International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Historical Trend of Riverbank Erosion Along the Braided River Jamuna

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Abstract

The Jamuna, the lower part of the Brahmaputra River of India, enters into Bangladesh at Nageshwari upazila of Kurigram district and meets the Ganges at Aricha, is the most dynamic among the rivers of Bangladesh. This river is one of the largest sand-bed braided rivers in the world which is complex and chaotic by nature. The annual erosion along this river is highest among all the rivers in Bangladesh. However, the rate of erosion along this river varies over time and space. The history of riverbank erosion shows a decreasing trend in recent years. The erosion rate of the Jamuna was around 5,000 ha per year in the 1980s while in recent years the rate has been around 2,000 ha per year. Their might exist some reasons behind the existing erosion trend that are aimed to find out in this study.

Compared to its complexity, data, information and knowledge of the riverbank erosion are not enough. In general, understanding on riverbank erosion process of large braided rivers is limited. Old maps and time-series satellite images during low flow facilitate this study in looking into the historical trend of riverbank erosion process. Bank erosion process has been found to be associated with other factors including natural factors such as change in river width. Being a braided river, the Jamuna has multiple channels. An attempt has been made in this study to find out the response of erosion to the presence of the main channel. Water level and discharge are two important hydrological parameters governing the erosion process. It has been attempted to find out the influence of these indicators. It has been found that bank erosion along the Jamuna is not width sensitive. In addition, presence of main channel along the right bank is found to play an important role in bank erosion. This study shows that riverbank erosion along the both banks of this river is well responsive to flood discharge though the left bank is more susceptible to it. This research also recommends using the relationship between erosion and maximum water level only for left bank.

Keywords: Jamuna River; braided river; riverbank erosion

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1. Introduction

The Bengal delta is the world's second largest delta which comprises riverine floodplains and deltaic plains [1; 2]. A major part of this delta lies within Bangladesh which consists of 144,570 km^2. The delta drains the runoff of large catchments of the Ganges, the Brahmaputra and the Meghna. Only 7.5 % of these catchments lie within Bangladesh [3]. This delta has a mild slope from north to south and it meets the Bay of Bengal in the south. The foodplain of Bangladesh is formed by enormous sediment deposition by a large number of tributaries and distributaries of the world's three great rivers—the Ganges, the Brahmaputra and the Meghna.

The erosion-accretion process is very common here. Deposition mainly occurs in rivers inside chars and in estuaries, whereas erosion destroys the valuable floodplains along these rivers. Consequently, riverbank erosion has become one of the major disasters in Bangladesh. The major rivers of this country such as the Jamuna, the Ganges, the Padma and the Lower Meghna are very dynamic in nature. These rivers annually erode about six thousand hectares of floodplain land, leaving thousands of people homeless and damaging or destroying valuable infrastructures. Understanding of bank erosion process is essential to improving the livelihoods of millions of floodplain dwellers in Bangladesh.

The course of the Brahmaputra River between the entry in Bangladesh and the confluence with the Ganges at Aricha is referred as the Jamuna River in Bangladesh and this convention is adopted here. The Brahmaputra rises in China and flows eastward for 1,100 km across the Tibetan Plateau as the Tsangpo, before turning south to cross the east-west trending ranges of the Himalayas. The river breaks through these ranges via a series of deep, narrow gorges before entering the Indian State of Assam. After travelling 700 km in a south-westerly direction through the Assam valley, the river again turns south to enter Bangladesh. Within Bangladesh, the length of the river is about 220 km before it meets with the Ganges (Fig. 1).

Within Bangladesh, the course of the Brahmaputra River shifted from the east to the west of the Madhupur Tract in between 1776 and 1830 [4]. They recommended that this avulsion was not a unique event, but was actually the latest in a series of periodic switches of the Brahmaputra from one side of the Madhupur block to the other during the Holocene. According to their palaeo-geographic maps, the average period between switches is only about 2,000 to 3,000 years.

There are different opinions on the cause of the avulsion, including tectonic influence, tributary switching, and the occurrence of a very large flood [5]. There is a general consensus that tectonics are the main cause of the Brahmaputra switching from the east of Madhupur to the west. Fergusson mentioned [6] tectonic movement to be responsible for avulsion (specifically to the uplift) of the Madhupur. Morgan and McIntire [7] concluded that the avulsion occurred gradually in response partly to the tectonic tilting of the Madhupur block and partly due to the addition of the flow from the Teesta River following its sudden avulsion from west to east, to the confluence with the Brahmaputra just upstream of the point of avulsion.

While the tectonic uplift and tilting of the Madhupur block and associated subsidence in the Sylhet Basin and along the 'zone of weakness' between the Madhupur and Barind Tracts are probably the underlying causes of the course switching, different events may have acted as triggers for particular avulsion events. The trigger events might have included earthquakes, tributary diversions, and major floods [8]. To these might be added the crossing of geomorphic thresholds intrinsic to the fluvial system [9] associated with channel slope adjustments driven by sediment accumulation that is alternately centered in the Sylhet Basin and the trough between the Madhupur and Barind Tracts [10].

The geographical location of the flow path of the Jamuna makes it a unique system and hence the erosion process is associated with different channel parameters which result as natural process of avulsion. Moreover, it may be a response of hydrological parameters such as flood discharge.

2. Methodology

Different planform data such as width, length of main channel and erosion have been calculated using satellite images available in CEGIS which have been analyzed using ArcGIS software. On the other hand, hydrological data of the BWDB have been used in this study. At first, banklines are delineated on geo-referenced satellite images following bankline criterion [11]. The width of this river was calculated using these banklines which start at Nageshwari upazila of Kurigram district and end at Aricha. Erosion data were extracted by superimposing consecutive banklines. Some old maps were also collected from CEGIS to use in this study. The length of main channels was measured by summing the length where the main channels touched the banklines (floodplain). Hydrological data, like water level and discharge were collected from the BWDB. It has been attempted to establish a correlation of different planforms and hydrological parameters with riverbank erosion.

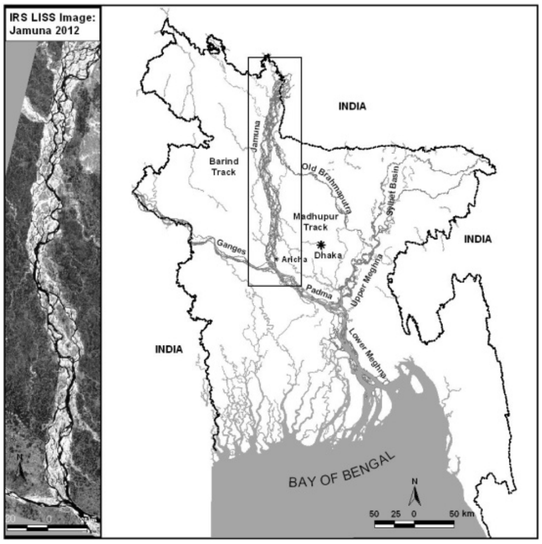

Fig. 1. location of the Jamuna River

3. Results and Discussion

The sensitivity of riverbank erosion with respect to the above mentioned indicators is described in the following sub-sections.

3.1. River width

The Wilcox map of 1830 shows the Jamuna River as a single-threaded meandering planform. The planform remains meandering in the 1914 map, though the river shifted noticeably westward and its average width (5.55 km) was somewhat narrower than that in 1830 (6.24 km) (Fig. 2). Between 1914 and 1953 the river continued migrating westward while widening significantly and transforming from meandering to braiding (Fig. 3). By 1973, the average width of the river had reduced slightly, but rapid westward migration continued. Between 1973 and 2010 the rate of increase of the average width accelerated at a very high speed, although the rate of westward migration of the river's centerline slowed down (Fig. 3).

An attempt has been made to find out the relationship of riverbank erosion with river width. Since satellite images and banklines of every year are available from 1994, annual erosion rate has been compared with river width for the period 1994 to 2010. Annual erosion has been plotted in primary Y-axis and river width in secondary Y-axis. The X-axis represents the years (Fig. 4). The figure shows that although the width is about 12 km for the period 1994-

2010, the erosion rate fluctuates from 1100 ha to 5800 ha. Although the width is quite stable, erosion may vary due to the presence of main channels. Bankside channels have greater chance of eroding floodplains

Fig. 2. historical changes in the width of the Jamuna River over time

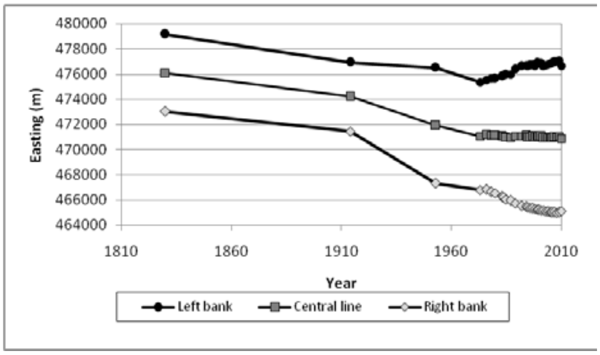

Fig. 3. historical changes in centerline and bankline positions of the Jamuna River

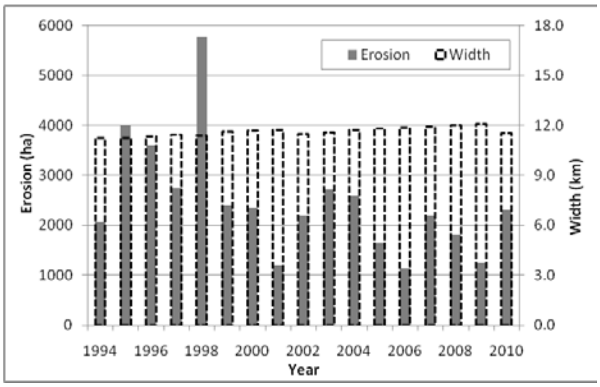

Fig. 4. relationship between river width and riverbank erosion

3.2. Main channel

This study aims to recognize the influence of main channels on riverbank erosion. For this purpose, the length of main channels from 1994 to 2010 has been measured with GIS technology. Channels of reasonable width and upstream connectivity have been considered as ‘main channels’ in this study (Fig. 5).

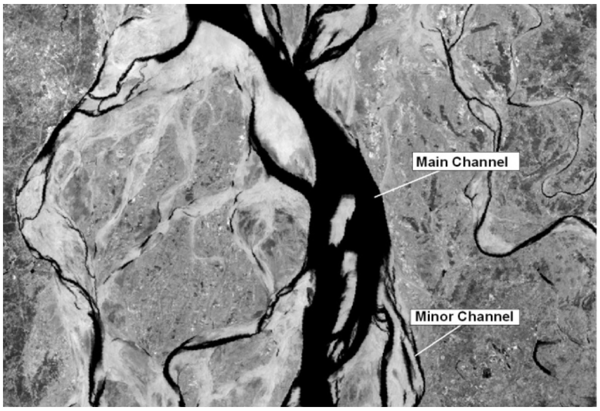

Fig. 5. major and minor channel on satellite image

A reasonable sensitivity of the main channels adjacent to the floodplain to riverbank erosion has been found for the right bank (Fig. 6a). However, the left bank shows nothing representative (Fig. 6b). The formation of the flow path of the Jamuna might be the reason. Since the right bank is always eroding old floodplains which are relatively stable, its response to an attack by main channels is rational. On the other hand, in recent years (1994 to 2010), erosion is continuing on developed floodplains along the left bank. As a result, loose bank materials need no strong attack (by main channels) to become eroded. Hence, huge erosion is also caused along the left bank by minor channels.

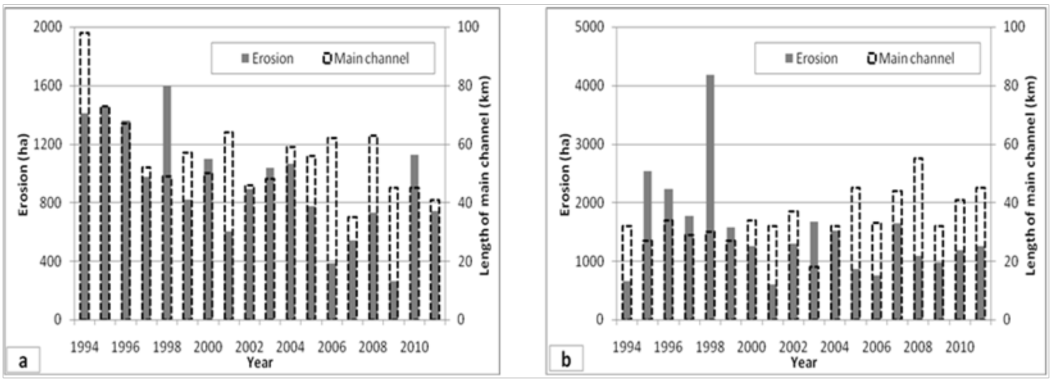

Fig. 6. relationship between main channel and erosion along the right (a) and left (b) bank

3.3 Flood discharge

It is generally accepted that the annual rate of bank erosion in a river is related to the duration of the time that the bank shear stress exceeds the threshold value for entrainment of the bank material. However, the relationship between bank shear stress and discharge in a large, braided river like the Jamuna is impossible to quantify. Instead, bank retreat has been related to the annual peak discharge (as a proxy variable for the magnitude and duration of bank shear stress) for the period of 1994 to 2010. The results (Fig. 7) reveal a marked contrast in the way the left and right banks respond to changes in the magnitude of the annual flood peak. The best-fit lines for the relationship between annual maximum discharge and annual rate of erosion at the right and left banks are (r^2 = 0.8 for both bank data).

Right bank
$E = 0.018Q_{max} - 308$ (1)

Left bank
$E = 0.057Q_{max} – 2468$ (2)
where, E = annual riverbank erosion (ha), Q_{max} = maximum annual discharge (m^3s^{-1})

The above mentioned equations show that a 10% increase in the annual maximum discharge (flood discharge) will generate 13% increase in erosion along the right bank but an increase of 26% along the left bank. That is the striking finding regarding the response of bank erosion on peak discharge. This might happen due to the type of materials along the banks of the Jamuna. The right bank is composed of relatively stable materials which are less sensitive to high discharge, while the materials of the left bank are highly erodible since they are newly developed. The consequence of this is that the left bank is very susceptible to flood discharge and causes a high rate of erosion.

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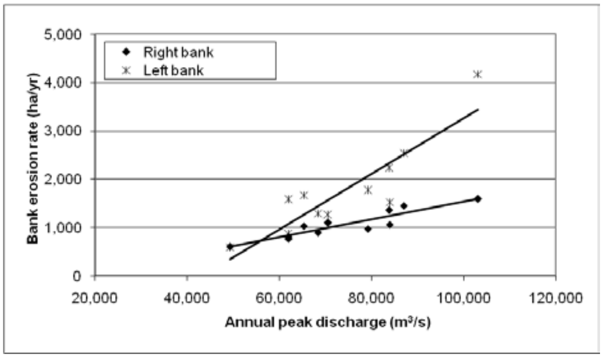

Fig. 7. relationship between flood discharge and bank erosion rate in the Jamuna

3.4 Water level

An attempt has been taken in this study to find out response of riverbank erosion on maximum water level (flood level) and erosion rate for both banks of the Jamuna River. For right bank, very poor relationship has been found ($r^2 = 0.2$), but for left bank a reasonable good relationship has been found ($r^2 = 0.5$). Fig. 8 shows the relationship for both banks. The best-fit lines for the relationship between annual maximum water level and annual rate of erosion at the left and right banks are:

Right bank
$E = 285WL_{max} - 4713$ (3)

Left bank
$E = 1192\ WL_{max} – 22070$ (4)
where, E = annual riverbank erosion (ha), WL_{max} = maximum annual water level (m, pwd)

It has been found from the co-relationships that left bank is better responsive to maximum water level. Since the right bank is composed of relatively old bank materials, this bank is comparatively stable. Hence it does not quickly respond to high water level. Therefore, it has been recommended not to use the relationship equation for right bank (Equation 3).

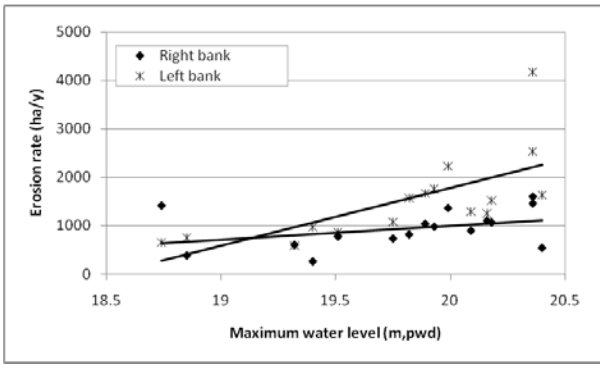

Fig. 8. relationship between maximum water level and bank erosion rate in the Jamuna

4. Conclusion

Bank erosion is a response to the different indicators of fluvial processes and morphological parameters, and a few of the indicators and parameters has been considered in this study to describe their influence on the erosion process of the braided river Jamuna. Planform parameters sometimes govern erosion but sometimes may not have significant role in the process. This study shows that the bank erosion process of the Jamuna is completely independent of the river width. On the other hand, the presence of main channels adjacent to the floodplain plays a role in bank erosion, especially along the right bank. Hydrological factors such as flood discharge and maximum water level also manipulate the erosion process. For the Jamuna River, erosion along the both banks responds well to flood discharge. The erosion along the left bank reacts nicely to flood level but that along the right bank reacts less to it.

Acknowledgement

The author expresses her deepest sense of gratitude and thanks to the Center for Environmental and Geographic Information Services (CEGIS) for giving permission to use times series satellite images and old maps of the Jamuna River. Bangladesh Water Development Board (BWDB) also deserves thanks with gratitude for providing water level and discharge data of the Jamuna River at Bahadurabad gauging station.

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