Chapter 28
Application of Numerical Modelling for Geomorphological Evolution and River Bank Shifting Part of Damodar River

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Abstract River bank erosion is a naturally occurring process along the lower parts of the River and Delta. Constant erosion and deposition due to natural and anthropogenic causes the River to migrate constantly and creating new geomorphological process. Numerical modelling helps in analyzing complex physical changes that occurred in a particular area. It can play a dominant role in studying the erosion and depositional rate along the River banks with higher accuracy. The current research is focussed on assessing the Geomorphological evolution and River bank shifting for the parts of the Bhagirathi River through numerical methods. A Survey of India's topographical maps is taken as a baseline for the study. The River bank was digitized from multi-temporal LANDSAT data from (1990–2018) at five years of temporal interval. The spatial variation in accretion and erosion rate was classified into five different types, namely: Extreme Erosion, High erosion, No change, High deposition, and Extreme deposition. The analysis revealed that both Extreme erosion and deposition were present during all of the study years. Both the east and west bank undergoes the River change at different rate for each period. The highest rate of erosion (-149 mts) and deposition (278 mts) for the west bank of the River was observed between the year (2005–2011) and (2015–2018). The highest rate of erosion (-168 mts) and deposition (375 mts) for the east bank of the River was observed between the year (2015–2018) and (1995–2000).

28.1 Introduction

Rivers play a pivotal role in the global sedimentary cycle. They are responsible for the transport of continental sedimentary particles to the oceans. According to a study annually, Rivers transport approximately $34.7 * 10^{12}$ m^3 of water and $13.5 * 10^{12}$ kg

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(Al-Abadi et al. 2020; Chakrapani and Saini 2009). Rivers are highly sensitive to environmental and anthropogenic activities. They tend to migrate or readjust the course of the River drastically depending upon the type of causative factors such as tectonic activities, regional geomorphology, sediment inputs, and a number of human activities at temporal and spatial conditions (Dewan et al. 2017; Paul et al. 2019). Bhagirathi River is a part of the Bengal delta present in Eastern India. Bhagirathi River is one of the very few Rivers in West Bengal that undergoes severe bank erosion and accretion due to a variety of hydrological inputs (Islam and Guchhait 2018). In recent years, anthropogenic activities have enormously affected the course of the Bhagirathi River. Construction of Railroads, practicing of agriculture in tidal inlets had a great impact on the morphology of the River (Pal et al. 2016; Du et al. 2020; Schmidt and Barron 2020). Many researchers, both international and national, have studied the impact and morphology of changing Rivers to a certain extent. Islam and Guchhait (2018) have studied the societal and psychological victims due to River bank erosion. Yao et al. (2011) discussed the various causative factors and their impact on erosion and accretion rate along the yellow River of magnolia. Guchhait (2018), Thakur (2014), Das et al. (2014), Panda and Bandyopadhyay (2011), De Rose and Basher (2011) are some of the few other researchers to have extensively studied the Ganges and the Bhagirathi Rivers morphological changes to a greater extent.

The present study is focussed on assessing the erosion and accretion rate along the part of Bhagirathi River extending from Durgapur to Chalbalpur. The study uses numerical-based modelling to analyze the rate of change for the years 1974–2018. The final output of the research is to delineate areas that had undergone enormous changes due to various fluvial process.

28.1.1 Objective

- To digitize the River banks of the Bhagirathi River for the year 1974–2018 using various data sources.
- To spatially predict the rate of changes of erosion and accretion along the River course.
- To delineate the areas that have undergone extreme amount of erosion and deposition due to changes in River morphology.

28.2 Study Area

The geographical extent of the study area is 87°16′24″ to 88°1′59″ East longitude to 23°5′14″ to 23°30′43″ North latitude. Damodar River flows from Jharkhand to West Bengal for 592 Kms. It has a number of tributaries and sub tributaries, such as Barakar, Konar, Bokaro, Haharo, Jamunia, Ghari, Guaia, Khadia, and Bhera. The
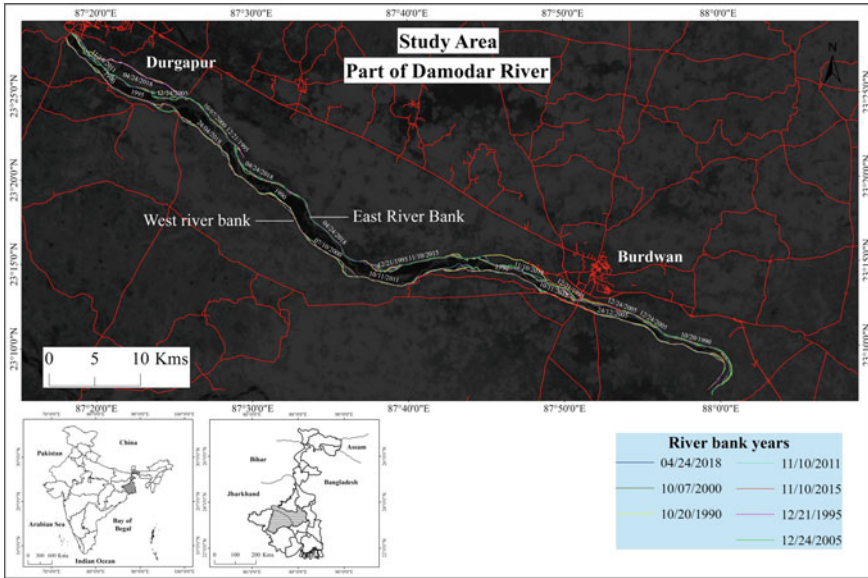
Fig. 28.1 Study area

total length of the River taken for the present study is 92 km. The River is located along Burdwan and Bankura district of West Bengal. The major Rivers of the study area are Hoogli, Damodar, Kangsbati, and the Dwarakeswar. The general geology of the state is occupied by the unconsolidated sedimentary deposits of the quaternary periods. About 75% of the land mass comprises of subrecent to recent alluvial deposits of the Quaternary period. The sedimentary formation includes essentially the Gondwana formations (Barakar formations, etc.) in the Eastern plateau (Outliers) that belong to the Permo Carboniferous to Triassic age, whereas the Siwalik formations belong to the Territories in Eastern Himalayas. The basic flows belonging to the upper Mesozoic age form a conspicuous horizon setting between the two broad sedimentary groups. The climate area consists of very mild winters and hot-wet summers. The mean annual rainfall of the West Bengal is 1,250 mm. The study area is given in Fig. 28.1.

28.3 Data Used and Method

The base map of the study area was digitized from Survey of India Toposheets. The River bank was digitized from multi-temporal LANDSAT data. Five decades of data were used to study the spatial variation of the River banks along the study area. The types of data used for the study are given in the table.

Sl. no.	Data	Source	Date	Resolution
1	Toposheets	SOI	1987	1:50,000
2	LANDSAT 8 OLI	USGS	24/04/2018	30 mts
3	LANDSAT 8 OLI	USGS	10/11/2015	30 mts
3	LANDSAT 8 OLI	USGS	10/11/2011	30 mts
4	LANDSAT 7ETM+	USGS	24/12/2005	30 mts
5	LANDSAT 7ETM	USGS	07/10/2000	30 mts
6	LANDSAT 7ETM	USGS	21/12/1995	30 mts
7	LANDSAT 7ETM	USGS	20/10/1990	30 mts

To analyze the long-term change in River bank, multi-temporal data from [Landsat 7, 8] for the years (1990, 1995, 2000, 2005, 2011, 2015, and 2018) were used at the five-year interval. Band 5 in Landsat 7, Pan-merged data from Band 6, and band 8 in Landsat 8 uses short wave infra-red that clearly distinguish between land and water. This band was used to clearly demarcate the River/land boundary in the satellite imageries. The digitized River banks were then assigned respective dates [mm/dd/year]. The digitized River was then processed in a GIS environment. Both the west and eastern River banks were processed individually. The entire length of the River bank was then divided into 100 mts of transects to individually analyze the erosion and accretion rate. The results were derived at five-year intervals for each year considered for the study. The results were then retrieved in excel sheets with erosion and accretion information for individual transects. These tables were then used to create maps to identify erosional and depositional areas throughout the study area. The research methodology is depicted in Fig. 28.2.

28.4   Result and Discussion

The long-term change in River bank from Durgapur to Chalbalpur was estimated using visual image interpretation for the year (1974–2018). The analysis was carried out in a GIS environment at the five-year interval for all the years, respectively (1990–1995, 1995–2000, 2000–2005, 2005–2011, 2011–2015, and 2015–2018). The analysis was also carried for the year 1974–2018 to study the decadal change in River banks for erosion and accretion along the study area. The spatial variation in accretion and erosion rate was classified into five different types, namely: Extreme Erosion, High erosion, No change, High deposition, and Extreme deposition. The final results were then plotted into maps and scatter plots through statistical means for final results.

The analysis revealed that both Extreme erosion and deposition were present during all of the study years. Both the east and west bank undergoes the River change at different rate for each period. The highest rate of erosion (−149 mts) and deposition (278 mts) for the west bank of the River was observed between the year
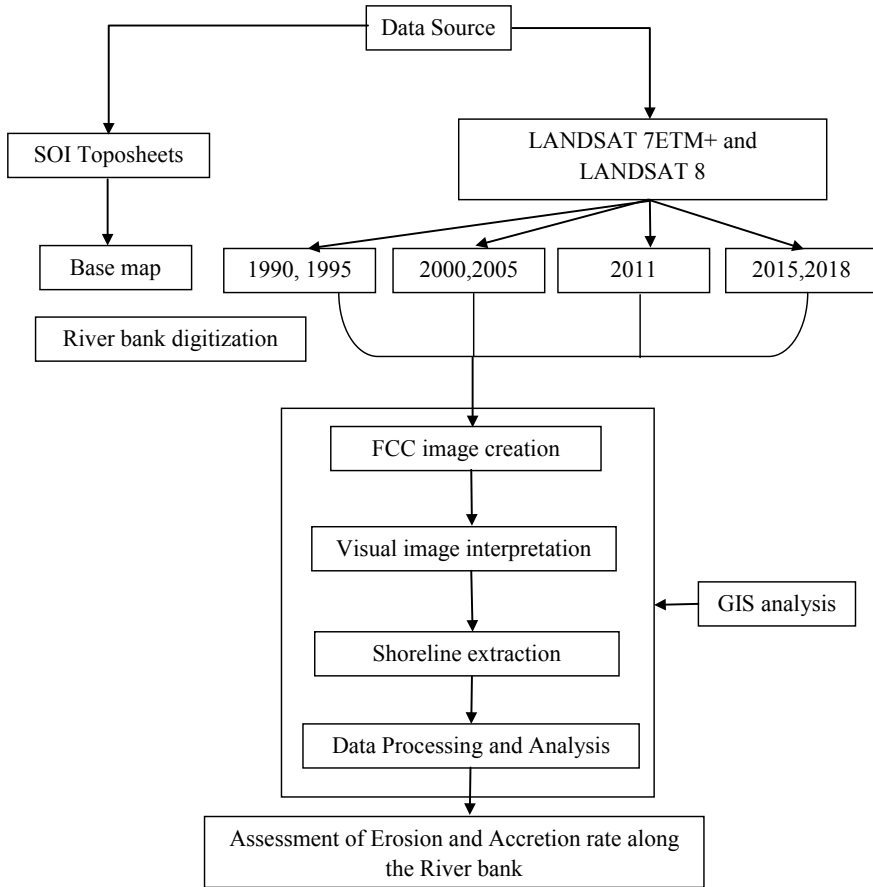
Fig. 28.2 Research methodology

(2005–2011) Fig. 28.3c and (2015–2018) Fig. 28.3f. The highest rate of erosion (−168 mts) and deposition (375 mts) for the east bank of the River was observed between the year (2015–2018) and (1995–2000) Fig. 28.3a. These extreme level of change rates is attributed various anthropogenic and natural activities. These changes occur due to varying sediment transport and deposit in the area. In accordance with that various anthropogenic activities also pose stress along these River banks (Table 28.1).

The analysis was also separately calculated out between the years 1974 and 2018. Toposheets and LANDSAT 8 of the study area were used as reference data for the years. Two different types of analysis were carried for this study. One is to find out the total movement in River bank for the year considered and the second one is to estimate the average movement of the River bank for the period of the study. From the analysis, it can be interpreted that most of the Eastern bank of the River

(a)

(b)

(c)

(d)

(e)

(f)
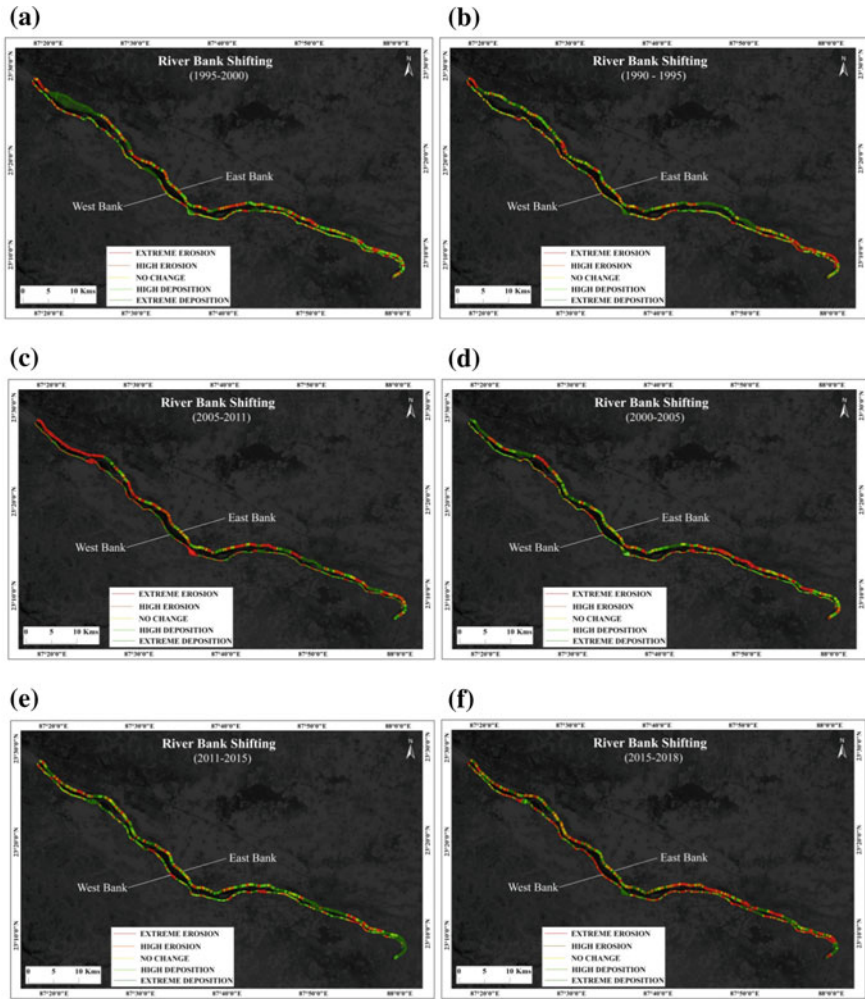
Fig. 28.3 **a** Erosion and accretion rate between (1995–2000); **b** Erosion and accretion rate between (1990–1995); **c** Erosion and accretion rate between (2005–2011); **d** Erosion and accretion rate between (2000–2005); **e** Erosion and accretion rate between (2011–2015); **f** Erosion and accretion rate between (2015–2018)

(Fig. 28.6b) has undergone an extreme amount of erosion near the Babnabera area. The highest erosion and accretion rate along the eastern bank was (−1800 mts) and (586 mts). This is due to the encroachment of tidal inlet near that area. The inland was converted into an agricultural area for practices and joined with the adjoining land surfaces. Depositions were found along the area of Burdwan and Barsul. As for the western bank of the River (Fig. 28.6a), the highest amount of erosion (−746

Table 28.1 Erosion and accretion rate for various years

Sl no	Year	West bank		East bank	
		Highest erosion (mts)	Highest deposition (mts)	Highest erosion (mts)	Highest deposition (mts)
1	1990–1995	−47	159	−123	52
2	1995–2000	−40	116	−49	375
3	2000–2005	−106	40	−102	131
4	2005–2011	−149	72	−76	86
5	2001–2015	−110	194	−58	182
6	2015–2018	−148	278	−168	111

mts) was observed near Beola and the highest amount of deposition (526mts) was observed along near Burdwan area (Figs. 28.4 and 28.5).

Figure 28.7 depicts some of the places that had undergone a massive amount of changes between the years 1974–2018. The image addresses the River bank change along the Eastern part, near Shrilampur, where a part of the land eroded over the course of the River. The rate of change of River bank near Shrilampur, Banpot, and Hotsimul area averages up to 900 mts. In another image, the inland has been converted for agricultural practices over the course of time. The average rate of the
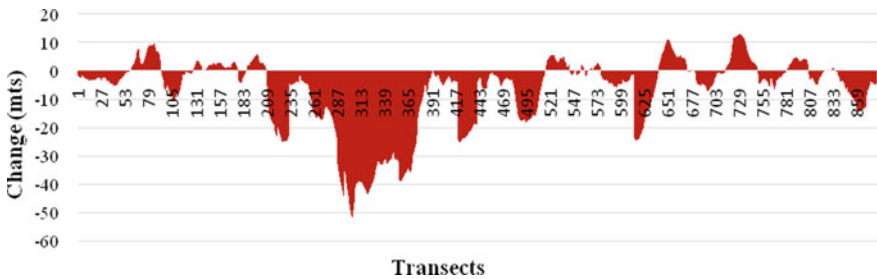
Fig. 28.4 Average River shift of the Eastern bank (1974–2018)

Fig. 28.5 Average River shift of the Western bank (1974–2018)
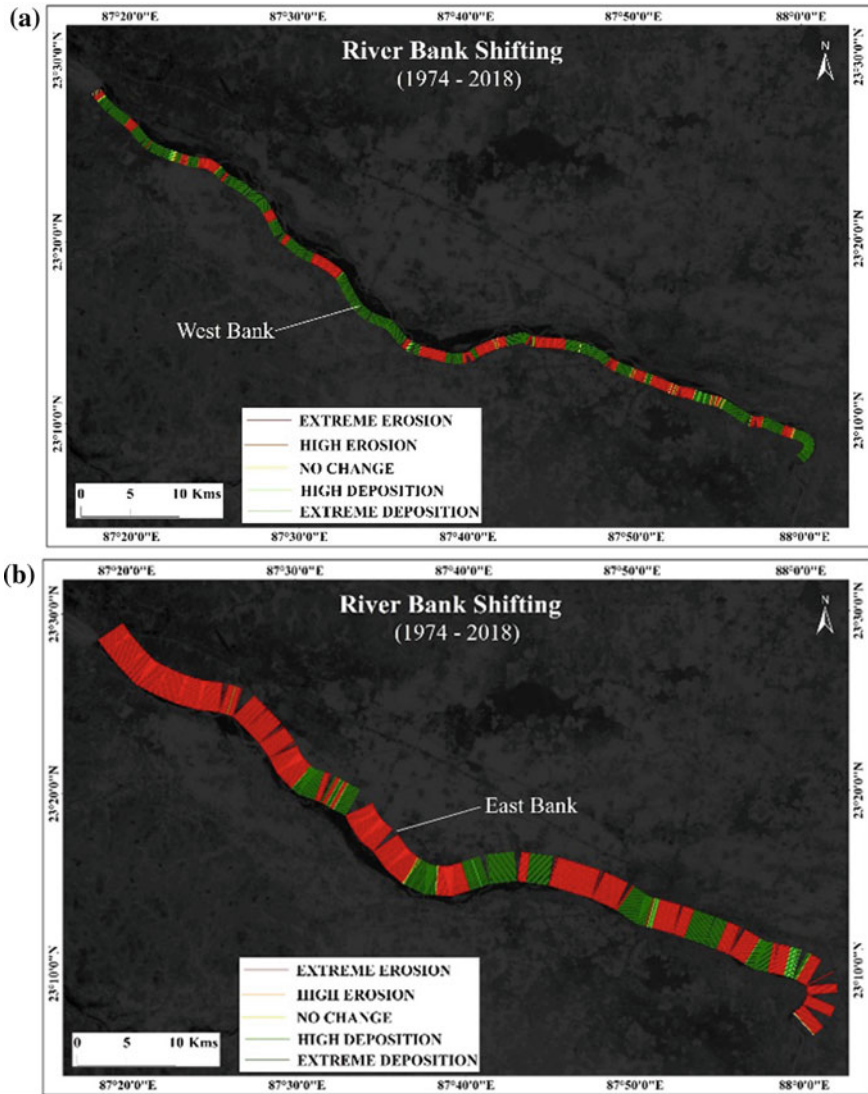
Fig. 28.6 River bank shifting (1974–2018)

River shift has been calculated for the year 1974–2018. This change in River shift was calculated by dividing the River bank through the number of years that had elapsed between them. The Eastern bank (Fig. 28.4) varies from −13.1 (erosion) to 13.2 (deposition). Whereas the western bank (Fig. 28.5) ranges from −52 mts (erosion) and 12.3 mts (deposition).
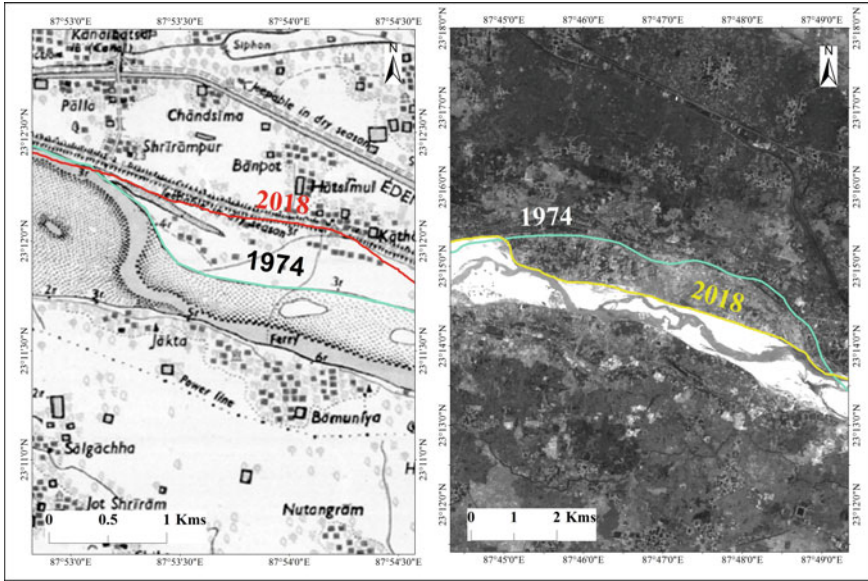
Fig. 28.7 Locations with part of River banks that had undergone massive erosion and deposition

28.5   Conclusion

The spatial and temporal variations of the River bank extending from Durgapur to Chalbalpur have been presented as a case study. The analysis revealed that both Extreme erosion and deposition were present during all of the study years. Both the east and west bank undergoes the River change at different rate for each period. The highest rate of erosion (−149 mts) and deposition (278 mts) for the west bank of the River was observed between the year (2005–2011) Fig. 28.3c and (2015–2018) Fig. 28.3f. The highest rate of erosion (−168 mts) and deposition (375 mts) for the east bank of the River was observed between the year (2015–2018) and (1995–2000) Fig. 28.3a. The overall results of the study area suggest that the eastern bank of the study area has undergone an enormous amount of change within these past five decades. Most of the area along the eastern bank had eroded. The western bank of the study area indicated that a major part of the study area had undergone a massive amount of deposition and erosions are found along the fewer parts such as Khandagosh, Somsar, Rupsa, and near Jamna areas. These results would indicate that the River is gradually shifting from western to side of the study area during the study period. The results presented here depict the application of satellite imageries for River bank modelling. However, remote sensing data coupled with field studies would provide much accurate information on River morphology and changing River dynamics overtime.

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