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Impact of riverbank erosion on riparian society: a micro-level study along the Ganga-Padma river in Samserganj C.D. Block of Murshidabad District, West Bengal

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Abstract. The present paper is a micro-level study aimed at analyzing the impacts of riverbank erosion on riparian society. To fulfill the objective, the study has been carried out from two distinctive perspectives; viz. general outlooks and specific inquiry. For the general outlook, the Ganga-Padma river in its lower reach downstream of Farakka Barrage in Samserganj Community Development Block has been explored in terms of channel shifting using multi-dated satellite images. For specific inquiry, the effects of riverbank erosion on society have been studied using primary data in two selected active bank-erosion-prone cadastral units. The results show that recurrent bank erosion has brought a drastic change in the social fabric and caused huge losses rendering riparian inhabitants quite vulnerable, since most of the people in the study units are dependent on land-based economy and belong to poor economic groups. These situations necessitate significant outside assistance. However, there is a significant difference ($\chi 2 = 10.85$ at $p<0.01$) in terms of assistance received during the previous year between the two selected study units.

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1. Introduction

The Ganga River (entered as "Padma" in Bangladesh), after skipping the Rajmahal hills, shares its lower course in Malda and Murshidabad districts of Indian territory. The lower reach of the river after Farakka Barrage in Murshidabad extended up to Jalangi, a stretch of about 102 km (Rudra, 2006), and has been subjected to changes in its course at various times, adjusting with time and space, leading to lateral mobility along with the emergence and submergence of riverine islands (Chakraborty, 2017). The morphological characteristics of the Ganga-Padma channel form a complex interaction of channel dynamics and sediment characteristics (Md and Islam, 2016). According to Meade (1996, as cited by Bhuiyan et al., 2017) about 600 million tonnes of sediments are deposited annually in the Bengal delta. Over-siltation on the river bed decreases the channel depth and thus, in the rainy season or at the time of over-discharge, the river's capacity to transport the excess discharge and sediments is impeded; this causes the river to become unstable and to adjust its channel configuration depending upon the varying nature of morphometric variables. Channel instability and rhythmic fluctuation through erosion–deposition sequences are very common phenomena. Most of the alluvial rivers in monsoon climates basically exhibit a system of dynamic equilibrium in their lower course. According to Couture (2008) (as cited by Ghosh, 2015: 16584):

> *"When river channels are altered under naturally dynamic hydrologic conditions, the river readjusts itself with respect to dimension, profile, and pattern to reach its former balance or equilibrium."*

When the deposition process is active on one side, the erosion process is active on the other bank side, as a free-flowing river always tries to adjust the equilibrium condition through erosion, transportation and deposition processes (Ghosh, 2015). Therefore, "River bank erosion is a natural geomorphic process which implies separation and entrainment of bank materials in form of grains, aggregates or blocks by fluvial, sub-aerial, and/or geo-mechanical processes" (Islam, 2016: 13) and it is not a serious problem so far as no human existence is present. But being a socio-economically backward district of West Bengal, the impact of riverine hazards on the local community residing along downstream of Farakka Barrage of the Ganga-Padma river covering 11 Community Development Blocks (C.D. Blocks) of Murshidabad district is a great concern to geographers (Chakraborty, 2017). Again, Ghosh (2015) considered riverbank erosion and flood to be twin environmental hazards of the Murshidabad district, but the effect of bank erosion on society and the economy is greater and has a prolonged effect on riparian livelihood than the effect of flood which yields huge environmental neo-refugees in the district. "It is no less than 10000 people who are evicted every year from their homelands by erosion in Murshidabad district alone" (Rudra, 1996: 26). Land and property losses are the foremost impact of bank erosion hazard on the economy, and the homeless victims of erosion become environmental neo-refugees in search of new habitation after losing their settlements. They are forced to resettle with uncertainty, poverty, vulnerability, border clash between nations, improper governance, etc. within a paralyzed socio-economic setup (Ghosh and Sahu, 2018a). Though these are age-old problems along the downstream, considerable morphometric changes have been reported in the river system since the construction of Farakka Barrage on the Ganga-Padma river in 1975, and those changes in turn have enhanced the severity of these problems (Rudra, 1996; Chakraborty, 2017).

While researching the nature, causes and consequences of Bhagirathi riverbank erosion in Nadia, Islam (2016) noted that the severity of bank erosion is not always proportional to social vulnerability, because social vulnerability is often determined by socio-economic factors as well. Islam (2016) also identified a paralyzed socio-psychological terrain of erosion victims who have lost their assets and lands due to bank erosion and have been forced to leave their familiar homeland. Chatterjee and Mistri (2013) commented on the impact that the Bhagirathi riverbank erosion has on the socio-economic lives of the poor inhabitants in Shantipur Block of Nadia district, where erosion causes mass population displacement and huge economic losses, rendering the people into poverty. Ghosh and Sahu (2018b), while studying the socio-economic problems associated with the Ganga-Padma riverbank failure in Dhulian municipality area, identified a very poor level of development of erosion victims in respect of their basic infrastructural facility. Again, Ghosh and Sahu (2019) identified a positive association between population displacement due to riverbank erosion and education of the erosion victims in Jangipur sub-division of Murshidabad district. Now the question arises: why did bank erosion along the Ganga-Padma river in the present study area emerge as an environmental problem? In this context, a study has been done at the level of the *mouza* (small administrative units in India) to unearth the adverse impacts of bank erosion on the riparian social environment in specific and, in general, to explore the Ganga-Padma river in its lower reach in terms of channel shifting.

Additionally, a study is also done to understand the livelihood adjustment and adaptation strategies of the riparian inhabitants with the adversities induced by bank line shifting, which is also almost ignored in the previous works. The major findings of the paper show that changing hydro-geomorphic parameters of the channel make the Ganga-Padma river quite instable. Consequently, the channel starts to readjust itself by frequent channel lengthening by bank erosion. Devastating bank failure in the study area has brought a drastic change in the social and economic life of the riparian inhabitants, and the adversities associated with riverbank erosion every year burdened the riparian inhabitants with adjusting and adapting their livelihood using their indigenous coping strategies. From this point of view, the study is significant as it is a synthetic one taking into consideration physical geography as well as human geography to understand the problems of riverbank erosion. Thus, the paper will not only allow the readers to understand the problem of riverbank erosion holistically but also will be useful to the administration in adopting proper management strategies for riverbank erosion and its impact on riparian society.

2. Study area

The study area is Samserganj C.D. Block under Jangipur sub-division in Murshidabad district of West Bengal, India. The locational extent of this area is 24°42'12"N–24°36'21"N and 87°52'32"E – 88°2'14" E (Fig. 1). Since the present study concerns the nature of riverbank erosion and its impact on society and the economy, the study is a synthetic one taking into consideration physical geography as well as human geography. From the standpoint of physical geography, the present study area is located on the western bank of the Ganga-Padma river, which is one of the most active bank-erosion-prone areas downstream of Farakka Barrage. Again, from the standpoint of human geography, the study area is well defined as it marks an inconsistent social mosaic triggered by bank erosion of the Ganga-Padma river.

3. Materials and methods

The study includes data from both primary and secondary sources. Primary data was collected through extensive field surveys. The collection of multi-dated secondary data was given top priority because the current study is focused on the shifting of the Ganga-Padma river channel. Cadastral maps (Revenue survey 1913–1917, Government of West Bengal); satellite images of different years (Table 1) have been taken for detecting the oscillating nature of the Ganga-Padma river within the study area by on-screen digitization of the course of the river in GIS environment. To visualize the depth of the Ganga-Padma river, the USGS's (United States Geological Survey) Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) (30-meter spatial resolution) data has been used. In addition, published data from various Government authorities like *Census Handbook: Murshidabad, 2011*, Directorate of Census Operations, West Bengal, India; *District Disaster Management Plan: Murshidabad, 2018-2019*, West Bengal Disaster Management and Civil Defense Department, etc. were used for the study. Other relevant information has been collected from various articles in different journals, books, etc. A total of two erosion-affected cadastral units (*mouza*) along the western bank of the Ganga-Padma river in Samserganj C.D. Block were selected purposively as sample sites to identify the impact of riverbank erosion on society considering the severity of bank erosion in these areas. The *mouzas* are Loharpur (J.L. No. 102) and Nimtita (J.L. No. 108). But to unfold the impacts of bank erosion upon the socio-economic environment of these sample sites, sample households were chosen randomly along the riverbank from each *mouza*.

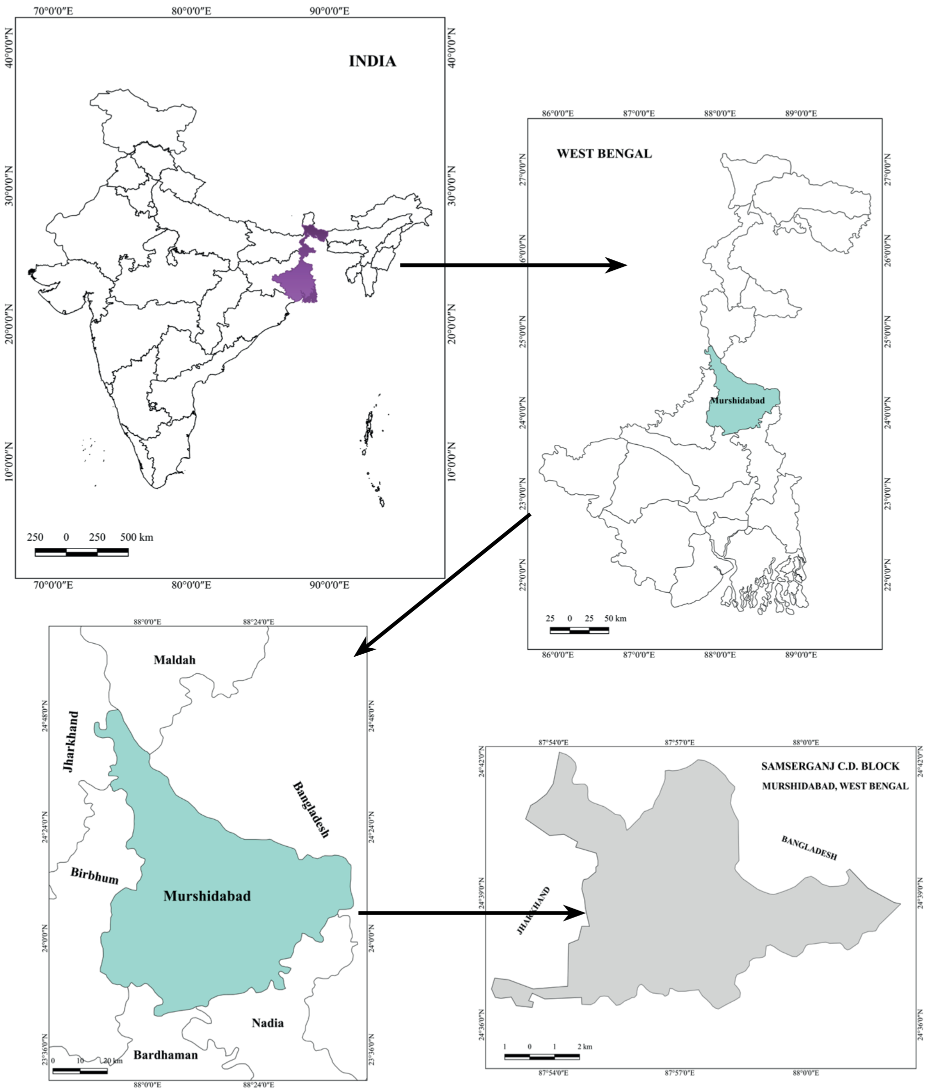

Fig. 1. Location map of the study area
Source: Authors' work

3.1. River morphometric indices used in this study

Sinuosity Index (S.I.)

This is the calculation of the deviation of the observed path (O_L) from the expected path (E_L) of a channel (Singh, 2019). In this study, the method of S.A. Schumm (1963) was adopted to compute the S.I value. It is represented in the following formula:

$$S.I. = {}^{O_L}/_{E_L}$$

where, O_L= Observed length of the river; E_L = Expected length of the river.

Based on the above equation, Schumm identified five categories of channel sinuosity; viz. straight course when S.I. is 1.0, transitional course, regular course, irregular course, and tortuous course, and he also clarified braided and meandering channels have S.I. values of 1.06 and 1.49, respectively (Singh, 2019).

Braiding Index (BI)

This is an important measure to understand the stability of riverine islands. "J.C. Brice (1964) has devised a braiding index to determine the degree of braiding" (as cited by Singh, 2019).

$$BI = \frac{2\text{ (Sum of the length of islands or bars)}}{\text{Length of the reach}}$$

Table 1. Detail of satellite images

Date of acquisition	Projection	Datum	Resolution	Source
23.12.1990	UTM	WGS 84	30 m	LANDSAT 5 (TM)
10.12.2000, 04.11.2010	UTM	WGS 84	30 m	LANDSAT 7 (ETM+)
25.12.2020	UTM	WGS 84	30 m	LANDSAT 8 (OLI/TIRS)

Source: own elaboration

3.2. Statistical technique used in this study

Chi-square test

The chi-square test is a non-parametric inferential statistics. The basis of Chi-square analysis is the comparison of frequencies expected under precisely defined conditions with frequencies observed in the actual pattern under investigation (Mahmood, 2019). It is represented in the following formula:

$$x^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

where, x^2 = Chi-square value; O_i = Observed data frequencies; and E_i = Expected values of the distribution.

3.3. Other techniques used for socio-economic data analysis

Infrastructural Index

The Infrastructural Index propounded by the United Nations Development Program (UNDP, 2011) (as cited by Ghosh & Sahu, 2018b) was calculated to identify the level of development of the erosion victims with regard to infrastructural facilities. The parameters for calculating the Infrastructural Index for the present study units are not similar to the Infrastructural Index propounded by UNDP. The following parameters were selected for calculating Infrastructural Index after Ghosh and Sahu (2018b).

- Infrastructural Index: *Per-Capita* Small Savings Index (in Rs/Month) + Toilet Facility Index + Household Having Electric Facility Index + Drinking Water Facility Index + Doctors Facility Index/5
- Dimension Index: (Actual Value-minimum Value/Maximum Value-minimum Value)
- *Per-Capita* Small Savings (in Rs/Month): (Total small savings of each area/Total population of area)
- Toilet Facility Index: (Total no. of toilets in area /Total no. of population of area)
- Household Having Electric Facility Index: (Total no. of household having electricity facility/Total no. of household)
- Drinking Water Facility Index: (Total no. of tube-wells in area/Total population of area)
- Doctors Facility Index: (Total no. of doctors in area/Total population of area)

Effective literacy rate

The literacy rate calculated taking into consideration population aged 7 and above in the denominator is termed as effective literacy rate (*Census*, 2011). The formula for computing effective literacy rate is as follows:

$$\text{Effective Literacy Rate} = \frac{\text{Number of literate persons aged 7 and above} \times 100}{\text{Population aged 7 and above}}$$

4. Results and discussion

4.1. The scenario of changing channel morphometric variables in terms of channel configuration and instability in the Ganga-Padma river downstream of Farakka Barrage

The changing course of the Ganga-Padma river downstream of Farakka Barrage from 1990 to 2020 has been analyzed here taking into account some crucial channel morphometric variables (e.g., sinuosity, braidedness) directly associated with such changes through erosion–deposition sequences with the help of satellite images for the respective years

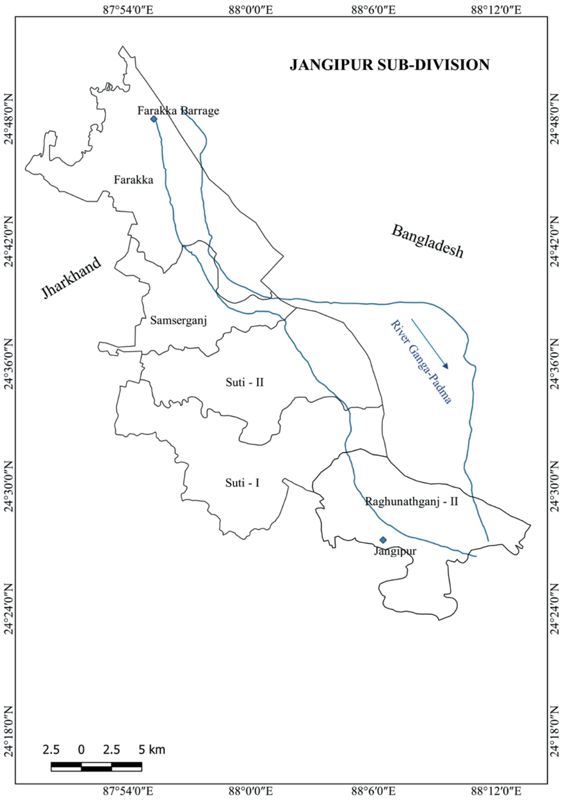

Fig. 2. Flow path of river Ganga-Padma over Jangipur sub-division
Source: authors' work

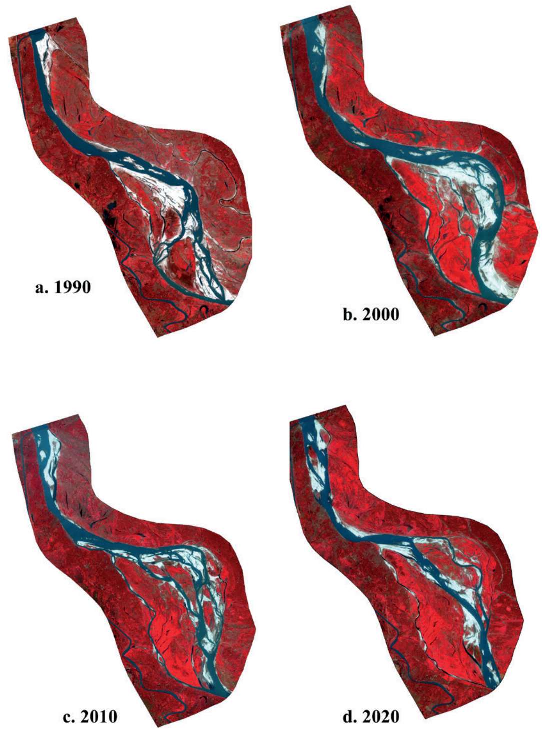

Fig. 3. Ganga-Padma river course during different decades (based on satellite images as in Table 1)
Source: authors' work

(Table 1). Since it is difficult to assess the hydro-morphometric variables in terms of bank line shifting within a small reach, hence a ~55-km-long reach extending from Farakka Barrage in the north to Jangipur in the south has been considered for better understanding. This selected reach of the river passes through a total of five C.D. Blocks under the Jangipur sub-division (i.e., Farkka, Samserganj, Suti-II, Suti-I, and Raghunathganj-II (Fig. 2).

Sinuosity of the Ganga-Padma

The sinuosity index (SI) exhibits the displacement of the actual path from the theoretical path of a river channel. For the investigation, the last four decades have been taken into consideration adopting the formula of Schumm (1963). The maximum value of the sinuosity index (i.e., 1.20) of this selected reach was found for the year 2010 and the lowest sinuosity index (i.e., 1.14) was found for the year

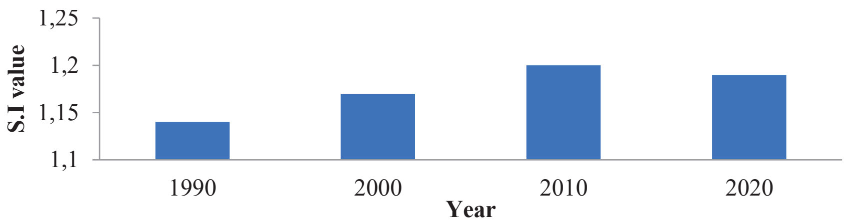

Fig. 4. Increasing trend of Sinuosity Index during last four decades between the reach from Farakka Barrage to Jangipur of Ganga-Padma river (Computed by the authors, based on satellite images as in Table 1)
Source: authors' work

1990 (Fig. 4). The sinuosity index of the years 2000 and 2020 was found to be 1.17 and 1.19, respectively (Fig. 4). Such a rise and fall in SI initially indicates frequent channel lengthening by bank erosion and shortening by chute cut-off (Islam, 2016).

Braidedness of the Ganga-Padma

A braided river consists of multiple channels wherein these channel ways are separated by bars and riverine islands (Singh, 2019). The braiding of a river channel primarily initiates with the formation of a mid-channel bar or *char* land, which bifurcates the channel, diverting the original flow towards the riverbanks. Consequently, the banks, having erodible geomaterials, are eroded, leading to channel widening. The eroded bank materials increase additional bars and islands which in turn further divide the channels (Singh, 2019).

From the computed Braiding Index (after J.C. Brice, 1964) of the last four decades, it is clear that the bars of the Ganga-Padma river in Jangipur Subdivision are unstable because the Braiding Index values are not constant. They vary from 3.03 in the year 1990 to 3.52 in the year 2020 (Fig. 5). It is also observed that the channel area was considerably changed by the sudden huge sedimentation in the channel, and the Braiding Index became 3.56 and drops a bit to the year 2020. The lowest Braiding Index was found at 2.89 for the year 2000, when the number of braided channels was lessened (Fig. 5).

Width of the Ganga-Padma

To measure the channel width of the respective years, a total of six cross-sections (i.e., A, B, C, D, E, and F) were drawn manually across the channel segment between Farakka Barrage and Jangipur (Fig. 6).

Figure 7 depicts that, in the present years, the river is wider than in the previous years. Areas where bars have formed in the river have stretched the most. The highest width of the river in the respective segment was 11.369 km along cross-section E in 2010. The lowest width was 1.451 km along line B in 1990. The river is less wide along lines A, B and C and became much wider along lines D, E and F during the last four decades. Line A falls under Farakka C.D. Block, which shows its lowest channel width of 2.595 km in the year 2000 and highest width in 2020. Lines B and C fall under Samserganj C.D. Block. Line B, located near Dhulian, shows its lowest width of 1.451 km in 1990 and highest width in 2020. Line C is located near Loharpur, where the lowest channel width was 2.664 km in the year 2000, and the highest width was found in 2010 but again dropped a bit in 2020. Line D falls under Suti-II C.D. Block, where the lowest width was 5.456 km and the highest width was 11.138 km in 2010. The rest of the years also exhibit a drastic increase in channel width from the width found in 1990. Line E falls under Suti-I C.D. Block, which shows the lowest channel width in 1990, i.e. 7.284 km, and the highest width in 2010, i.e. 11.369 km. Line F falls under Raghunathganj-II C.D. Block, which shows a lowest width of 5.69 km in 1990, and the years 2000 and 2010 also reveal very minor widening, but a sudden increase in width along the line is reported in 2020 (i.e., 7.132 km) (Fig. 7). The increased sediment load aided in increasing the channel width by forming a huge number of bars and islands and consequent lateral erosion in the post-Farakka Barrage construction period (Chakraborty, 2017).

Depth of the Ganga-Padma

The Ganga-Padma river in its lower reach amplifies itself by lateral movement, and thus the channel depth decreases. In places where the width of the valley lessens, the depth increases. To visualize river depth from DEM data, different cross-sectional lines were drawn along the respective segment of the Ganga-Padma river; viz. AB, CD, EF, GH, and IJ (Fig. 8). In the northern part of the study area, the AB cross-sectional line shows that the river flows in a single channel. The CD cross-sectional line shows that the river flows in a bi-channel (Fig. 9). The EF cross-sectional line shows the presence of a point bar in the western bank and river flows in a single channel (Fig. 9). Cross-sectional line GH exhibits the presence of numerous *char* lands with varying elevations. Along this cross-section, river water is passing through multiple channels with varying depths but the midrib along the section line shows a greater depth than the rest. Along the IJ cross-sectional line, the presence of *chars* forming a multi-channel to convey river water freely was also found (Fig. 9).

4.2 Shifting of bank lines over the period

Superimposing the digitized bank lines of the years 1990, 2000, 2010, and 2020 and total seven cross-sections (i.e., A, B, C, D, E, F and G) were drawn manually to measure the extension of bank line shifting in a GIS environment (Fig. 10). In this regard, the reach between Farakka Barrage and

Jangipur has been taken into consideration to get a vivid picture of bank line shifting. The negative values in Table 2 indicate erosion and the positive values indicate deposition across the drawn cross-sectional lines.

Table 2 reveals that, in the time span between the years 1990 and 2000, the amount of maximum negative shifting – i.e., erosion along the western bank of the river occurred across cross-section C in the amount of −40.466 meters. This cross-sectional line falls under Samserganj C.D. Block near Dhulian town. But in this period, along the eastern bank maximum negative shifting has been noticed along the cross-section F, and the amount of shifting is −3751.541 meters. The highest positive shifting (which means deposition) along the western bank has been found at 69.448 meters along the cross-sectional line F, and the highest amount of

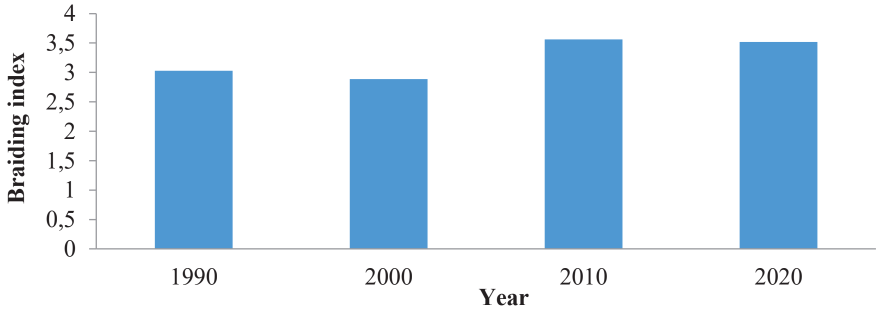

Fig. 5. Braiding Index of different years in Ganga-Padma river between the reach from Farakka Barrage to Jangipur (Computed by the authors, based on satellite images as in Table 1)
Source: authors' work

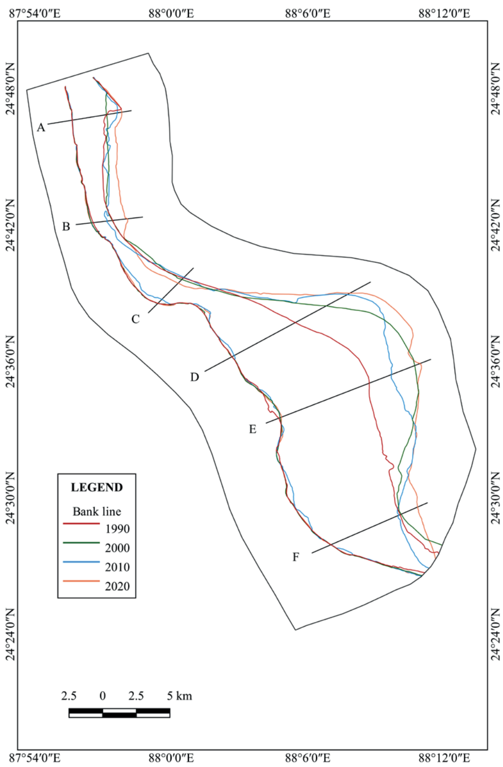

Fig. 6. Different cross sections are drawn along the selected reach between Farakka Barrage to Jangipur to measure the Ganga-Padma river width in different years (based on satellite images as in Table 1).
Source: authors' work

deposition along the eastern bank has been found at 255.589 meters along the cross-section D, which falls under Samserganj C.D. Block and is located near Loharpur. All of the cross-sectional lines except F and D show negative bank line shifting in this time tenure. In 2010, the western bank shifted −53.923 meters westward from its position in 2000 and this highest amount of negative shifting along the western bank occurred along cross-section G. Along the eastern bank the highest amount of negative shifting has been found −3217.429 meters along the cross-section E between 2000 and 2010. In this period the highest amount of positive sifting (i.e., deposition) along the western bank has been found at 63.274 meters along cross-section F, and the highest amount of deposition along the eastern bank was 156.422 meters along the cross-sectional line C, which is located near Dhulian town. The period between the years 2010 and 2020 is slightly different from the previous time tenures because during this tenure the amount of deposition along the western bank of the river was much greater. The highest amount of erosion was −16.902 meters along cross-section F, and the highest amount of deposition was 101.757 meters along cross-section G. Remarkable deposition was also found along the eastern bank, but the amount of erosion is greater than deposition here. The highest amount of deposition was 1058.391 meters along cross-section

E and the highest amount of erosion was –1194.256 meters along cross-section G.

4.3. Nature of bank erosion in the representative *mouzas*

Bank erosion along the Ganga-Padma river is a hazard of both national and international significance since the river at this segment acts as an Indo-Bangladesh boundary, but the channel shifting and emergence and submergence of *char* lands often originate intentional border disputes between the two neighboring countries. Most of the villages and towns along the banks of the Ganga-Padma river throughout the district have felt the impulse of episodic erosion since time immemorial (Ghosh & Sahu, 2018b; Rudra, 1996). According to Rudra (2006), the present site of Dhulian town under Samserganj C.D. Block is reportedly the fourth site it has occupied. Bank line shifting and bank erosion have been assessed here at the micro level (*mouza* level) for long-term changes. The extent of river shifting was shown along the Nimtita *mouza* under Nimtita *Gram Pnachayat* (G.P.) and Loharpur *mouza* under Pratapganj G.P. of Samserganj C.D. Block in 1915–2000 with the help of the cadastral map and satellite images using geoinformatics. The investigated *mouza*s are located on the western bank of the Ganga-Padma river. From comparative study of the *mouza* maps of the mid-1910s and recent maps of 2000 based on field survey and satellite images, it is observed that both of the selected *mouza*s are threatened by the hazard of riverbank oscillation. In the case of Loharpur, the river moved southward of the *mouza*, engulfing nearly 5.89% of the *mouza* area (Fig. 11, 12, 13) from 1915 to 2000. Out of this 5.89% grabbed by the river, nearly 5.86 p.p. is covered by channel while about 0.031% emerged as *char* (Fig. 13). The total amount of deposition along the bank and mid-channel is nearly 7.4% of the *mouza* area during this period (Fig. 13).

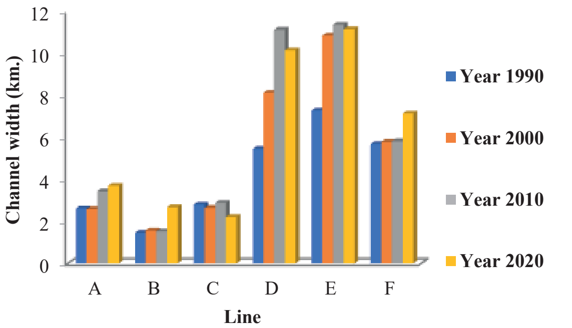

Fig. 7 . Ganga-Padma river width changes during the last four decades along different cross sections (Computed by the authors, based on Fig. 6)
Source: authors' work

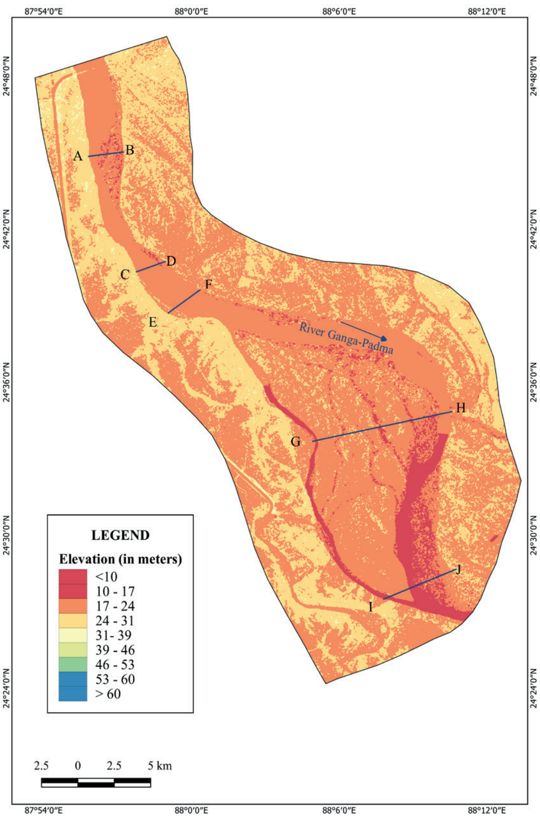

Fig. 8. Different cross sections are drawn along the selected reach between Farakka Barrage to Jangipur to measure the Ganga-Padma river depth (based on SRTM DEM data, 2000)
Source: authors' work

For Nimtita, the river moved north of the *mouza* (more specifically, towards the interior portion of the *mouza*), snatching nearly 13.43% of the total *mouza* area within the same period (Fig. 13, 14, 15). At the southern portion, the channel shifted eastward of the *mouza*, resulting in the deposition of nearly 1.55% of the total *mouza* area (Fig. 15). Out of the two surveyed *mouza*s, the maximum amount of erosion and deposition relative to their respective areas occurred at Nimtita.

Actually, the very weak textured soil of this segment, which is composed of unconsolidated micaceous geomaterials at the bottom and a thin silt-clay layer upon it, makes the riverbank vulnerable to erosion when the fast-flowing turbulent water current acts along the bank obliquely and removes unconsolidated sandy materials from the base of the shelving bank, which ultimately collapses (Rudra,

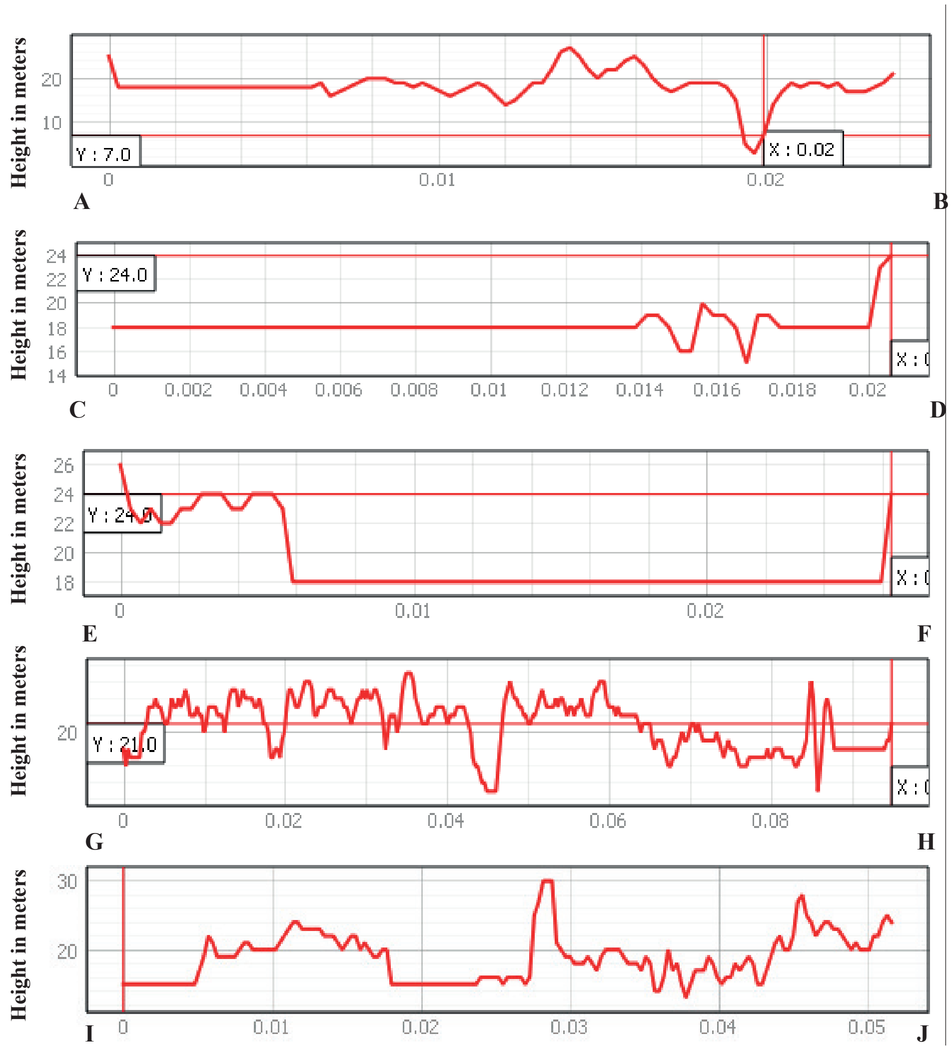

Fig. 9. River depth along the sketched cross sections in the selected reach of river Ganga-Padma (based on Fig. 8)
Source: authors' work

Table 2. Bank line shifting of Ganga-Padma river on cross-sections during 1990–2020 (in meters)

Cross-sections	1990–2000		2000–2010		2010–2020	
	Left bank	Right bank	Left bank	Right bank	Left bank	Right bank
A	-0.059	-116.948	-4.988	-768.432	40.343	-332.925
B	-6.57	-451.803	-25.286	-47.213	-1.33	-520.993
C	-40.466	-12.862	-9.769	156.422	57.25	-565.161
D	-25.399	255.589	-5.291	-317.944	2.226	910.164
E	-15.22	-2586.681	-19.84	-3217.429	-10.247	1058.391
F	69.448	-3751.541	63.274	-51.512	-16.902	38.202
G	-4.593	-185.44	-53.923	-232.264	101.757	-1194.265

Source: Computed by the authors (based on Fig. 10)

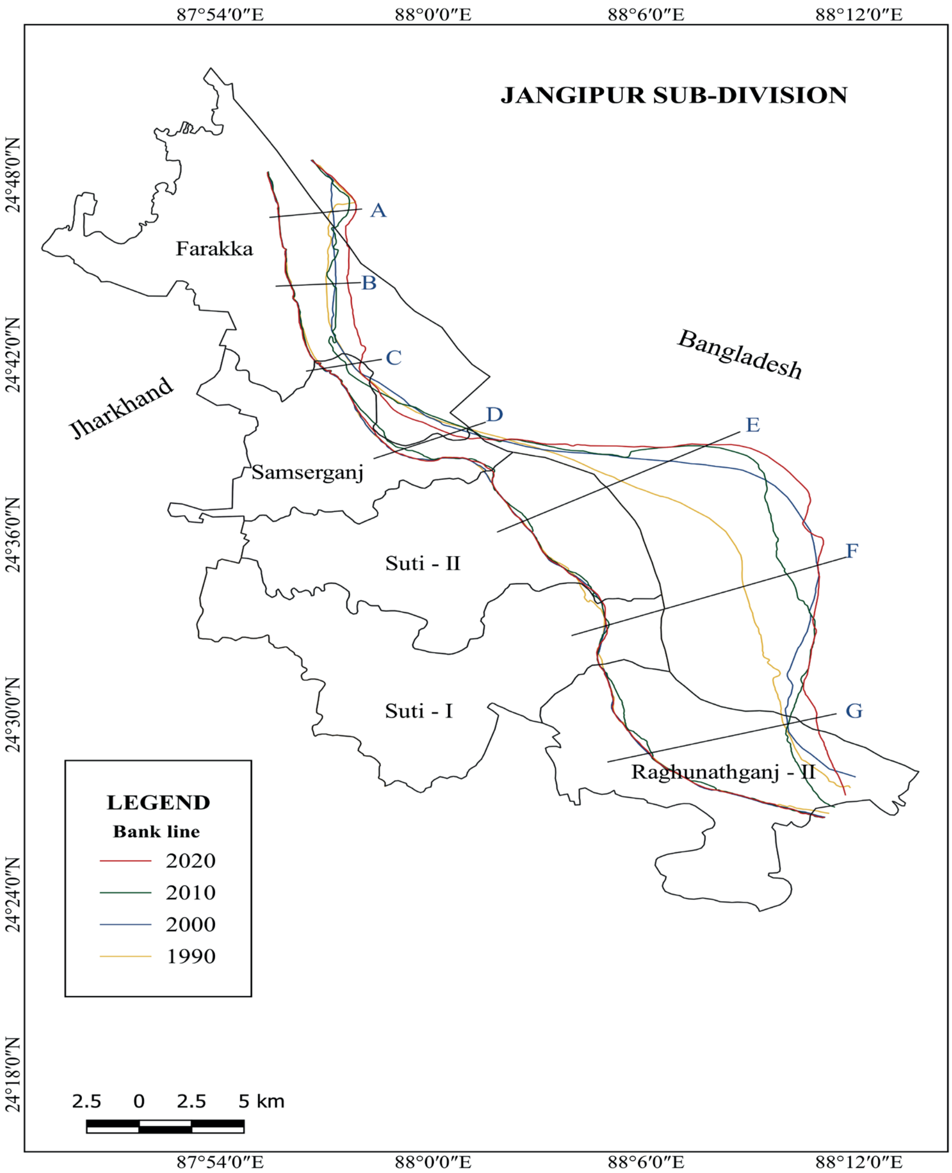

Fig. 10. Different cross sections are drawn along the selected reach between Farakka Barrage to Jangipur to measure bank line shifting of Ganga-Padma river during the last four decades (based on satellite images as in Table 1)
Source: authors' work

1996). Again, Rudra (1996) stated that, though erosion along the bank of this reach is restricted during the monsoon months, in the post-monsoon the groundwater flow towards the channel leads to liquefaction and flowage of basal sediments of the bank.

4.4. Impact of riverbank erosion on society and economy

Riverbank erosion has emerged now as a big environmental problem in our country, introducing multiple consequences, such as environmental, social, economic and sometimes political (Ghosh, 2015). The present study units (i.e., Loharpur and Nimtita) are also facing the same problem due to severe bank erosion during the last century. In this regard, an attempt has been made to assess the short-term socio-economic impact of riverbank erosion. According to the Refugee and Migratory Movement Research Unit (2007) (as cited by Das et al., 2017), short-term economic impacts include loss of home, agricultural land, job, assets, etc. Social impacts have been analyzed here in terms of deteriorating

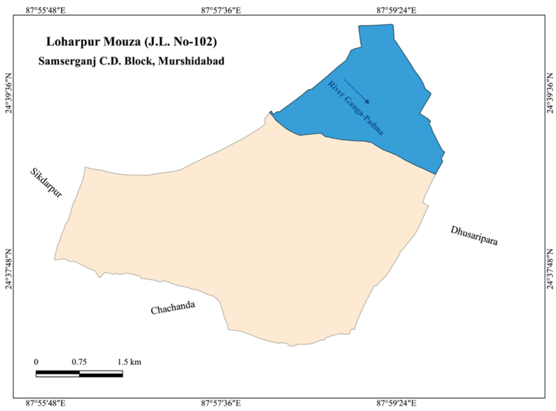

Fig. 11. Flow of the river Ganga-Padma at the boundary of Loharpur *mouza*, 1913–1914 (Computed from mouza map surveyed during 1913–1914)
Source: authors' work

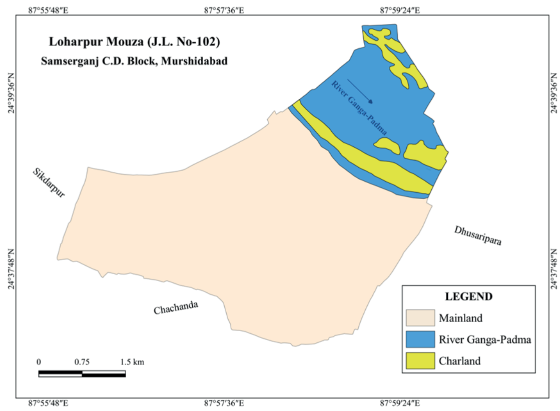

Fig. 12. Flow of the Ganga-Padma river within Loharpur *mouza*, 2000 (Computed from LANDSAT 7 (ETM+), 10.12.2000)
Source: authors' work

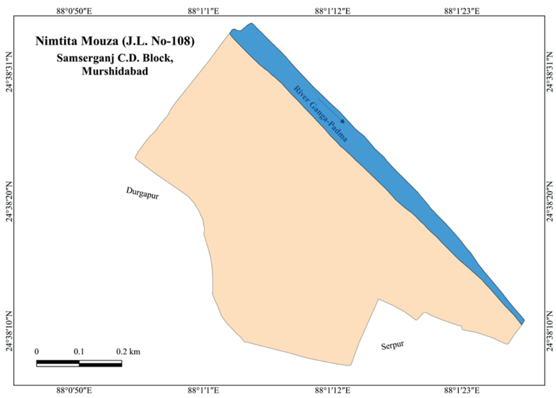

Fig. 13. Flow of the Ganga-Padma river at the boundary of Nimtita mouza, 1916–1917 (Computed from mouza map surveyed during 1916–1917)
Source: authors' work

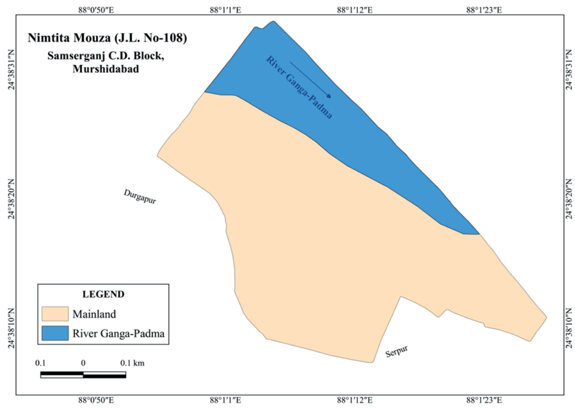

Fig. 14. Flow of the river Ganga-Padma within Nimtita *mouza*, 2000 (Computed from LANDSAT 7 [ETM+], 10.12.2000)
Source: authors' work

social institutions because their dysfunction may lead to a collapse of the social fabric of an area.

4.4.1. Changes in social institutions

Social institutions are the package of societal norms beliefs, rules, etc. that in turn determine the stability as well as the survival of a particular society through their carrying out the fundamental functions of the society (Islam & Guchhait, 2018). An unusual event leading to the dysfunction of social function may deteriorate the social fabric. Four primary social institutions, i.e. family, government, education and health, have been discussed here with reference to Islam (2016).

Family

Basically, normal societies of both rural and urban settings now experience an abundance of nuclear families, but a society ravaged by riverbank erosion hazard shows a reverse trend in family size (Islam, 2016). In the studied *mouzas*, average family size is higher due to the loss of their habitats due to erosion (Fig. 17). According to the *Census of India* (2011), the average family size was 5.27 in Loharpur and 4.23 in Nimtita.

Figure 17 also depicts a remarkable percentage of households representing the average family size, which ranges from five to eight in both *mouzas*. According to Mollah (2013), cultural norms often act as an influential factor regarding family size, which in turn determines the social vulnerability of a hazard-prone area, and families having a large number of dependent members are likely to

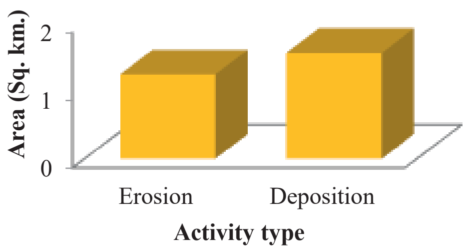

Fig. 15. Amount of area under erosion and deposition at Loharpur *mouza* from 1915 to 2000 (Computed by the authors, based on Fig. 11 and 12)
Source: authors' work

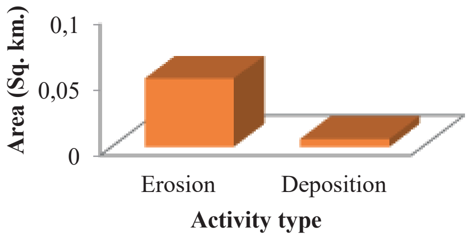

Fig. 16. Amount of area under erosion and deposition at Nimtita *mouza* from 1915 to 2000 (Computed by the authors, based on Fig. 13 and 14)
Source: authors' work

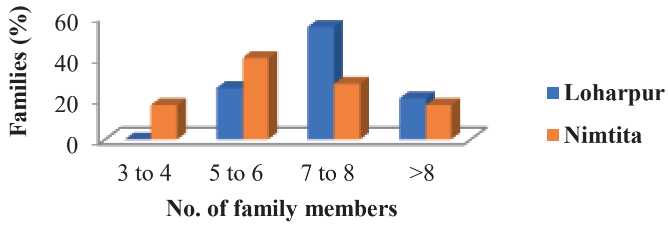

Fig. 17. Family size of surveyed households according to number of family members (based on field survey, June 2021)
Source: authors' work

encounter greater financial obstacles than smaller families when coping with hazard impacts. At the flood center in Nimtita High School and in some places at Loharpur, very much congested, unhygienic habitation has been noticed, with 20–25 people living together in a small room in very poor conditions. Such a dense population along with the fragile socio-economic condition of a hazard-prone area often acts as an added factor to exert further vulnerability (Das et al., 2017).

Government

Government and local administration hold greater responsibility for a society that is tremendously stressed by hazards. A perception rating of the government's role was done among the erosion victims in both *mouzas*. But the results show they are not satisfied with the role of government. Only a few works, such as bank protection by sandbags and the allocation of a very small amount of compensation to a few families, have secured comparative success, but others have not been properly implemented. Bank protection work by sandbags has achieved a comparatively higher positive rating (20% mean rating in Loharpur and 66.66 % mean rating in Nimtita) (Figs. 18, 26).

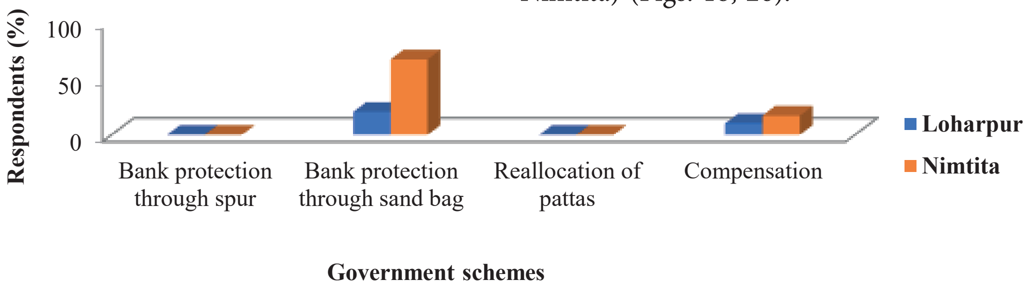

Fig. 18. Effectiveness of various Govt. schemes to protect riparian inhabitants from bank erosion (based on field survey, June 2021)
Source: authors' work

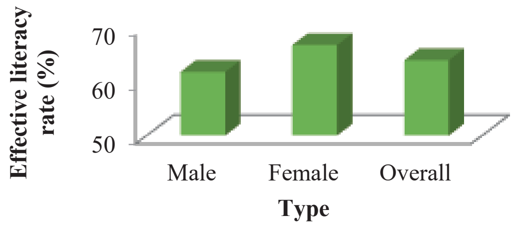

Fig. 19. Effective literacy rate of Loharpur (Computed by the authors using field survey data, June 2021)
Source: authors' work

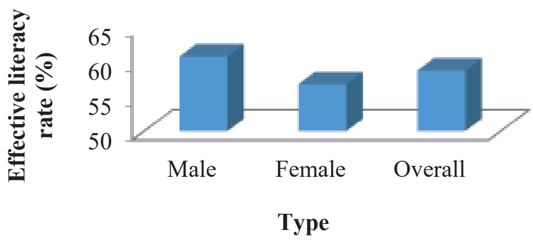

Fig. 20. Effective literacy rate of Nimtita (Computed by the authors using field survey data, June 2021)
Source: authors' work

Table 3. Major health problems related to bank erosion within the last year in Loharpur and Nimtita

Name of problem	Affected male (%)				Affected female (%)			
	Loharpur		Nimtita		Loharpur		Nimtita	
	Age 0–18	Age >18	Age 0–18	Age >18	Age 0–18	Age >18	Age 0–18	Age >18
Gastrointestinal problems	28.57	50	46.51	40.74	30	51.85	32.35	33.75
Covid 19	0	0	0	1.23	0	0	0	0
Headache	0	25	4.65	24.7	5	22.22	5.88	12.5
Psychological problems	0	7.14	0	7.41	0	3.701	2.94	1.25

Source: Field survey, June 2021

Education

In the study units, the hazardous effects of riverbank erosion have negative impacts on education. According to Islam and Guchhait (2018), there are two types of negative associations between the education system and environmental hazards – if the society experiences frequent hazards, then there is a chance of the education system collapsing; and on other hand, if a society depicts poor education attainment, then the shock-absorbing capacity of the particular society is weakened.

The poor villagers do not consider education – even up to a minimum standard to be a basic need. The overall effective literacy rate is comparatively greater in Loharpur (63.85%) and Nimtita has an overall effective literacy rate of 58.77% (Fig. 19 and 20). An increasing trend in female literacy has also been noticed in both *mouzas*. In Loharpur, effective literacy rate is greater among females than males (Fig. 19). This may be due to the active involvement of males in work to compensate for their family income, whereas female work participation is less in rural areas and various government schemes also encourage them to continue on to higher education.

Health

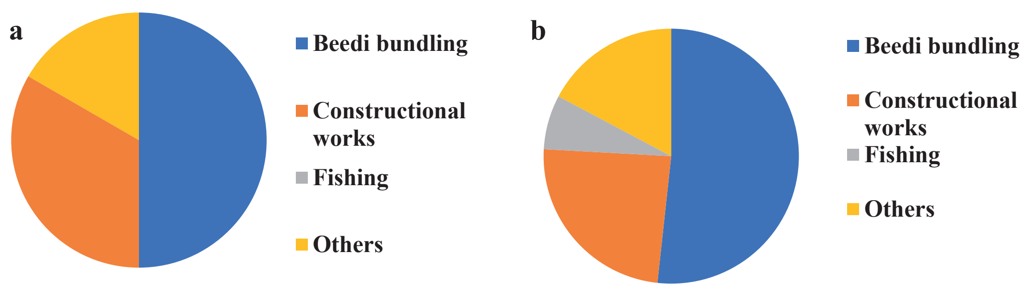

Fig. 21. Diversification of economic activity from and along with agrarian to others within last three years in Loharpur(a) and Nimtita(b) (based on field survey, June 2021)
Source: authors' work

Any sudden shock imposed by a hazard may trigger insecurity among a group of people, which in turn induces various psycho-physical health problems (Islam, 2016). Both surveyed *mouzas* are facing the same problem. People from both *mouzas* have responded more or less uniformly to the health problems in relation to bank erosion hazard depending upon the severity of erosion and corresponding economic losses.

Various gastrointestinal diseases (e.g., diarrhoea, hepatitis, abdominal pain) are very common to both children and adults of both sexes. Unhygienic drinking water and toilets in open spaces are likely responsible factors for such problems. Gathering and frequent visits by outsiders may spread Covid-19 in the community, but, surprisingly, only one person in Nimtita was found who had suffered Covid-19 (Table 3). Apart from these general physical problems, a considerable percentage of people also suffered from psycho-physical problems in connection with huge economic losses in both study units during the last year. However, such psychological problems have been noticed among adult people and most significantly among the male members of the surveyed households (Table 3).

4.4.2. Shifting of economic activity

The economic base of the study area is mainly agriculture and *beedi* (local cigarette in India) bundling. Where agriculture is a fully land-based economy, and if such an agrarian economy faces adversities due to land loss by severe riverbank erosion, the degree of socio-economic marginalization is intensified, trapping the people in economic crisis (Islam, 2016). Both the farmers and agricultural laborers being uprooted from agriculture are now diversifying their livelihood for merely physical survival. However, such diversification basically occurs by compulsion, not by choice (Islam & Guchhait, 2018).

As per the field survey, many workers are involved in two or more economic activities at different times of a single day. In both villages, on average >50% of people are engaged in *beedi* bundling as an alternative source of income for a very minimum wage (INR 110 rupees/1000 *beedi*) (Fig. 21). In order to survive, a significant percentage of workers have shifted towards construction activity over the last three years (Fig. 21), and some of the relatively physically abled people have migrated to other states in search of better livelihood opportunities, having left their elders, children and housewives behind in

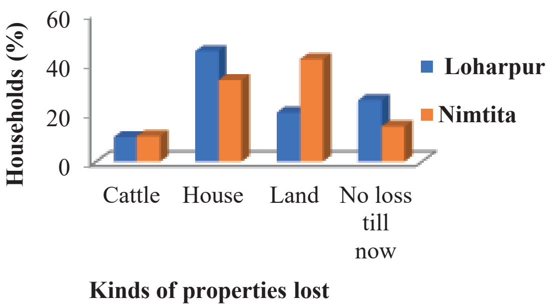

Fig. 22. Kinds of properties lost (based on field survey, June 2021)
Source: authors' work

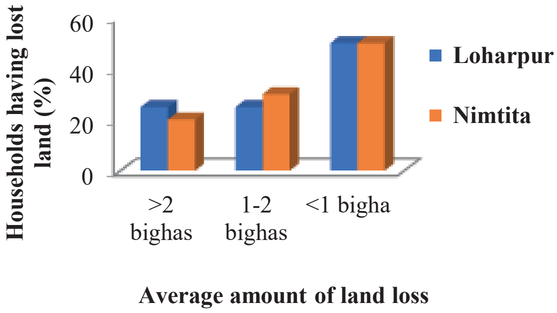

Fig. 23. Amount of land loss of the households having lost land (based on field survey, June 2021)
Source: authors' work

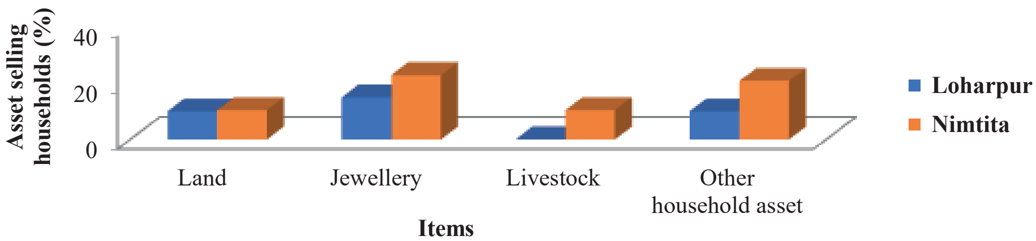

Fig. 24. Forced selling of properties and assets for survival of victims (based on field survey, June 2021)
Source: authors' work

their villages. According to locals, because the study area is so close to the Bangladesh border, traffickers or smugglers use this opportunity to entrap women in trafficking. Many migrants face repeated police harassment at their workplaces because they lack a domicile identity, such as a voter identity card, *Aadhar* card, ration card or land-holding records (Mollah, 2013).

4.4.3. Loss of property

Loss of properties and assets due to severe riverbank erosion basically happens in two ways –by direct loss of properties like land, settlement and other household amenities and indirectly by selling of properties and assets for survival (Fig. 25) (Islam, 2016). In the case of direct loss due to severe bank erosion, a greater percentage of households lost their house in Loharpur (45%) (Fig. 22), where 20% of households lost their lands. Among such families, 25% of households lost >2 *bighas* and 1–2 *bighas* of land and 50% suffered a loss of <1 *bigha* land (Fig. 23). The percentage of households having lost cattle in Loharpur is 10, whereas 25% responded that they had not yet lost any kind of property (Fig. 22). On the other hand, in Nimtita, the percentage of households having lost land is comparatively high; i.e. 41.66 (Fig. 22). Among them, 50% of households lost <1 *bigha* land, 30% lost 1–2 *bighas* land and 20% have lost >2 *bighas* land, and the percentage of households having lost a house is 33.33 (Fig. 22, 23). Meanwhile, 10.4% of households responded that they lost their cattle and nearly 14.28% had not lost any item till now (Fig. 23).

In cases of indirect loss, the assets and properties they sell are mostly women's jewelery, land, livestock and other household amenities like a bicycle, van, TV, etc. (Fig. 24). Among these two *mouzas*, such

Table 4. Combined Infrastructural Index (CII) in Loharpur and Nimtita

Infrastructural parameters	Loharpur	Nimtita
Electric facility index	0.55	0.5833
Toilet facility index	0.0485	0.0462
Drinking water facility index	0.097	0.063
Per-capita small savings index	0.3398	0.3109
Doctors facility index	0.0194	0.0084
Combined Infrastructural Index (CII)	0.21094	0.20235

Source: Computed by the authors using field survey data, June 2021

Fig. 25. House leans towards the Ganga-Padma river at Loharpur
Source: field photographs, 22.6.2021

Fig. 26. Bank protection through sand-filled bags at a vulnerable pocket in Dhangara
Source: : field photographs, 22.6.2021

activities are a little bit low in Loharpur. In the case of selling land, both *mouzas* responded in more or less the same manner. Otherwise, in respect of selling jewelry, livestock and other household assets, Nimtita tops the list (Fig. 24).

4.5. Infrastructural index of the erosion victims

To identify the level of development of the erosion victims in regard to basic infrastructural facilities, Combined Infrastructural Index (CII) for both *mouzas* was computed after Ghosh and Sahu (2018b) based on surveyed data. The CII value is 0.21094 for Loharpur and 0.20235 for Nimtita (Table 4). If we categorize both CII values according to the UNDP (2011) categorization (where a value below 0.5 indicates Low Human Development, 0.5–0.7 indicates Medium Development, 0.7–0.8 indicates High Human Development, and above 0.8 indicates very High Human Development), then we see the low category of infrastructural development prevails in both *mouzas*. Such deplorable infrastructural development also accentuates that people along the riverbank or the erosion victims do not get basic facilities in respect of drinking water, toilet and doctor facilities, that they are also financially feeble. The infrastructural index of an area signifies the coping ability of the society with hazardous impacts as well.

4.6. Livelihood adjustment and adaptation of riparian inhabitants

Based on their previous experiences, they try to cope with the adversities in several ways and their adaptation strategies depend on several factors like their socio-economic conditions, shock-absorbing capacity, degree of individual's exposure to erosion hazard, etc. As per the field survey in June 2021, in the present study units, a significant variation in the value of chi-square (24.78 at $p<0.01$) was computed in terms of acceptance of flood shelters or relief camps in adversities. Of respondents from Nimtita, 83.33% moved to flood camps in adverse situations. In the case of Loharpur, the distance from the flood camp is greater, and hence only 20% of respondents can access it. Areas where the risk of houses being washed away by frequent riverbank failure are widespread, and the inhabitants of such areas intend to build temporary housing structures; this is not only due to their poverty but also because of their unwillingness to invest money, as they accept the fate that they will have to further rearrange their houses after the destruction of their existing houses (Chakraborty, 2017; Mollah, 2013). Instead of using any durable house building material, the use of earthen material predominates in both *mouzas*. Many poor families from both *mouzas* have opted for bamboo pulp, jute sticks, hay, etc. instead of any durable permanent wall materials, because these are easily portable and less susceptible to loss. Nevertheless, a considerable percentage of households in both Lohapur (50%) and Nimtita (37.5%) *mouza* have been found with the wall made of bricks. But most are not plastered with cement. The use of earthen wall material is 25% in Loharpur and 20.83% in Nimtita. Corrugated tin is used in the highest number of respondents' houses in Loharpur (35%) and Nimtita (27.08%) as a household roof material. Tarpaulin, earthen tail and hay are also utilized as roofing materials. But concrete cemented roofing is scarcely seen in both *mouzas*. Otherwise, no significant variation in house building materials has been found between these two study units as per the field survey. Basically, for monsoon season, when bank erosion accelerates, the dwellers of both *mouzas* stock their fuels for sustenance. Dung cakes are largely used in both *mouzas*. The use of jute sticks, kerosene and dry bark is also common. In both *mouzas*, the use of mud furnaces was highest (about 60% in Loharpur and 41.66% in Nimtita). Since shifting is common in both *mouzas*, nearly 25% of respondents from Loharpur and 41.66% from Nimtita commented that a portable mud stove is also kept to handle emergency situations. Since inundation and water logging issues are not common in this area, very few respondents from both *mouzas* reported using raised stoves. As a result, there are no discernible differences in the furnace patterns of these two *mouzas*. To adapt to the effects of bank erosion by earning for family, the womenfolk also come forward. A remarkable percentage of womenfolk from Nimtita (54.16%) earn for their family, while only 10% of womenfolk are engaged in any economic activity in Loharpur. This is why the significant value of chi-square (11.36 at $p<0.01$) implies a distinction of female employment between the two *mouzas*. Severity of bank erosion and religious background are both responsible for such variation. Nevertheless, there is no significant variation observed in the source of female income between the two selected *mouzas*. After completing their daily household duties, most of the womenfolk from Loharpur (100%) and Nimtita (80.77%) opted for *beedi* bundling as an alternative source of income in their free time since other economic activities for women are limited, and because beedi bundling can be done while sitting at home. This aside, a very small percentage of womenfolk from Nimtita also earn from agricultural activity (7.69%) and 100 days of employment (11.54%). But in all activities, the amount they earn is very small. Significant values of chi-square (10.85 at p<0.01) signify that there is a strong difference between the two *mouzas* in terms of assistance received during the last year. According to the field survey, 72.91% of respondents from Nimtita received assistance, while only 30% from Loharpur stated that they had received assistance during the last year. The aid received by the victims from both of the *mouzas* is mostly from their relatives. However, low infrastructural development, when combined with the major indicators described for sensitivity and exposure to the erosion hazard, has a negative impact on the capacity of households to secure sustainable livelihoods and recover from hazards, making them vulnerable.

5. Conclusion

The present study reveals that riverbank erosion has emerged as a big issue in the study area, introducing many consequences for the riparian social environment. The losses due to bank erosion are permanent and hold a long-term chain impact on the riparian society. A deplorable standard of living and poor state of hygiene coupled with poor health facilities are quite debilitating to the lives of the erosion victims. This calls for great assistance. But the government and administrative initiatives to combat this problem are not proactive, being instead found to be reactive, localized and temporary. Since riverbank erosion is an inevitable phenomenon, attempts at bank protection by spurs or embankment are just a waste of money, because much evidence of embankment failure along the Ganga-Padma river has been reported in the recent past at several places in Murshidabad district. The governments have to fight against this problem proactively with a holistic approach instead of employing piecemeal remedies. The most important recommendation in this context is to provide proper rehabilitation and compensation packages to the displaced without delay and capacity building of the poor riparian society is very much necessary to make them resilient to the bank erosion hazard.

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