares of agricultural land annually due to river erosion highlights the severity of this issue (Dey et al., 2022, Mamun et al., 2022). The following sections delve into the extent of river erosion and its implications on land loss and food production. Riverbank erosion is a prevalent issue along major rivers like the Jamuna in Bangladesh, where satellite imagery has been used to track erosion events, revealing significant land loss post-monsoon seasons (Dahal et al., 2023). In the Brahmaputra Valley of Assam, India, riverbank erosion has been linked to socioeconomic challenges, including poverty and migration, due to the loss of cropland and other resources (Mandal et al., 2023).

Food security and poverty: There is a consistent downward trend in rice yields over a five-year period from 2015 to 2019 and in 2015, yield was 3,000 kilograms per hectare, but by 2019, decreased to 2,800 kilograms per



Source: Gazi et al., 2020; Chowdhury et al., 2021; Alam & Ahamed 2022; Dey et al., 2022; Haque et al., 2022; Mamun et al., 2022

Fig. 3. Annual land loss due to river erosion

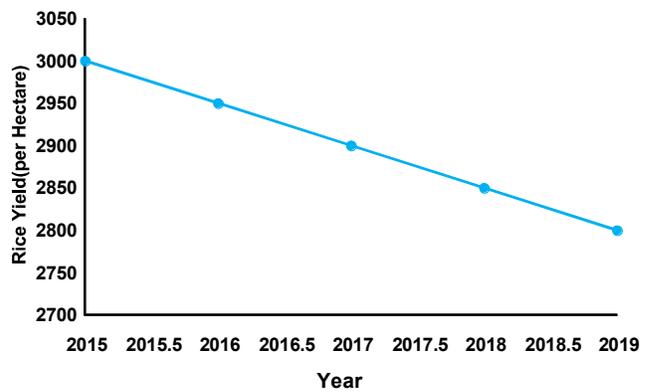
hectare (Fig. 4). Each subsequent year saw a slight decline in yield, with reductions of 50 to 100 kilograms per hectare annually (de Pee and Pérez-Escamilla 2022, Upasana 2023). This decline can be attributed to the negative impacts of river erosion, which leads to the loss of fertile agricultural land and soil degradation, resulting in lower crop productivity. The data suggests that the cumulative effects of erosion over time have contributed to a gradual but significant reduction in rice production, with implications for food security and agricultural sustainability in the affected regions. The loss of agricultural land significantly threatens food security by reducing domestic production of staple crops, leading to higher food prices and exacerbating poverty, particularly among low-income households. This situation is further aggravated by factors such as climate change, land degradation, and socio-economic inequalities, which collectively undermine food availability and access.

The decline in crop yields, especially in erosion-prone areas, highlights the urgent need for sustainable agricultural practices and effective land management strategies. The reduction in agricultural land directly affects food availability, as seen in the decline of rice production by 5% between 2015 and 2019 in erosion-prone areas (de Pee and Pérez-Escamilla 2022). Land degradation, including soil nutrient depletion, further diminishes crop yields and farming incomes, posing a significant threat to food security (de Pee and Pérez-Escamilla, 2022). Poverty is intricately linked to food insecurity, as economic inequality limits access to resources necessary for adequate nutrition (Ribotta 2023). The high incidence of poverty and unemployment exacerbates food insecurity, as seen in Nigeria, where unemployment significantly worsens food insecurity (Upasana 2023). While the loss of agricultural land poses a significant threat to food security, it is essential to consider the broader socio-economic and environmental context.

Changes in land use patterns: River erosion in Bangladesh significantly impacts agricultural productivity, leading to the loss of fertile land, reduced crop yields, and forced displacement of farmers. This phenomenon is exacerbated by the country's dense population and socio-economic pressures, which drive changes in land use patterns (Dey et al., 2022). The erosion-induced loss of soil particularly affects crops like rice and jute, which are heavily dependent on fertile soil. The consequences extend beyond agriculture, affecting food security and socio-economic stability. River erosion has led to a significant decrease in agricultural land, with a reduction of 11.68% in agricultural land use across various divisions in Bangladesh (Alam and Ahamed 2022). In the southwestern coastal areas, land use changes due to erosion and other climatic factors have resulted in decreased

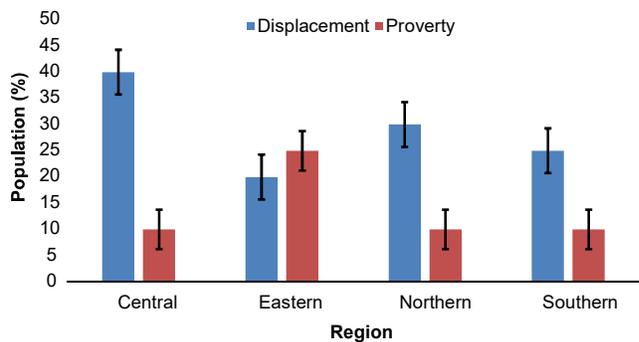
crop production and increased salinity, further reducing agricultural productivity (Islam et al., 2023). The shift from traditional crops like rice and jute to less soil-dependent crops is a direct consequence of soil erosion and land degradation (Hoque et al., 2022). The expansion of aquaculture, often replacing agricultural lands, has altered the landscape, impacting traditional farming practices and crop yields (Hasan et al., 2023).

Socio-economic impacts: Both the percentage of the population living in poverty and the levels of displacement caused by erosion (Fig. 5). In the Central region has the highest percentage of the population living in poverty, at 50%, followed by the Eastern region and Southern region, Northern region at 45, 40 and 35%. Central region also has the highest displacement rate, with 40% of its population displaced due to river erosion Followed by the Northern region with Southern region and Eastern, at 30, 25 and 20%, respectively. The study demonstrate that river erosion not only exacerbates poverty levels in affected areas but also forces significant portions of the population to migrate, further straining local economies and infrastructure. The socio-economic impact of erosion is particularly severe in the Central and Northern regions, where both poverty and displacement rates are highest.



Source: de Pee & Pérez-Escamilla 2022; Upasana 2023

Fig. 4. Decline in rice yield due to river erosion



Source: Khan et al., 2022; Kaiser 2023; Upasana 2023

Fig. 5. Socio-economic impact of river erosion

The socio-economic impacts of river erosion are profound, affecting both individuals and communities. River erosion leads to the loss of agricultural land, which is a primary source of income for many farmers, resulting in financial instability and poverty (Kaiser 2023). Displacement due to erosion forces communities to migrate, often to urban areas, exacerbating urban overcrowding and straining infrastructure (Tanjeela and Billah 2022, Ali and Ferdos 2024). This displacement disrupts social structures and increases dependency on government aid. Riverbank erosion results in the loss of cropland and property, severely affecting the livelihoods of those dependent on agriculture (Kaiser 2023). In Bangladesh, erosion-induced displacement leads to livelihood uncertainty, contributing to socio-economic instability and poverty. The severity of poverty among riverbank inhabitants is directly related to the degree of erosion (Rahman and Gain 2019, Kaiser 2023).

Correlation between erosion and agricultural productivity: Soil erosion significantly impacts agricultural productivity by degrading soil quality, which is crucial for crop growth (Hossain et al., 2020). This degradation leads to reduced soil fertility, loss of nutrients and diminished water retention capacity, ultimately affecting crop yields and economic stability for farming communities (Chowdhury et al. 2022, Hossain et al., 2020). In Bangladesh, where agriculture is a primary livelihood, these effects are particularly pronounced. Soil erosion reduces soil organic carbon, water holding capacity and nutrient availability, which are vital for crop productivity, severely eroded soils can see a decline in soil organic carbon by up to 81.4% and water holding capacity by 31% (Mandal et al., 2023, Musa et al., 2024). The loss of topsoil and nutrients due to erosion leads to decreased agricultural productivity, as seen in the Rangun watershed of Nepal, where productivity decreased by $0.238 \text{ t ha}^{-1} \text{ yr}^{-1}$ (Bhandari et al., 2021).

Mitigation strategies for river erosion: The review of secondary data highlights the significant negative impact of river erosion on agriculture in Bangladesh including land loss, reduced crop yields and, forced displacement are directly tied to the socio-economic vulnerability of farming communities. To mitigate these impacts, various strategies have been assessed for their effectiveness in reducing land loss due to river erosion. The strategies assessed include embankments, vegetative stabilization, crop diversification, and flood control measures, with each strategy given an impact score based on its projected effectiveness (Fig. 6). Among these, vegetative stabilization is projected to have the highest impact, with an impact score of 75, suggesting it is the most effective strategy to reduce erosion and stabilize riverbanks followed by crop diversification (score of 70).

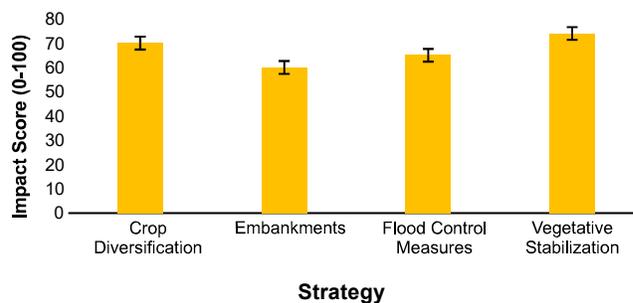


Fig. 6. Projected impact of mitigation strategies on erosion

Flood control measures score 65, highlighting their moderate effectiveness in mitigating erosion, while embankments score the lowest at 60. These findings highlight the significance of integrating multiple strategies for sustainable erosion management and agricultural resilience (Mondal and Patel 2018, Gazi et al., 2020). However, the combined effects of river erosion and its socio-economic repercussions highlights the need for targeted interventions. Effective land management strategies and sustainable agricultural practices are crucial to mitigating the adverse impacts of river erosion and ensuring food security in Bangladesh.

CONCLUSION

This study highlights the significant and ongoing impact of river erosion on agriculture in Bangladesh, emphasizing the vulnerability of agricultural land, which continues to be lost at alarming rates, threatening the sustainability of farming practices. Erosion-induced land degradation has led to decreased crop yields, particularly for staple crops such as rice and jute, which are highly dependent on fertile soils. These environmental changes have resulted in profound socio-economic consequences, including increased poverty and forced displacement, as affected communities migrate to urban areas, further straining local economies, and infrastructure. The changing land use patterns, particularly transition from traditional agriculture to aquaculture, illustrate the broader ecosystem disruptions induced by erosion. The study also indicates that various mitigation strategies, including vegetative stabilization, crop diversification, and flood control measures, have proven effective, with vegetative stabilization emerging as the most promising for sustainable erosion management. Overall, the findings emphasize the urgent need for integrated river management policies and sustainable agricultural practices to address the challenges of river erosion, ensuring the resilience of agricultural livelihoods and securing food security in the region.

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