

Meghna riverbank erosion on lives and livelihoods of rural people: impacts and coping strategies



Halima¹, Amima Najnin Maria^{1, a, *} 

¹ Department of Economics, Hamdard University Bangladesh, Munshiganj, Bangladesh,

* Correspondence: E-mail: anm.marnaj@gmail.com (corresponding author).

 ^a <https://orcid.org/0000-0002-0815-5299>

Abstract. Riverbank erosion is one of the most hazardous disaster types for Bangladesh. It has both a direct and a negative impact on people and their livelihoods. This study aims to explore the impacts of Meghna riverbank erosion and the coping strategies that have been adopted by the affected people to combat this calamity, considering four unions under Matlab Uttar of Chadpur District. The findings reveal that the occupational status, income and expenditure of the affected people have changed due to erosion. Ninety-one percent of the respondents' houses were fully damaged and 48% of them are living in shelter houses. The results also show that a large portion of the affected populace lost their assets and most of them are suffering from psychological distress. Around 87% of people borrowed money to cope with this hazard, and a strict law against sand dredging is recommended as one of the effective strategies to prevent Meghna river bank erosion.

Key words:
 riverbank erosion,
 livelihoods,
 impact,
 coping strategies,
 Bangladesh

Introduction

Bangladesh is a riverine and floodplain country and it is recognised as one of the most disaster prone countries in the world. The major part of it lies in the Ganges-Brahmaputra-Meghna Delta and it is Asia's largest and the world's most populated delta; it developed – and is continuously changing – through processes of alluvium and erosion by these three mighty rivers. Rivers have been playing a vital role in the lives and livelihoods of the people, and the poor especially are highly dependent on the river as a resource. However, rivers are dynamic by nature and continuously change their courses, and thus erosion and accrual are very common in the context of Bangladesh (Mollah and Ferdaush 2015).

Riverbank erosion is a natural erratic calamity and takes place year-round, which results in an enormous amount of land and forest loss, population displacement and landlessness (Rahman and Gain 2019). In Bangladesh, the riverine and coastal districts are certainly vulnerable to riverbank erosion and affected by this disaster several times. This calamity has serious adverse impacts and it causes permanent displacement and impoverishment of a large number of people living in these coastal districts (Khan et al. 2018).

Meghna is one of the holiest rivers in Bangladesh. Due to the meandering pattern and continuous lateral movement, it is associated with the development and cut-off of meander loops,

the growth of chars, and widespread bank erosion (Shahjahan and Reja 2012). A variety of studies of river bank erosion have been conducted so far, and have focused on different areas, but very little literature is available on the disastrous impact of Meghna riverbank erosion. Thus, this study aims to address the following objectives to understand the impact of riverbank erosion not only on long-term parameters (income and expenditure) but also on damage to other aspects (health, education, cost of living and psychological distress):

- To delineate the effect of riverbank erosion on economic condition and social life.
- To identify the psychological distress allied with displacement.
- To investigate the strategies in order to cope up with the erosion.

Overview of the World Risk Index

Riverbank erosion affects countries to different extents and this erosion not only leads to landscape

degradation but also has adverse environmental and socio-economic impacts (Ahmed and Fawzi 2009). In all cases, the extent of impacts on human settlements in any riverbank erosion situation depends on population density (Das et al. 2017).

Table 1 shows the world risk index, which has been determined on the basis of each country's vulnerability to natural hazards. It represents that people living in countries with a higher population density and having a lower *per capita* income are at higher risk of natural calamities.

In order to support the rationality of the proposed study, it is important to find out the research gap by reviewing the existing literature, which includes journals, reports and internet sources.

Das et al. (2014) reviewed some cases of river bank erosion and discussed the effects in the paper entitled "River Bank Erosion Induced Human Displacement and Its Consequences". It was observed that displaced people faced economic insecurity due to loss of agricultural land and became unemployed. Moreover, the victims also suffered from social insecurity due to deprivation of civic rights and health insecurity due to lack of basic infrastructure, etc. Along with this, Das

Table 1. Population density, economic condition and World Risk Index of different countries

Countries	¹ Population density/km ²	² <i>Per capita</i> income (international \$)	³ World Risk Index (%)	³ Vulnerability
Australia	3	50,844	4.54	25.10
Bangladesh	1,116	5,138	16.40	57.98
Egypt	102	12,718	1.78	47.98
Germany	235	53,571	2.63	22.81
India	420	6,283	6.62	52.94
New Zealand	18	41,072	5.11	28.81
Nigeria	223	5,065	13.09	66.56
Poland	121	16,740	3.04	39.17
United States	35	63,051	3.90	30.06
Vietnam	294	10,754	10.3	46.76

Classification	World Risk Index (%)	Vulnerability (%)
very low	0.31– 3.29	22.81 – 34.13
low	3.30– 5.67	34.14 – 42.38
medium	5.68– 7.58	42.39 – 48.12
high	7.59 – 10.75	48.13 – 61.49
very high	10.76– 49.74	61.50 – 76.34

Source: World Population Review (2020)¹, International Monetary Fund (2020)², World Risk Index Report 2020³

et al. (2017) assessed these long-term impacts of bank erosion along the River Ganges in the article titled "Impact of riverbank erosion: A case study". The findings of the survey showed that the long-term socio-economic impacts are severe, including increased income or expenditure and poverty. They also discussed human poverty in terms of poor living conditions, health and education and concluded with a discussion of rehabilitation policy.

Ghosh and Sahu (2019) aimed at finding out if there is any impact of river bank erosion on education of the erosion victims of the developing countries in the article entitled "The Impact of Population Displacement Due to River Bank Erosion on The Education of Erosion Victims: A Study in Jangipur Sub-Division of Murshidabad District, West Bengal, India". The result of the study revealed a positive and significant relation between population displacement and percentage of child labour. Additionally, a low mean year of schooling had been observed in nearly all selected study units of the people living along the river banks.

Keya and Harun (2007) explored the psychological stress of riverbank erosion on women in Bangladesh in their study "Riverbank Erosion induced Stress and Coping of Displaced Women in Bangladesh". Displaced women used less aggressive coping mechanisms, like more positive reappraisal and seeking social support, which is a sign of constructive adaptation strategy. In comparison with their non-displaced counterparts, the displaced women were found to use less self-control and focused on problem-solving strategies to cope with the bank erosion.

Islam et al. (2007) inspected the Meghna river bank erosion, population displacement and socio-economic impacts in Bangladesh in their article "Bank Erosion of the River Meghna: Population displacement and socio-economic impacts". Data revealed that the condition of the household size, educational attainment, labour force participation and occupational status, land holding and income were negatively affected at both individual and households levels due to the bank erosion.

Baki (2014) carried out both qualitative and quantitative research in his study entitled "Socio-Economic Impacts of Gorai Riverbank Erosion on People: A Case Study of Kumarkhali, Kushtia". The findings of the study revealed that the socio-

economic impacts of Gorai riverbank erosion on the people of Kumarkhali were crucial. The affected people have experienced substantial socio-economic hardship and among them 93% are impacted negatively, and 2% positively. Another study on socio-economic impact of erosion was conducted in the article "Socio-economic impacts of riverbank erosion on Durgapasha union in Bakergonj Upazila, Bangladesh". The findings showed that this hazard has a long-term impact on the livelihood pattern of people and, for most people, has an indirect impact on health by decreasing their expenditure, which does not allow them to meet their daily needs for food. In addition, most of the displaced people are now migrating to nearby cities to seek employment and involving themselves in hazardous jobs (Roy et al. 2017).

Rabbi et al. (2013) worked on the impact of riverbank erosion on the displaced people of Sirajganj in the article entitled "Recent Study on River Bank Erosion and Its Impacts on Land Displaced People in Sirajgonj Riverine Area of Bangladesh". The findings revealed that the lowest amount of land was eroded by the right bank of the river in 2005–2006 sessions. In addition, 55% of the people migrated permanently and 40% of the people shifted temporary due to the riverbank erosion. Another study was conducted by Shetu et al. (2016) to measure the economic losses of the affected people along with their food security condition in their article named "Population Displacement due to River Erosion in Sirajganj District: Socio-economic Impact and Food Security". The results showed that the level of income was positively significant while, the effect of age of the family head and family size were found to be significantly negative for the food safety status based on both calorie and protein intake.

Islam et al. (2017) investigated the impacts of Brahmaputra riverbank erosion hazard on livelihood pattern of char people, agriculture and environment in their article named "Impacts of riverbank erosion hazards in the Brahmaputra floodplain areas of Mymensingh in Bangladesh". The results revealed that erosion has an immense impact on livelihood, agriculture and environment, and that population displacement is a common phenomenon. The study has also explored that the people of the villages have to formulate and undertake various

adaptation techniques all by themselves without any organisational support.

Iva et al. (2017) focused on identifying the link between riverbank erosion and population displacement and tried to assess the economic condition of the people in the article “River bank erosion and its impact on population displacement in Bauphal upazila under Patuakhali district, Bangladesh”. They noted that folks lost their homestead area and house, had financial problems, changed their occupation and migrated from one place to another. Similarly, Rana et al. (2017) conducted a study on riverbank erosion and population migration in their article entitled “Impact of Riverbank Erosion on Population Migration and Resettlement of Bangladesh”. The study found out that two thirds of people migrated permanently from one union to another union not only because they got support from their relatives, friends and neighbours but also because living costs are lower there than in another area.

Bhuiyan et al. (2017) investigated the impacts of bank erosion on local people and livelihood vulnerability due to land loss. The study showed that the left bank was more vulnerable to erosion than the right bank, which destroyed permanent stable lands. As a result, a lot of large farmers have become marginal farmers and even been made landless due to this hazard. Moreover, agricultural land becomes infertile and the cropping pattern has changed significantly, and the infrastructure and property losses are enormous as well.

Arobi et al. (2019) aimed to find out the difference in mental health status and coping strategies between people affected and those not affected by riverbank erosion in Bangladesh in their article entitled “Impact of River Bank Erosion on Mental Health and Coping Capacity in Bangladesh”. The findings showed that the mental health well-being score of the non-affected group was significantly higher than the affected group. However, accounting for gender, income and age, the affected group had a statistically insignificant lower mean score in coping than the non-affected group.

Material and methods

The study area covers Matlab (Uttar) which is an Upazila of Chandpur district in the Division of Chittagong, Bangladesh. It has an area of 260 square kilometres and consists of 14 unions. The unions are Banganbari, Durgapur, Eastfatehpur, Eklaipur, Farajikandi, Gazra, Islamabad, Jahirabad, Kalakanda, Mohanpur, Sadullapur, Satnal, Sultanabad and Westfatehpur. Considering the main objectives of the study, three chars and one shelter house, namely, Jahirabad Char, Dasani, Char Charaiani and Amirabad shelter house were selected, being under four unions, namely, Jahirabad, Kalakanda, Satnal and Farajikandi, respectively. These unions are situated near the river Meghna and the chars under these four unions are highly affected by riverbank erosion.

The study is based on primary data and three chars and one shelter house of four unions of Matlab (Uttar) have been selected purposively and, later, simple random sampling was adopted for individual households. There are 197 households in Jahirabad Char, 107 households in Dasani, 90 households in Char Charaiani and 200 shelters in Amirabad shelter

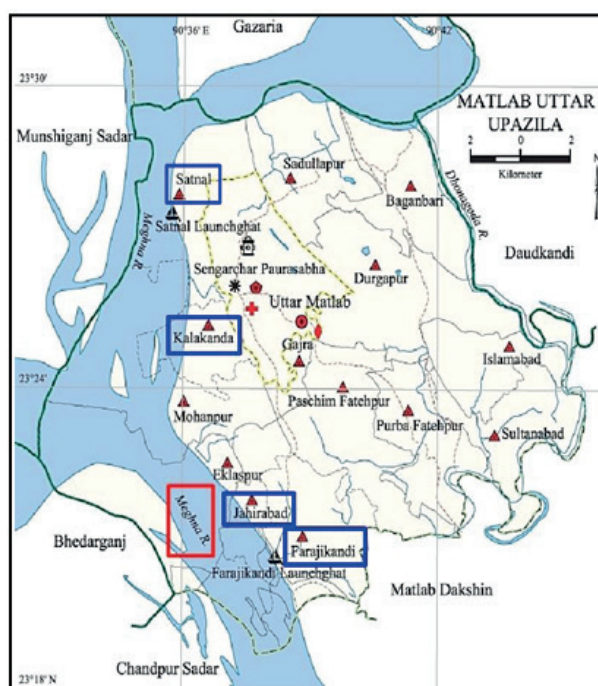


Fig. 1. Map of study area

Source: <https://www.thebangladesh.net/chittagong-division/chandpur-district/matlab-uttar-upazila-chandpur.html> (Retrieved March 18, 2020)

house. In total, 594 households were surveyed in the study area (Source: Bangladesh Bureau of Statistics [Population and Housing Census 2011]). By using 95% confidence level and 5% margin of error, altogether 240 samples were taken randomly from 594 households (15 October –10 December 2020) based on the Yamane (1967) formula, as follows: where;

$$n = \frac{N}{[1 + N(e)^2]} = \frac{594}{[1 + 594(0.05)^2]} = 240$$

n = sample size,

N = total number of households (594),

e = margin of error (0.05).

Descriptive statistical tools were used to illustrate the demographic and other characteristics of the re-

spondents. In addition, t-test was run to observe the pre and post impact of bank erosion on income and expenditure of the participants. Data were analysed using STATA version 14.2 and Microsoft Excel was used to create the necessary figures.

Results and discussion

Demographic information on respondents

The demographic profile of the study population is shown in Table 2. Out of 240 participants, 83.33% are male and around 17% of families are female-headed. The majority of the rural people belong

Table 2. Demographic information on respondents

Variables	Frequency	Percentage
Gender		
Male	200	83.33
Female	40	16.67
Age (in years)		
25–35	23	9.58
36–45	55	22.92
46–55	101	42.08
56–65	50	20.83
66 and above	11	4.58
Educational Status		
Illiterate	78	32.50
Below primary	30	12.50
Primary	94	39.17
Secondary	35	14.58
Higher secondary	3	1.25
Family Type		
Nuclear	158	65.83
Joint	82	34.17

Source: Calculation based on field survey, 2020 (n = 240)

to the age group 46–55 years and only 4.58% of the total respondents are above 66 years. A major portion of the participants are illiterate (32.50%) because they live under the poverty line and cannot bear the expense of education. In addition, above 65% of the people belong to a nuclear family.

Socio-economic status on respondents

The table illustrates the occupational status of the respondents before river erosion and after river erosion (Table 3). It shows that most of the rural people of the study area are illiterate; hence more than half of the participants (52.50%) were involved in working on agricultural land before erosion. In contrast, due to riverbank erosion this involvement

has fallen by approx. 20 percentage points to 30%. In addition, 22.08% were fishermen, 17.08% were involved in services, and only 8% were engaged in business. Conversely, due to bank erosion the involvement of people in business has doubled. Due to bank erosion a lot of people have lost their arable lands and been made both jobless and homeless. Some of the people faced this problem several times and thus they find it more convenient to have their own businesses. Farooq Ali pers. comm.: “I have lost my cultivating land due to bank erosion and now I and my son have started our own business.”

The income differences of the affected people is demonstrated in the above Table 4 and it is based on the hypothesis that “There is no difference in income of the respondents before and after river erosion”. The part of the descriptive statistics clearly

Table 3. Occupational status of respondents

Previous Occupational Status			Present Occupational Status		
Occupation	Frequency	Percentage	Occupation	Frequency	Percentage
Agriculture	126	52.50	Agriculture	72	30.00
Fishery	53	22.08	Fishery	63	26.25
Service	41	17.08	Service	64	26.67
Business	20	8.33	Business	41	17.08
Total	240	100.00	Total	240	100.00

Source: Calculation based on field survey, 2020

Table 4. Income difference of respondents

Description Statistics					
Income (monthly)	n	Mean		Std. Error	Std. Deviation
Before Erosion	240	13,608.33		333.6431	5,168.776
After Erosion	240	11,416.67		279.7293	4,333.548

Description Statistics					
Income (monthly)	Mean	Std. Dev.	95% Conf. Interval	t	p - value
Difference	2,191.66	3,508.02	1,745.59– 2,637.743	9.679	0.000

Source: Calculation based on field survey, 2020

Table 5. Expenditure difference of respondents

Description Statistics					
Income (monthly)	n	Mean		Std. Error	Std. Deviation
Before Erosion	240	13,716.67		528.1268	8,181.706
After Erosion	240	10,752.08		243.643	3,774.501

Description Statistics					
Income (monthly)	Mean	Std. Dev.	95% Conf. Interval	t	p - value
Difference	2,964.583	7,455.152	2,016.593 – 3,912.573	6.160	0.000

Source: Calculation based on field survey, 2020

shows the difference in mean income (monthly), where before erosion average monthly income was 13,608.33tk and it has declined by 2,191.66tk after erosion. Further, the part of inferential statistics, $p < 0.05$ indicates that the null hypothesis is rejected, hence proving the changes in income of the rural people due to bank erosion. Hamid Molla pers. comm.: “I am a poor farmer and I lost my arable land. My income was more than 10,000tk but now it is 5000tk only. My son is a school dropout because I am the only bread earner of my family and I cannot bear the expense anymore.”

Table 5 above shows the monthly household expenditure difference of the participants in the period before and after bank erosion and the result in the table is based on the hypothesis that “There is no difference in expenditure of the respondents before and after river erosion”. Table 5 expounds the fall in average monthly income of the people due to bank erosion. As a result of this reduction in income, the average monthly expenditure has also decreased from 13,716.67tk to 10,752.08tk (Descriptive Statistics). Moreover, the p -value ($p < 0.05$) in the table also indicates that there is a difference in monthly average expenditure of the affected people due to bank erosion.

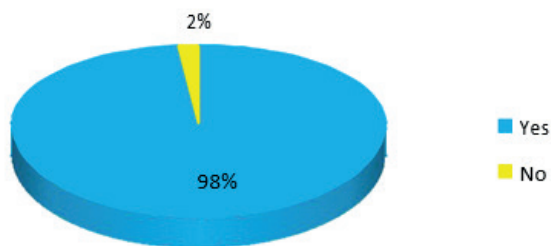


Fig. 2. Changes in social life due to river erosion
Source: Calculation based on field survey, 2020

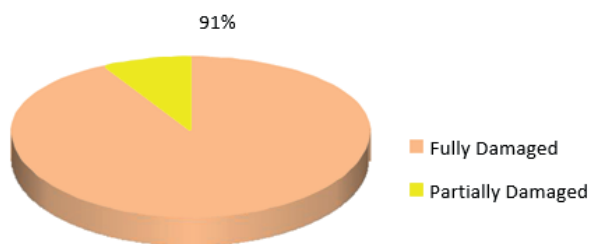


Fig. 3. Types of habitat damage due to river erosion
Source: Calculation based on field survey, 2020

Impact of riverbank erosion

Social life consists of several bonds and it can be measured by the quality of the life someone leads. It has a vital influence on the mental and physical state of a person. The following graph shows that 98% of the total respondents are in fragile condition and facing changes in social life due to Meghna river erosion (Fig. 2).

Habitat refers to the usage of houses for the sake of sheltering a family where the members live together and are closely related to each other. The majority (91%) of the participants’ houses were fully damaged and the remaining 9% respondents’ houses were partially damaged due to riverbank erosion (Fig. 3).

Figure 4 represents the present living status of the respondents. It shows that 48% of the affected people are living on shelter house and approximately 37% respondents live at their own house even though 91% were fully damaged due to bank erosion. A major portion of the respondents have built their house using polythene and tents. Out of the 240 participants, 9% and 6% live at their relative’s house and on the street, respectively, because of the river erosion. Abul Hossen pers. comm.: “I have an extended family. I had my own house but lost it due to riverbank erosion. Now, I am not financially capable enough to build a new house for us. My family is living in a shelter house now.”

Table 6 represents the psychological sufferings of the affected people as a result of riverbank erosion. It is quite alarming that all of the respondents are suffering from psychological stress due to bank erosion. Approximately 70% respondents opine that they feel dizziness when remembering the incident.

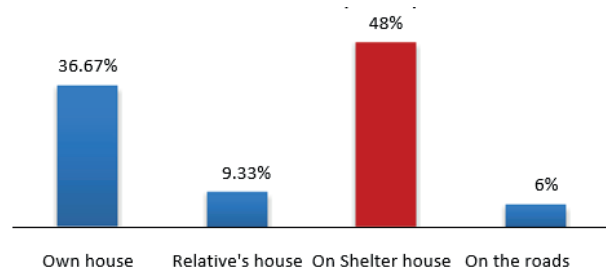


Fig. 4. Present living status
Source: Calculation based on field survey, 2020

Table 6. Psychological distress due to river erosion

	Frequency	Percentage
Suffering from Psychological Problem		
Yes	240	100
No	0	0
Total	240	100
Feeling remembering that incident		
Dizziness	167	69.58
Insomnia	55	77.08
Pain disorder	137	57.08
Flashback	137	57.08

Dichotomy group tabulated at value 1(Yes)

Source: Calculation based on field survey, 2020 (n = 240)

Table 7. Loss of livelihood due to riverbank erosion

Life Span (in years)	Loss of Livelihood				Total
	Never	1–3 times	4–6 times	7–9 times	
10–20	4	46	5	15	70
20–30	0	51	3	0	54
30–40	0	53	3	0	56
40–50	0	20	0	0	20
50–60	0	2	0	0	2
60 and above	0	0	23	15	38
Total	4(1.67%)	172(72%)	34(14%)	30(12.5%)	240

Pearson $\chi^2 = 247.285$ p-value = 0.000

Source: Calculation based on field survey, 2020

Table 8. Loss of assets

Properties	Percentage
Agricultural Land	72.08
Crops	68.33
Livestock	16.67
Poultry Farm	5.42
Hatchery	3.33
Homestead	93.33
Trees	89.17
Water Bodies	3.33
Home Appliances	74.58
Machinery and Other Equipment	2.92

Dichotomy group tabulated at value 1(Yes)

Source: Calculation based on field survey, 2020

Table 9. Cost of Living

Attributes	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
Food and Medical Cost	20.00	78.75	1.25	0	0
Cost of House Repairing	23.33	73.75	2.08	0.83	0
Cost of Education	12.08	81.25	6.67	0	0

Source: Calculation based on field survey, 2020

More than 75% people cannot sleep at night and 57% of the affected people have flashbacks and pain disorder (Table 6). Some of the participants pers. comm. that they cannot sleep at night remembering the incident and some of their family members have panic attacks. They cannot get any proper treatment because of the lack of doctors in rural areas.

Table 7 represents the linkage between life span (in years) of the respondents and loss of livelihood, based on the hypothesis "There is no association between life span and number of losses of livelihood". The result of the study shows that 98% of households suffered from bank erosion and lost their livelihood from 1 to 9 times depending on age. Since $p < 0.05$, we can reject the null hypothesis at 95% level of confidence. Hence we have enough evidence to support that there is a relationship between respondents' life span and loss of livelihood.

Table 8 above elucidates the loss of assets due to Meghna riverbank erosion. Most of the rural people have lost their homestead (93.33%) and home appliances (74.58%) along with their agricultural land (77.08%). Among them, 68% lost their crops and 89% lost trees that were their source of income.

Table 9 illustrates the perception of the participants about their cost of living. The five-point Likert scale (Strongly agree to strongly disagree) was employed to measure the respondents' perception. The frequent bank erosion has a negative impact on the cost of living of the affected people. More than 80% of people agreed that the cost of education has increased as compared to before and that, as a result, some of their children had dropped out from school. Since 90% of respondents' houses were fully damaged, therefore, around 74% people agreed that the cost of repairing houses has massively increased. A lot of people have lost their arable land and crops that were the sources of their food and earnings; as a result, approximately 79% agreed that they have to buy food from outside, which has raised their costs.

Coping strategies of affected people

Table 10 represents the results for coping strategies to fight against bank erosion. It shows that a significant portion of the participants of this study coped or adapted by borrowing money (86.67%) from different sources. About 50% of people were internally displaced or migrated to adjust to bank erosion. Since the income of the affected people has declined, to fight against this disaster, they take on extra workload so that they earn more to bear the cost of living. Since there is a stark increase in the educational cost, about 13% of them adjusted by decreasing the number of school-going offspring. Most of the respondents shared that they borrowed money from others to bear the expense of the family because they became unemployed immediately after the bank erosion. Each year a lot of people migrate due to this bank erosion. Some of them become homeless or live in a shelter house. Halim pers. comm.: "I borrowed a lot of money to survive and now I am struggling to repay them. I am doing overtime now so that I can pay the money back."

Recommended preventive strategies against riverbank erosion

The respondents of this study spontaneously recommended some strategies to prevent bank erosion and have drawn government attention to take necessary steps in order to help them to get rid of this severe problem (Table 11). A huge portion (95%) of the affected people have asked for a strict law against sand dredging, as this is one to the main reasons for the Meghna riverbank erosion. Almost 80% of the respondents opined that repairing dams has become necessary as the dams of the affected

Table 10. Adaptation strategies of bank erosion affected people

Coping Strategies	Frequency	Percentage
Internally displaced/migrated	129	53.75
Borrowed money	208	86.67
Changed their livelihood	68	28.75
Earning extra money by additional workload	124	51.67
By reducing meal(s)	47	19.58
Decrease the number of school-going children	30	12.50
Remove all children from formal education	42	17.50
Dichotomy group tabulated at value 1(Yes)		

Source: Calculation based on field survey, 2020

Table 11. Preventive strategies to cope with bank erosion

Preventive Strategies	Frequency	Percentage
Repairing dams	190	79.17
Riprap	188	78.33
River excavation	28	11.67
Set up of sluice gate	2	0.83
Cyclone shelter	26	10.83
Strict law against sand dredging	230	95.83
Dichotomy group tabulated at value 1(Yes)		

Source: Calculation based on field survey, 2020

area are of very poor quality. Seventy-eight percent of people recommended the use of riprap as one of the strategies to cope with bank erosion. Very few affected people suggested river excavation and cyclone shelters as preventive strategies against bank erosion.

Conclusion

Bangladesh is a flood-prone country and as per the world risk index it is the one of the most vulnerable countries in the world when it comes to natural disaster. Riverbank erosion is a dangerous natural calamity and every year a large number of people lose their habitats, arable lands, crops and other assets due to Meghna riverbank erosion. Ninety-one percent of the people's houses are fully damaged due to the erosion and nearly 50% live in a shelter house. The people of the study area are also facing financial crisis, food insecurity and psychological

stress. Approximately 87% of the rural people borrowed money and more than 50% migrated to other places and frequently change their settlement to cope with this disaster. It is high time to take necessary actions against sand dredging, as 95% of the victims recommended it to prevent river erosion. Besides the suggestions of the participants, some measures can be taken in order to ensure sustainable livelihoods of the affected or displaced people:

1. Training on disaster preparedness might be helpful for the rural people.
2. Since most of the affected people suffer from low income, loans should be given to them at low interest rates.
3. The rate of dropout of children is high in the affected area as the rural people want to reduce their expenditures. Government and other private organisation should come forward to help these people financially so that the children can continue their studies.

4. More shelter houses should be built so that the victims of bank erosions can have a shelter to live in immediately after being affected.
5. Relief should be sent to the affected people so that they can have food, not to suffer from hunger.

Disclosure statement

No potential conflict of interest was reported by the authors.

Author contributions

Study design: H; data collection H; statistical analysis: ANM; result interpretation ANM; manuscript preparation H, ANM; literature review: H.

References

- AHLBERG JH, NILSON EN and WALSH JL, 1967, The theory of splines and their applications. *Mathematics in Science and Engineering* 38, New York and London.
- AHMED AA and FAWZI A, 2009, Meandering and bank erosion of the River Nile and its environmental impact on the area between Sohag and El-Minia, Egypt. *Arab Journal of Geosciences* 4: 1–11.
- ARAI R and IWASAKI T, 2014, Crustal structure in the north-western part of the Izu collision zone in central Japan. *Earth Planet Space* 66: 1–12.
- AROBI S, NAHER J and SORON TR, 2019, Impact of River Bank Erosion on Mental Health and Coping Capacity in Bangladesh. *Global Psychiatry* 2(2): 195–200.
- BAKI ATM, 2014, *Socio-economic impacts of Gorai riverbank erosion on people: a case study of Kumarkhali, Kushtia*. PhD thesis. BRAC University.
- BANGLADESH BUREAU OF STATISTICS, BANGLADESH POPULATION AND HOUSING CENSUS, 2011, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.
- BHUIYAN MAH, ISLAM SMD and AZAM G, 2017, Exploring impacts and livelihood vulnerability of riverbank erosion hazard among rural household along the river Padma of Bangladesh. *Environmental Systems Research* 6(25): 1–15.
- DAS TK, HALDAR SK, GUPTA ID and SEN S, 2014, River Bank Erosion Induced Human Displacement and Its Consequences. *Living Reviews in Landscape Research* 8: 3–35.
- DAS TK, HALDAR SK, SARKAR D, BORDERON M, KIENBERGER S, GUPTA ID, KUNDU S and GUHA-SAPIR D, 2017, Impact of riverbank erosion: A case study. *Australasian Journal of Disaster and Trauma Studies* 21(2): 73–81.
- GHOSH D and SAHU AS, 2019, The impact of population displacement due to river bank erosion on the education of erosion victims: a study in Jangipur sub-division of Murshidabad district, West Bengal, India. *Bulletin of Geography. Socio-economic Series* 46(46): 103–118.
- INTERNATIONAL MONETARY FUND (IMF), 2020, World economic outlook database. Retrieved from <https://www.imf.org/external/datamapper/NGDPD-PC@WEO/OEMDC/ADVEC/WEOWORLD>
- ISLAM MA, PARVIN S and FARUKH MA, 2017, Impacts of riverbank erosion hazards in the Brahmaputra floodplain areas of Mymensingh in Bangladesh. *Progressive Agriculture* 28(2): 73–83.
- ISLAM MZ, ISLAM MN and AKTER ST, 2007, Bank erosion of the river Meghna: Population displacement and socioeconomic impacts. *Indian Journal of Power and River Valley Development* 57(10/11): 241–252.
- IVA TT, HAZRA P, FAISAL M, SAHA S and HOSSAIN S, 2017, River bank erosion and its impact on population displacement in Bauphalupazila under Patuakhali district, Bangladesh. *Journal of Science, Technology and Environment Informatics* 5(2): 371–381.
- KEYA MK and HARUN SMR, 2007, Riverbank erosion induced stress and coping of displaced women in Bangladesh. *Empowerment* 14: 17–30.
- KHAN B, NABIA SA and RAHMAN MA, 2018, The effect of riverbank erosion on lives and livelihoods of rural people: a study on Nolian village, Khulna, Bangladesh. *Journal of Science, Technology and Environment Informatics* 6(1): 466–473.
- MOLLAH TH and FERDAUSH J, 2015, Riverbank Erosion, Population Migration and Rural Vulnerability in Bangladesh (A Case Study on Gazipur Upazila at

- Sirajganj District). *Environment and Ecology Research* 3(5): 125–131.
- RABBI H, SAIFULLAH ASM, SHEIKH MS, SARKER MMH and BHOWMICK AC, 2013, Recent Study on River Bank Erosion and Its Impacts on Land Displaced People in Sirajganj Riverine Area of Bangladesh. *World Journal of Applied Environmental Chemistry* 2(2): 36–43.
- RAHMAN SM and GAIN A, 2019, Adaptation to river bank erosion induced displacement in Koyra Upazila of Bangladesh. *Progress in Disaster Science* 5: 100055.
- RANA MS and NESSA AM, 2017, Impact of Riverbank Erosion on Population Migration and Resettlement of Bangladesh. *Science Journal of Applied Mathematics and Statistics* 5(2): 60–69.
- ROY DK, GOSWAMI S, AHMED T, SAHA MK, EMON MH and RAHIM MA, 2017, Socio-Economic Impacts of River Bank Erosion on Durgapasha Union in Bakerganj Upazila, Bangladesh. *Barisal University Journal Part 1* 4(1): 165–183.
- SHAJAHAN A and REJA MY, 2012, Riverbank Erosion and Sustainable Planning Guidelines for Bangladesh. *Journal of Habitat Engineering and Design* 2(2): 145–156.
- SHETU MSR, ISLAM M, RAHMAN KMM and ANISUZZAMAN M, 2016, Population Displacement due to River Erosion in Sirajganj District: Socio-economic Impact and Food Security. *Journal of Bangladesh Agricultural University* 14(2): 191–199. DOI: [10.3329/jbau.v14i2.32694](https://doi.org/10.3329/jbau.v14i2.32694).
- WORLD POPULATION REVIEW, 2020, 2020 Revision of World Population Prospects. Retrieved from <https://worldpopulationreview.com>
- WORLD RISK REPORT, 2020, World Risk Index 2020 Overview. Germany: Bündnis Entwicklung Hilft and Ruhr University Bochum – Institute for International Law of Peace and Armed Conflict (IFHV).
- YAMANE T, 1967, *Statistics: An Introductory Analysis, 2nd Edition*. Harper and Row, New York.

Received 05 March 2021

Accepted 27 June 2021