International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review of Riverbank Erosion and Deposition Phenomena in Bangladesh

Md Nurul Kadir[1]* & Taznin Naher[2]

[1.] *Department of Agricultural Engineering, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.*
[2.] *River Research Institute, Harukandi, Faridpur, Bangladesh.*

A B S T R A C T

Excessive riverbank erosion and sedimentation threaten critical infrastructure, aquatic habitats, and water quality. In Bangladesh, a riverine nation, the impact of riverbank erosion is particularly pronounced. Countless Bangladeshis have seen their homes destroyed, compelling them to uproot their lives. This phenomenon predominantly affects the country's major rivers, such as the Ganges, Brahmaputra, and Meghna, along with their tributaries and distributaries. These rivers have eroded floodplains, and transportation infrastructure and displaced residents. To address this issue effectively, it is imperative to implement proper management strategies. However, a comprehensive understanding of the overall erosion and deposition dynamics of these rivers is a prerequisite for mitigation efforts. This paper seeks to provide an insightful review of the current erosion and deposition scenarios of these crucial waterways.

Keywords: Riverbank Shifting, Erosion, Sedimentation, Ganges-Brahmaputra-Meghna River, Floodplain management.

1. Introduction

Riverbank shifting (including erosion and sedimentation) has significantly shaped the physical, biotic, and demographic landscape for a long time (Hassan & Islam, 2016). Bangladesh is situated on the second-largest delta, the "Bengal delta" (Goodbred et al., 2003; Hori & Saito, 2007). With a mild north-to-south slope, this delta meets the Bay of Bengal in the south. The floodplain of Bangladesh is formed by enormous sediment deposition by many tributaries and distributaries of the rivers—the Ganges, the Brahmaputra, and the Meghna (GBM). These three rivers drain a catchment area of 1.74 million square kilometers, whereas approximately 7% of these catchments lie within Bangladesh (Figure 01) (Mirza, 2002). Annually, the river systems carry about two billion tons of sediment to the Bengal Delta (Hossain, M.Z., and Sakai, T., 2008). Indeed, the absolute length of the bank line of these significant rivers does not surpass 2,000 kilometers. However, more than 300 perennial tributaries and distributaries of this GBM river system make the total bank line around 150,000 kilometers. It has been estimated that 2,000 to 3,000 kilometers of this riverbank line experience significant erosion annually (Islam & Islam, 1985). Heavy siltation forms channel bars (Char land) inside the river course and changes the direction of river flows. The mechanism creates stress on the bank of the river, which causes erosion. In addition, substantial precipitation and abrupt flooding also influence and contribute to riverbank erosion (Hasan & Islam, 2016). The losses caused by erosion are usually slow and gradual. However, its baleful impacts are more in the long run than other natural hazards. The Flood Plan Coordination Organisation (FPCO) reports that 4.3 million inhabitants of the char land (growing island inside the river due to sedimentation) in the major river systems comprise the most vulnerable group in Bangladesh. Over 60,000 people have become landless due to riverbank erosion problems along the main rivers of Bangladesh.

On the other side, sedimentation also happens alongside the river. Around 33% of the yearly sediment load is stored in the river floodplain (Goodbred & Kuehl, 1998), 21% is deposited in the beds of the subaqueous delta (Michels et al., 2003), 20% adds into forest beds, and 25% is passed on to the Swatch of No Ground Canyon (Goodbred & Kuehl, 1998). 1-2% of the yearly sediment load adds to the sub-aerial delta (Allison, 1998).

This paper attempts to review the bank erosion and sedimentation of the rivers of Bangladesh. Understanding such erosion-sedimentation processes and techniques to detect such changes is beneficial for planning and managing the river's floodplain.

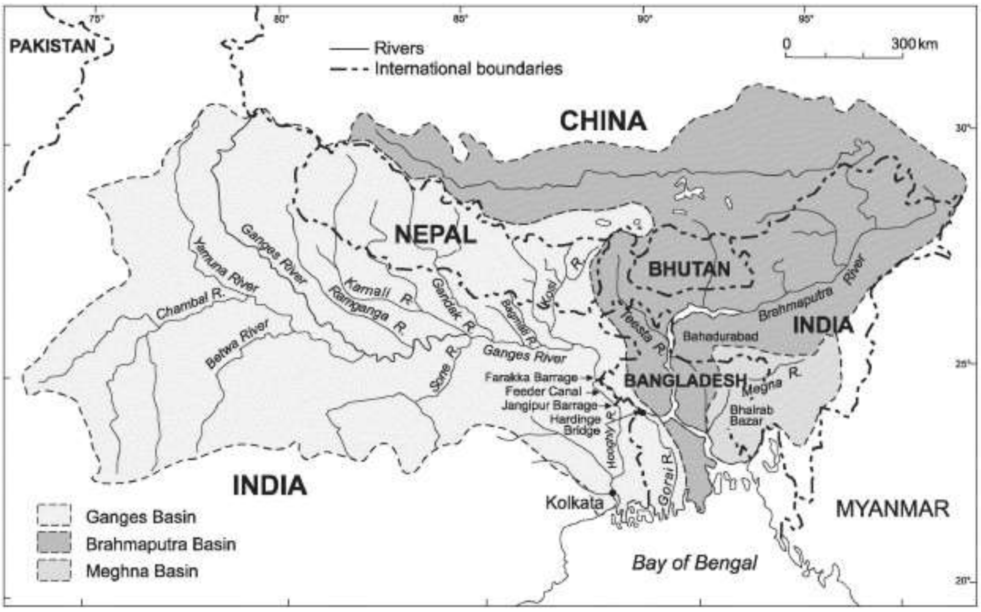

Figure 01: Geographical settings of the GBM basin. (Source: Mirza, 2002.)

2. Riverbank Shifting

2.1 River Dynamics and Erosion

River systems are in a dynamic harmony by adjusting between the water flow and sediment transport. When river channels are changed under naturally dynamic hydrologic conditions, the river readjusts itself by changing the dimension, profile, and pattern to reach its former balance or equilibrium (Couture, 2008). Free-flowing rivers tend to reach a state of equilibrium through erosion and sedimentation. Erosion at one location is balanced by deposition at another (CRJC, 1996). Various bank erosion processes occur throughout the river network, from upper reach to down reach. In the upper reach, close to its source, the river has a tremendous amount of material to cut through to reach a base level, so it primarily erodes downwards and creates a valley. The river continues to cut downwards and sideways/laterally in the middle reach. Once the river has reached the lower course (i.e., lower reach), it has almost reached its base level. Most of its erosive energy is concentrated on cutting laterally, creating features such as meanders. Figure 02 illustrates the occurrences of bank erosion along an idealized river network. The river bank erosion process in different sections of the river network is impacted by the discharge, size, shape, and flow strength (Florsheim et al., 2008). So, bank erosion is an ongoing natural process. Even rivers assumed to be stable today can be changed over a long period through erosion and sedimentation.

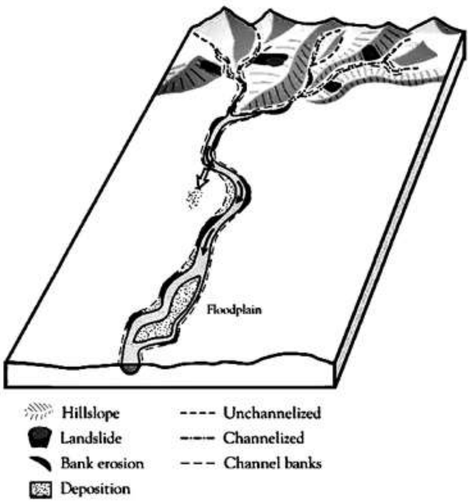

Figure 02: Bank erosion in different sections of an idealized river network. (Source: Florsheim et al., 2008)

A river becomes braided when the incoming sediment load exceeds the sediment-carrying capacity of the flow, resulting in an aggrading channel bed characterized by islands, locally known as "char" sandbars. The sediment particles of a braided river tend to settle down to the river's bottom due to gravity. However, they may remain suspended if the upward turbulent currents overcome the gravitational force (Alam et al., 2007), leading to a significant amount of suspended fine sediment load in the river. When the flow velocity decreases, the sediment suspended in the water will deposit on the river bed and river banks, a process known as 'River Bed Aggradations 'Bank Accretion.' ' A braided channel is characterized by multiple chars and mid-channel sandbars that separate the flow into several channels and tend to widen the river through bank erosion. This process of river widening and sediment becoming available from eroding banks would enhance the continued building of sandbars. As a result, clusters of sandbars could eventually merge to form more significant and permanent islands or chars (Sarker et al., 2003). The abandonment of any outflanking channel can convert islands into attached chars.

Considering the entire phenomenon, Das et al. (2014) classified the river channels into:

Straight – It is almost non-existent among natural rivers. Extremely short reaches of the river may be straight.

Meandering – It is a curved channel of the river. A meander is formed when moving water in a river erodes the outer banks and widens its valley, and the inner part of the river has less energy and deposits silt.

Braided – A channel consists of a network of small channels separated by small and often temporary islands called braid bars. Braided channels occur in rivers with high slopes and/or large sediment loads.

Anastomosing – Like braided channel, the branching of small channels from a single occurs at first, but after that, separated channels merge.

2.2 Riverbank Erosion/sedimentation in the rivers of Bangladesh

Riverbank Erosion is an endemic and intermittent natural hazard in Bangladesh. When rivers enter the mature stage (as in the GMB rivers), they become meandered or braided. These motions cause massive riverbank erosion. These rivers are assumed to have a braided pattern comprising a few channels isolated by little islands in their courses. Amid the most recent 200 years, the channels have been swinging between the central valley walls. Broad-over bank spills, bank erosion, and bank line shifts are expected during the rainstorm. The progressive relocation or moving of channels of the major rivers in Bangladesh ranges between 60 to 1,600m yearly (Rahman, 2010). The schematic view of moving conduct and infringements influence the floodplain populace, urban growth centres, and infrastructures (Figure 03).

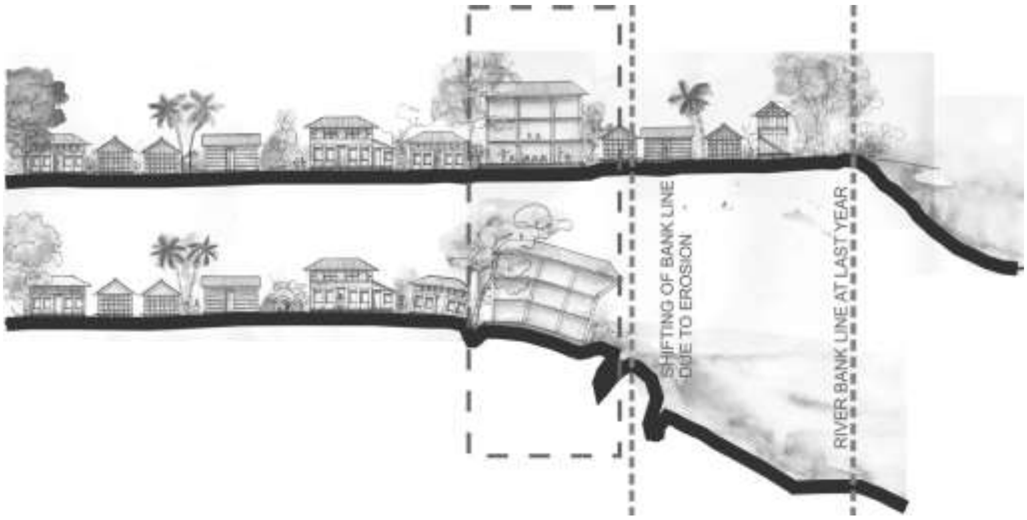

Figure 03: Section Showing Shifting of Bank Lines Due to River Erosion (Shajahan & Reja.,2012)

No systemic pattern has yet been seen in the erosion hazards because of the contribution of countless variables in the process. The force of bank erosion varies widely the river to river as it depends on such characteristics as bank material, water level variations, near bank flow velocities, plane form, and the amount of water and sediment in the river. Table 01 summarises some of the general characteristics of the major rivers as found in other literature in the recent past.

Table 01: General characteristics of the major rivers of Bangladesh

	Brahmaputra	Ganges	Meghna	Source
Total length L [km]	2,900	2,510	121	(Maswood & Hossain, 2016); (BanDuDeltAS, 2015)
Average rainfall [mm/year]	1,900	1,200	1,700	(Maswood & Hossain, 2016)
Average Discharge Qa [m3=s]	19,600	11,000	28,000	(Delft Hydraulics & DHI, 1996a)
Bankfull discharge Qb [m3/s]	48,000	43,000	75,000	(BanDuDeltAS, 2015) (Delft Hydraulics & DHI, 1996a)
Maximum discharge Qmax [m3/s]	100,000	78,000	128,000	(Maswood & Hossain, 2016)
Average Width	12	5	7	(BanDuDeltAS, 2015)

W [km]				(Delft Hydraulics & DHI, 1996a)
Suspended bed-material load Qsusp:[Mton/year]	125	76	227	(BanDuDeltAS, 2015)
Representative bed-material Grain size D50 [mm]	0.20	0.17	0.09-0.15	(Delft Hydraulics & DHI, 1996a)
Planform	Braided/ Anastomosing	Meanderin g/ Braided	Meanderin g	(BanDuDeltAS, 2015)

2.2.1 Brahmaputra River:

Among various major braided rivers in the world, the Brahmaputra River (also known as a Jamuna in Bangladesh side) is one of the largest and the most dynamic geo-morphologically (Figure 04a, 04b & 04c). The Brahmaputra is a braided river with bank materials that are exceptionally vulnerable to erosion. The average width of the river has vacillated significantly. It was found that the right bank of Brahmaputra was more prone to erosion than the left bank (Figure 04d) (Baki & Gan, 2012).

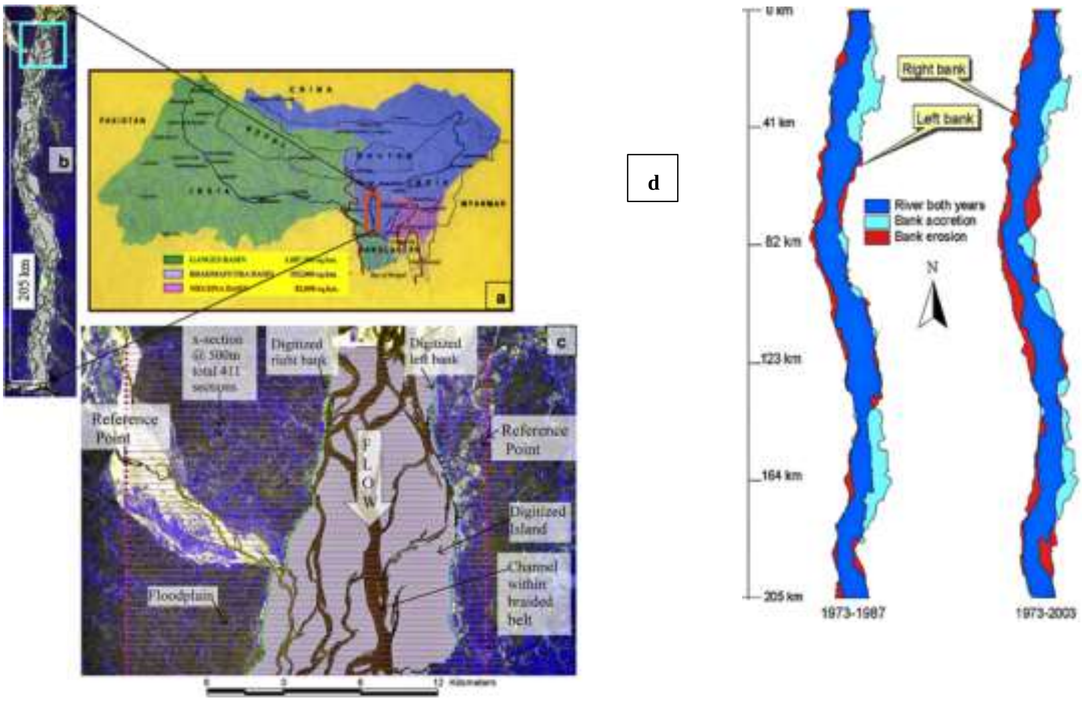

Figure 04: (a) The Jamuna River of the Ganges-Brahmaputra basin, (b) A 205 km reach length of Jamuna within Bangladesh, (c) enlarged reach length of Figure 04(b), and (d) Bank erosion and sedimentation of the Jamuna River, between 1973-1987, and 1973-2003. (Source: Baki & Gan, 2012).

The Brahmaputra determinedly extended from 1973 to the mid-nineties; however, the yearly rate appears to have gone down in the late nineties. The widening of the river in 28 years brought about the loss of a floodplain of 70,000 ha over the total 220km length of the river in Bangladesh (average of about 2,500 ha/year). Within the 1984-92 period, the river eroded 40,150 ha of floodplain accredited 7,140 ha, relating to an erosion rate of about 5,000 ha/year and a sedimentation rate of about 900 ha/year (Rahman, 2010).

Figure 05 (a) and (b) represent the bank movement (m/year) and bank shifting of the Brahmaputra River, respectively. From that figure, it is easily visible that bank movement and shifting in the Brahmaputra River is very high. The places where earlier was a river; now sand bars take those places, and the near floodplain lands are gone under the river.

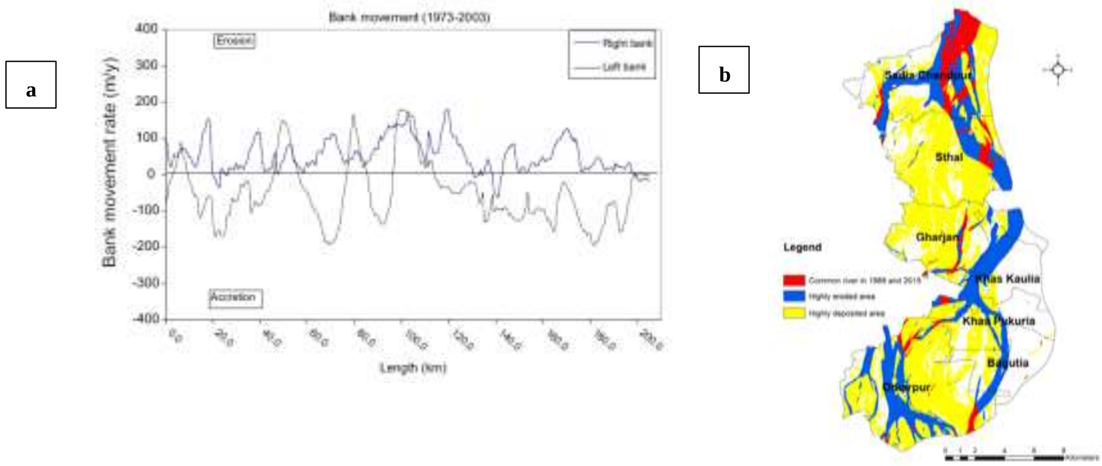

Figure 05: (a) The rates of bank movement (m/year) along the Jamuna River (Source: Baki & Gan,2012), and (b) Bank shifting in the Brahmaputra (also known as Jamuna) River (Source: Hasan & Islam, 2016)

2.2.2 Ganges River:

The Ganges is one of the three major rivers in Bangladesh and is morphologically exceedingly unique (CEGIS, 2010; Yeasmin, 2011). The Ganges River begins in the Gangotri Glacier of the Himalayas, goes through India, and subsequent to entering Bangladesh, it is known as Padma (Figure 06) (Sarifuzzaman et al., 2010). beds bed and banks of the Ganges/Padma River are fundamentally made out of alluvial materials (CEGIS, 2010). Due to fine sand and silty sediments with occasional clay, its banks are volatile (Mclean et al., 2012), and as often as possible, ceaseless erosion-sedimentation happens (Kammu et al., 2008).

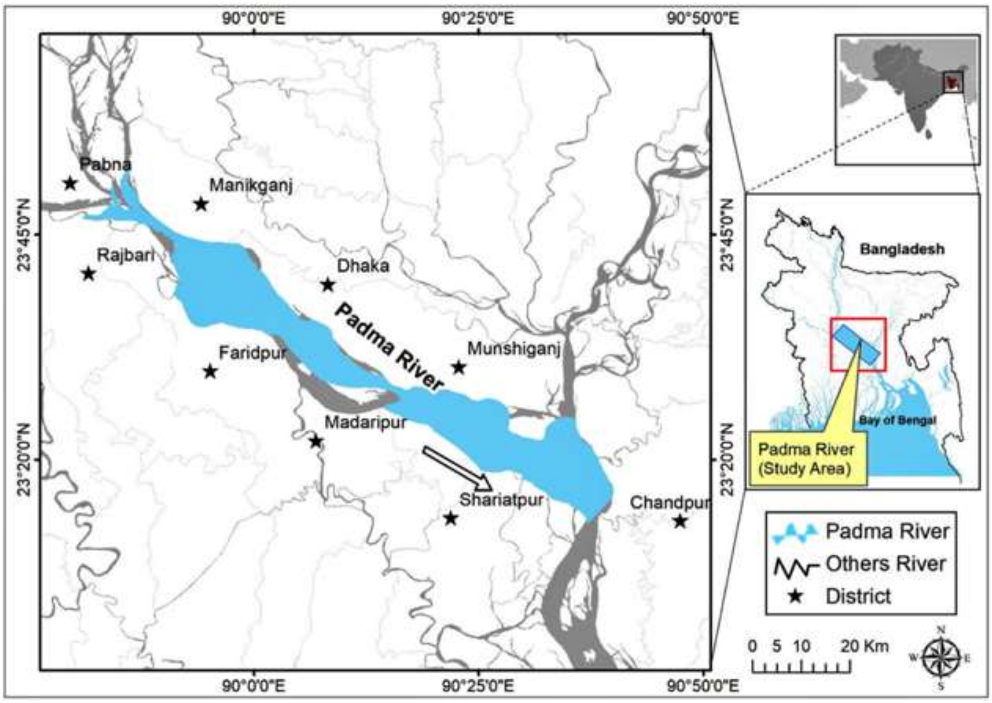

Figure 06: Location map of Ganges (also known as Padma) River (Source: Billah., 2018.)

Billah (2018) found that the total amount of erosion and sedimentation from 1975 to 2015 along both riverbanks were 49,951 ha and 83,333 ha, respectively. Amid this timeframe, the overall rate of erosion and sedimentation on both banks are 1,249 ha/yr and 2,083 ha/yr, respectively. There has been significant sedimentation in the Padma River over 40 years as compared to erosion. Erosion and sedimentation are more active on the right than on the left bank. From 1975 to 2015, in the left bank, the overall erosion was 24,387 ha at a rate of 610 ha/yr, and sedimentation was 36,037 ha at a rate of 901 ha/yr. Amid this time range, in the right bank, the overall erosion and sedimentation are 25,564 ha at a rate of 639 ha/yr and 47,297 ha at a rate of 1,142 ha/yr, respectively (Figure 07).

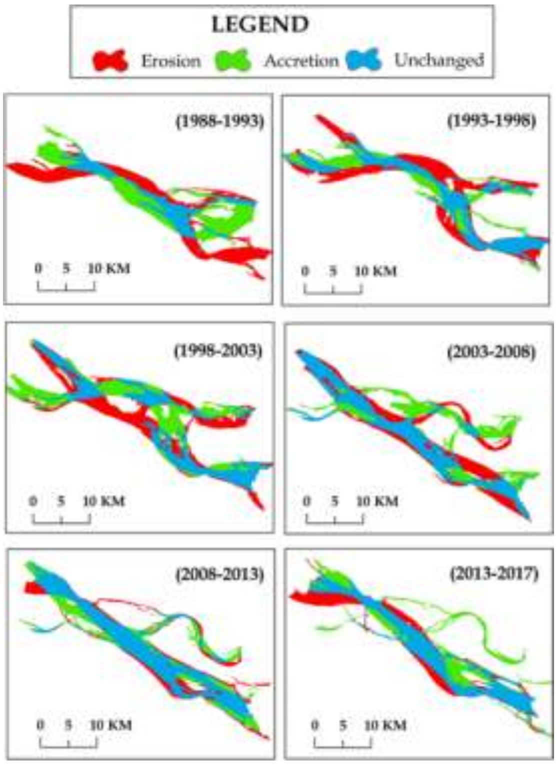

Figure 07: Riverbank erosion-accretion along the Padma River. (Source: Ophra et al., 2018.)

Another study was conducted by the Centre for Environment and Geographic Information Services (CEGIS, 2005) on the progressions of Bank Lines of the Padma River Based on Time-Series Satellite Images (Figure 08). From that review, it is found that the bank lines of the river have changed radically over the past 200 years and continue to change again. The Padma River has been changing from a single-threaded straight river to a multi-threaded braided river. These changes impact the yearly erosion and sedimentation process.

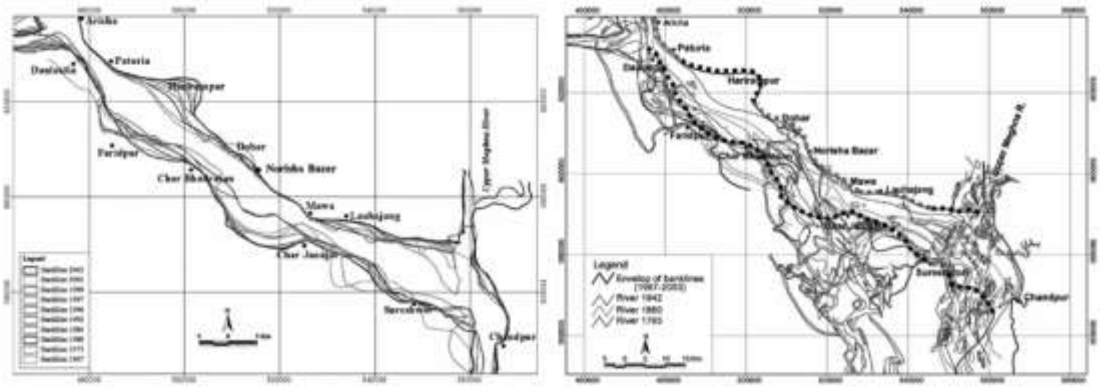

Figure 08: Bank Lines of the Padma River Based on Time-Series Satellite Images (Source: CEGIS. 2005)

2.2.2 Meghna River:

Unlike the other main rivers of Bangladesh, the Meghna is a stable and seemingly inert river (figure 09). The width of the river varied from 1 to 11.5 km in 1984, while the range of variation was 1 to 11.3 km in 1993 (Source: Sarker et al., 2011)

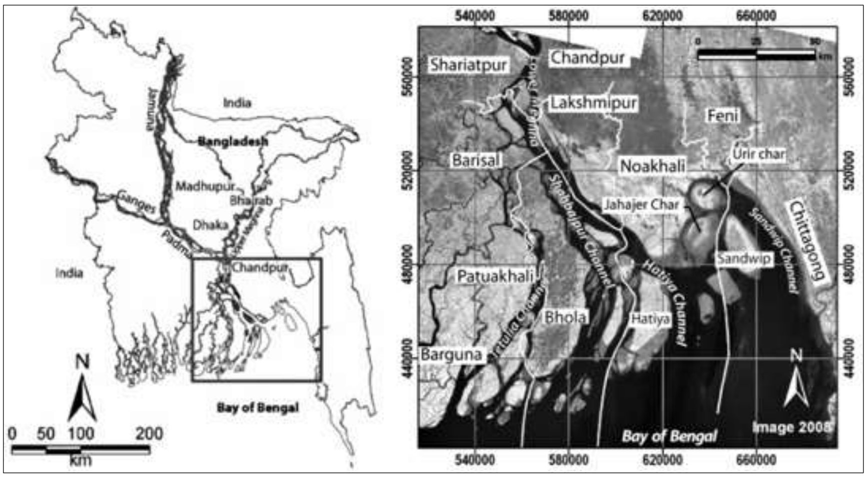

Figure 09: Location map of Meghna River (Source: Sarker et al., 2017)

Based on the analysis of satellite images, MES II (2001) estimated erosion and accretion for the period 1973–2000 (Table 02). During this period, 86,400 ha were eroded while 137,200 ha were accreted, resulting in a net accretion of 50,800 ha, equivalent to the net accretion rate of 1890 ha/yr.

Table 02: Erosion and accretion from 1973 to 2000 (MES II, 2001).

Period	Change (ha)		Rate of change (ha/yr)		Net accretion	Rate of net accretion
	Erosion	Accretion	Erosion	Accretion	(ha)	(ha/yr)
1973–2000	86,400	137,200	3200	5100	50,800	1890

The total accretion was about 60% higher than the erosion over 27 years and about 2.7 times higher than the net accretion.

Hassan et al, (2011) found sedimentation in the Meghna River is more dominating than erosion (Figure 10). Due to this sedimentation, lots of new lands formed in this river basin. This river also has some tidal effects as it carries all the sediment from Ganges-Brahmaputra and discharges it to the Bay of Bengal.

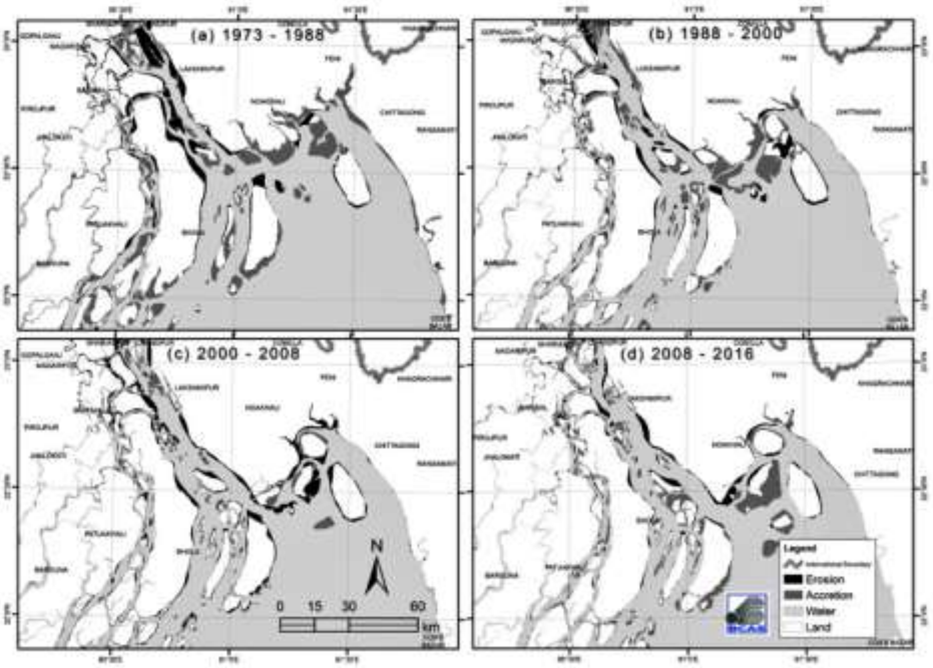

Figure 10: Erosion and accretion of Meghna River during 1973 – 2016 (Source: Hassan et al., 2011)

3. Discussion

The observed riverbank erosion and sedimentation along the major rivers of Bangladesh, including the Ganges, Brahmaputra, and Meghna, are issues of paramount concern. These phenomena have far-reaching consequences for both natural and human systems. The dynamic nature of riverbanks, as revealed in this review, underscores the need for action to address the challenges posed by erosion and sedimentation.

First and foremost, the impact on critical infrastructure cannot be overstated. Roads, railways, and settlements in the affected regions face continuous threats, leading to costly repairs and dislocation of communities. The alteration of riverbanks disrupts the delicate balance of ecosystems, potentially leading to long-term ecological consequences. Furthermore, the quality of water in these rivers can deteriorate due to the heightened sediment load, impacting both human consumption and agricultural practices.

The observed patterns of riverbank erosion and sedimentation are undoubtedly exacerbated by climate change. The anticipated increase in discharge and sediment flows in these rivers will only intensify the challenges faced by the people of Bangladesh. With climate change continuing to influence extreme weather events, the situation becomes even more critical. Bangladesh has already experienced numerous natural disasters, including cyclones and floods, which can trigger and exacerbate riverbank erosion. These phenomena have the potential to displace and disrupt the lives of countless individuals.

While the challenges posed by riverbank erosion and sedimentation are substantial, the data generated through this review provide a crucial foundation for informed decision-making and policy development. The necessity of a proactive approach to mitigate these issues cannot be overstated. Strategies to address riverbank erosion and sedimentation in Bangladesh must not only consider the immediate impact but also incorporate climate-resilient measures for the long term.

One potential strategy involves reinforcing riverbanks through a combination of natural and artificial structures. These may include afforestation projects to stabilize the soil, as well as the construction of embankments and levees to protect vulnerable areas. These measures can help to reduce the immediate risk and provide a buffer against further erosion. In addition to physical infrastructure, land-use planning and zoning regulations play a crucial role. Proper land-use practices can help minimize risks by limiting development in high-risk areas, preserving natural buffers, and ensuring that construction is resilient to potential erosion.

Furthermore, the establishment of early warning systems and community preparedness measures is essential. These systems can provide timely alerts to communities at risk, allowing them to evacuate and take protective measures. Additionally, education and awareness campaigns can empower communities to better understand and respond to the threat of riverbank erosion.

Overall, this discussion emphasizes the urgency of addressing riverbank erosion and sedimentation in Bangladesh. The findings from this review provide a critical foundation for informed decision-making and policy development, emphasizing the necessity of a proactive approach to mitigate these issues and ensure the sustainable coexistence of human and natural systems along these vital waterways. The challenges posed by climate change make it imperative to adapt and prepare for the future, protecting the people, infrastructure, and ecosystems of Bangladesh from the growing impact of riverbank erosion and sedimentation.

4. Conclusion

In conclusion, our comprehensive review underscores the profound impact of riverbank erosion and sedimentation on the major rivers of Bangladesh. These vital waterways are constantly in a state of flux, with their banks shifting and transforming over time. The dynamic nature of these processes, coupled with the increasing influence of climate change, presents a growing concern for the future. With expectations of higher discharge rates and increased sediment flows in these rivers, the challenges posed by erosion and sedimentation are poised to intensify. To safeguard the well-being of the region and its people, it is imperative that immediate and effective measures are put in place to mitigate the adverse effects of riverbank erosion and sedimentation. The future resilience of Bangladesh's riverine landscape hinges on proactive strategies, informed by a thorough understanding of the ongoing dynamics. As such, addressing this critical issue is not merely a choice but an absolute necessity, ensuring the preservation of infrastructure, the sustenance of aquatic ecosystems, and the maintenance of water availability for generations to come.

References

Alam, J. B., Uddin, M., Ahmed, U. J., Cacovean, H., Rahman, H. M., Banik, B. K., & Yesmin, N. (2007). Study of morphological change of river old Brahmaputra and its social impacts by remote sensing. Geographia Technica, 2, 1-11.

Allison, M. A. (2012). Historical changes in the Ganges-Brahmaputra delta front. Journal of Coastal Research, 14(4).

AZUMA, R., SEKIGUCHI, H., & ONO, T. (2007). Studies of High-resolution Morphodynamics with Special Reference to River Bank Erosion.

Baki, A. B. M., & Gan, T. Y. (2012). Riverbank migration and island dynamics of the braided Jamuna River of the Ganges–Brahmaputra basin using multi-temporal Landsat images. Quaternary International, 263, 148-161.Billah, M. M. (2018). Mapping and monitoring erosion-accretion in an alluvial river using satellite imagery–the river bank changes of River Padma river in Bangladesh. Quaestiones Geographicae, 37(3), 87-95.

BanDuDeltAS (Bangladesh Delta Plan 2100 formulation project), (2015). Baseline study on river systems management. Retrieved from http://www.bangladeshdeltaplan2100.Org/publications/baseline-studies/

CEGIS (Centre for Environmental and Geographical Information Services), (2010). Long-term Erosion Process of the Padma River. Prepared for Jamuna-Meghna River Erosion Mitigation Project. Bangladesh Water Development Board. Dhaka.

CEGIS (Centre for Environment and Geographic Information Services). (2005). Developing empirical

methods for predicting morphological changes in the Padma

Couture, S. (2008),"River Dynamics and Erosion, Presented to Great Bay Siltation Commission, December 1, 2000 "conference paper. Online version http://des.nh.gov/organization/divisions/water/wmb/coastal/ocean_policy/gb_commission. htm.

CRJC (1996), "River Dynamics and Erosion" Living with the River,

Charlestown, NH (Connecticut River Joint Commission (CRJC) http://crjc.org/erosion.htm.

Das, T. K., Haldar, S. K., Gupta, I. D., & Sen, S. (2014). River bank erosion induced human displacement and its consequences. Living Review of Landscape Research, 8(3), 1–35.

Delft Hydraulics & DHI – Danish Hydraulic Institute. (1996a). River Survey Project (FAP24): Main volume. Water Resources Planning Organization, Government of Bangladesh.

FPCO (Flood Plan Coordination Organization), Bank Erosion as a Desirable Attribute of River, BioScience, 58(6): 519–529.

Goodbred Jr, S. L., Kuehl, S. A., Steckler, M. S., & Sarker, M. H. (2003). Controls on facies distribution and stratigraphic preservation in the Ganges–Brahmaputra delta sequence. Sedimentary Geology, 155(3-4), 301-316.

Goodbred Jr, S. L., & Kuehl, S. A. Floodplain processes in the Bengal Basin and the storage of Ganges–Brahmaputra River sediment: an accretion study using 137Cs and 210Pb geochronology. Sedimentary Geology, 121(3-4), 239-258.

Hassan, S. T., Syed, M. A., & Mamun, N. (2017). Estimating erosion and accretion in the coast of Ganges-Brahmaputra-Meghna Delta in Bangladesh.

Hassan, M.S., and Mahmud-ul-islam, S. (2016). Quantifying River Bank Erosion and Bar Deposition in Chowhali Upazila, Sirajganj District of Bangladesh: A Remote Sensing Study. Journal of Geoscience and Environment Protection, 4, 50–57. http://dx.doi.org/10.4236/gep.2016.41006

Hori, K., & Saito, Y. (2007). Classification, architecture, and evolution of large-river deltas. Large rivers: Geomorphology and management, 75-96.

Islam, M. & Islam, A. (1985). A Brief Account of Bank Erosion, Model Studies and Bank Protective Works in Bangladesh. REIS Newsletter, 2, 11-13.

Kummu, M., Lu, X. X., Rasphone, A., Sarkkula, J., & Koponen, J. (2008). Riverbank changes along the Mekong River: remote sensing detection in the Vientiane–Nong Khai area. Quaternary International, 186(1), 100-112.

Maswood, M., & Hossain, F. (2016). Advancing river modeling in ungauged basins using satellite remote sensing: the case of the Ganges–Brahmaputra–Meghna basin. *International Journal of River Basin Management*, *14*(1), 103-117.

Mclean, D. G., Vasquez, J. A., Oberhagemann, K., & Sarker, M. H. (2012). Padma River morphodynamics near Padma Bridge. In River Flow 2012 (pp. 711-717). CRC Press.

Michels, K. H., Suckow, A., Breitzke, M., Kudrass, H. R., & Kottke, B. (2003). Sediment transport in the shelf canyon watch of No Ground" " (Bay of Bengal). Deep Sea Research Part II: Topical Studies in Oceanography, 50(5), 1003-1022.

Mirza, M. M. Q. (2002). Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Global environmental change, 12(2), 127-138.

MES, II. (2001). Hydro-morphological dynamics of the Meghna Estuary, Meghna Estuary Study (MESII). Prepared for BWDB, Dhaka, Bangladesh.

Ophra, S.J., Begum, S., Islam, R., & Islam, M.N. (2018). Assessment of bank erosion and channel shifting of Padma River in Bangladesh using RS and GIS techniques. *Spatial Information Research, 26*, 599–605.

Rahman, M. R. (2010). Impact of riverbank erosion hazard in the floodplain areas in Bangladesh. Journal of Science Foundation, 8(1-2), 55-65.

Sarker, M. H., Akter, J. A. K. I. A., Ferdous, M. R., & Noor, F. A. H. M. I. D. A. (2011). Sediment dispersal processes and management in coping with climate change in the Meghna Estuary, Bangladesh. In Proceedings of the Workshop on Sediment Problems and Sediment Management in Asian River Basins (pp. 203-218). (Hyderabad, India, IAHS: Publication 349,

Sarker, M. H., Huque, I., Alam, M., & Koudstaal, R. (2003). Rivers, chars, and char dwellers of Bangladesh. International Journal of River Basin Management, 1(1), 61-80. September 2014): http://pubs.er.usgs.gov/publication/pp282B

Shajahan, A., & Reja, M. Y. Riverbank Erosion and Sustainable Planning Guidelines for Bangladesh with Emphasis on Padma River. Journal of Habitat Engineering and Design 2012 Volume 4, Number 2, 145 – 156.

Sarifuzzaman M.N.E.A., Siddique M.A., Rahman M.A., Ahmed E., Alam A.M.S., (2010). Study of arsenic mobilization through the sediments of the Padma-Jamuna Belt. In: J. Jean, J. Bundschuh, P. Bhattacharya (eds), Arsenic in Geosphere and Human Diseases; Arsenic 2010. Paper presented at the Proceedings of the Third International Congress on Arsenic in the Environment (As-2010). London, CRC Press: 114–115.

Yeasmin, A., & Islam, N. (2011). Changing trends of channel pattern of the Ganges-Padma River. International Journal of Geomatics and Geosciences 2: 669–675.