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ASSESSMENT OF EROSION-ACCRETION AND IDENTIFICATION OF THE CHANGE IN BANK LINE OF THE PADMA RIVER IN BANGLADESH USING GIS AND RS APPROACH

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Abstract

The Ganges-Padma is an important river system in South Asia which supports the life and livelihoods of millions of people both in India and Bangladesh. Bangladesh is a riverine country. Every year the country faces many natural hazards due to the natural dynamic behavior of these rivers. These dynamic actions motivate massive migration of banks, producing thousands of homeless families and enormous land losses each year. This study has analyzed the severity of erosion, accretion and bank shifting of the Padma River at Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna and Bheramara, Daulatpur-Kushtia district. Remote Sensing (RS) and Geographic Information Systems (GIS) techniques were applied to calculate erosion, accretion and bank shifting. This study has been carried out to evaluate the river shifting and assessment of related effects on the land-use/land cover using geographic information system (GIS) and remote sensing (RS) techniques between 1972 and 2023 for Padma River in Bangladesh. Only secondary data has been applied for obtaining the research goal. Several computer software such as ArcGIS, Google Earth etc. have been applied to examine raw data. Seven USGS Landsat, MSS, ETM, OLI_TRIS, sensor, and data images between 1972 and 2023 were used in this study. Padma's riverbank shifting designs and changing land cover resulting from 51 years of erosion and accretion methods have been practical. These river shifting rates are based on the difference between 1972 to 1980, 1980 to 1990, 1990 to 2000, 2000 to 2010, 2010 to 2020 and 2020 to 2023. The average rates of erosion and accretion are 506.41 hectares/year and 468.70 hectares/year individually. This study shows that the river bank line shifted significantly between 1972 and 2023 and this triggered massive bank erosion and accretion.

Keywords: *Accretion, ArcGIS, Bank Shifting, Erosion, Khulna, Rajshahi, River Dynamics.*

Introduction

A river flows from upstream to downstream across the landscape and is an important part of the water cycle. Rainfall, surface runoff, groundwater flow and relief of huge volumes of water which is deposited in normal glacier basins can feed the rivers (Sinha and Ghosh, 2012). River channel migration frequently takes place in the river in the floodplain zones. The morphological dynamics of rivers in the floodplain zones act as an important ecological indicator of its profound effect on both ecological and human existence (Ritu *et al*.,2023). Still, natural hazards, such as bank erosion, flooding and sideways change also occur with this river. The rivers have been an important part of Bangladesh's history and culture. Rivers are particularly environmentally sensitive and deposited channels can reactivate or respond to varying levels activated by water, sedimentation, tectonic activity and human activity on a diversity of time and time scales (Ophra *et al.*, 2018). Any natural or anthropogenic alterations can lead to a deviation from a state of dynamic stability. In addition, this can cause channel variability, leading to channel and design changes (Midha and Mathur, 2014). The rivers have changed their courses often and therefore there is no actual permanent map of bank lines (Mithun *et al.*, 2012).

The hydraulic and deltaic deltas of Bangladesh are unique in this country which is established by the accumulation of the Padma, Meghna and Jamuna Rivers (Islam *et al.*, 2010). These river progressions and their dynamics over time have been an interesting subject of study in geomorphology (Petts, 1995). Bangladesh is intersected by more than 600 rivers, which makes this country fertile land (Khan and Islam, 2015). The Padma, the Meghna, and the Jamuna are the three main rivers in Bangladesh. These rivers and their distributaries & tributaries regulate their hydrological and fluvial-morphological activities. The Rivers vary from each other in their physical characteristics and the construction of the channels. The Padma River plays an important role in changing morphological activities than any other river (Hassan and Akhtaruzzaman, 2010). The river's dynamic occupation of the river causes erosion of riverbanks in Bangladesh that causes huge suffering every year to thousands of homeless and landless people (Elahi, 1991).

The Ganges river system is one of the biggest river systems in the world and covers an area of 1.09 million kilometres, Inventing on the Himalayan Gangotri Glacier. In its 2526-kilometer-long journey through China, Nepal, India and Bangladesh to reach the confluence with the Meghna, making it a famous international river. India's largest share of the entire catchment (79.1%) is, however, just 4.3% (equivalent to 32% of that country's area) located in Bangladesh (Dewan *et al.*, 2017). The data from the social survey showed that 95% of people living along the riverbank had lost most of their land. (Eshita *et al.*, 2023). Bank erosion is a regulated process which is mostly controlled by river dynamics. More than 230 rivers including Padma flow into the Bay of Bengal through Bangladesh, which drains 2.4 billion tons of sediment. This influences most of the country (Hussain *et al.*, 2021). Riverbank erosion usually occurs on the edges of bordered meandering channels and the erosion rate depends largely on the characteristics and bank materials of rivers. Bangladesh is possibly the world's most vulnerable to flooding, and some researchers claim that it is the world's most prone to disasters (Zaman, 2019). The Padma is one of Bangladesh's three largest rivers and one of the longest rivers in the sub-landmass. Two hundred and fifty million people of India and Nepal live in its catchment area. More than 20 million people of Bangladesh also live in the catchment area of this river (Kalam and Jabbar, 1991). The Remote Sensing technique is useful to inspect river channel vibrations across a wide range. It has been normally used to track the movement of river channels and identify polio-enlarged terrace surface channels. Several studies inspected the fundamental shift of channels using geospatial methods, such as overlaying a series of historical channel maps. For the checking of river channel changes, anthropogenic moves and movements of land use-related actions in Bangladesh remote sensing data is used (Islam *et al.*, 2014).The study Area Satellite images direct that the rivers consume approximately 8500 hectares of arable land yearly. The event affects around 1368459 people. At present, the study area is vital as it has

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significant installations by the Bangladesh Government like the Ruppur Nuclear Power Plant, Ishwardi EPZ, Bangladesh-India Friendship Power Transmission Station, the Bheramara Thermal Power Station, the Hardinge Bridge, the Lalon Shah Bridge, and the G.K Project, etc. This district is on the bank of the Padma River; shifting and meandering in this area is very rapid, and lastly, most parts have been eroded and deposited recently. The main objective of this study was to investigate the morphological dynamics as well as the effects of erosion and accretion in the study area of the Padma River.

Methodology

Study Area

The study area Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna, and Bheramara-Daulatpur, Kushtia is positioned in the north-western part of Bangladesh and this area is 45km long and its width varies from 4-14 Km. It is a part of the Rajshahi and Khulna divisions. It is situated between the latitudes 20'12.17 to 24'2.24 and longitude 88'44.96 to 89'2.37. In specific, no study of this place calculated the severe erosion, accretion, and rapid bankline movement of the Padma River at the micro-level. A specific emphasis of this research was on investigating morphological dynamics as well as the effects of erosion and accretion in the study area (**Fig. 1**).

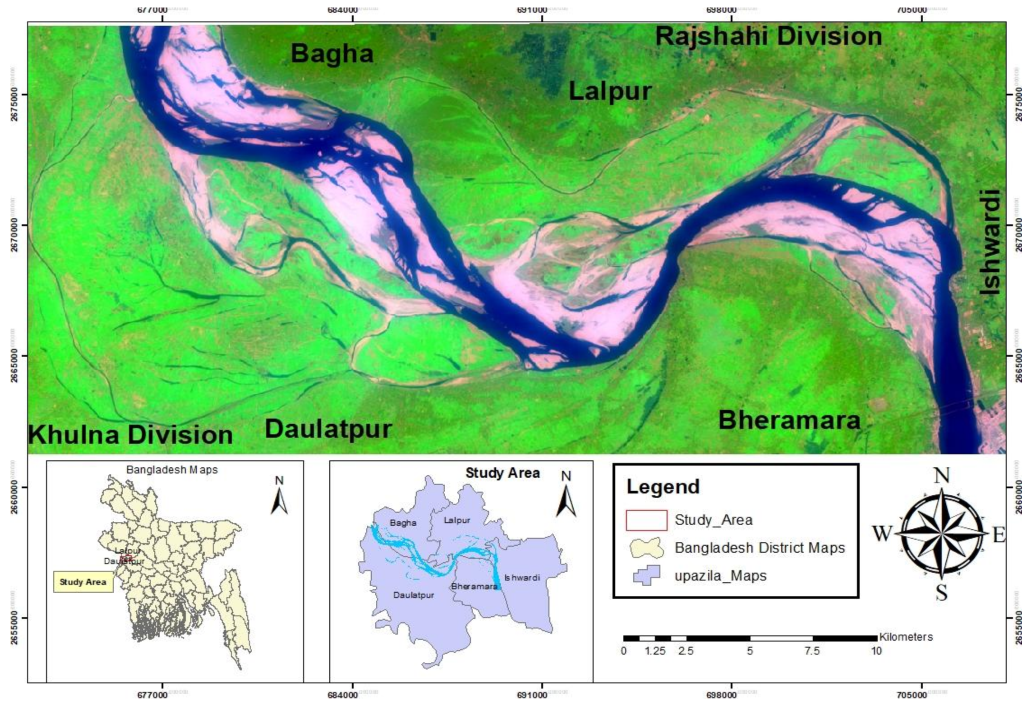

Fig. 1. Details Study Area.

RS and GIS methods

The Remote Sensing (RS) and Geographic Information System (GIS) methods and other statistical data techniques have been used for the assessment of river bank erosion-accretion and identification of the bank line shifting design of the Padma River. At first, the essential data were mainly collected from satellite image analysis to complete this research work. Such satellite images were taken from the United States Geological Survey (earthexplorer.usgs.gov) website, Google Earth Pro, and other maps from LGED. To investigate 51 years of river bank shifting; erosion and Accretion 7 satellite images of 1972, 1980, 1990, 2000, 2010, 2020, and 2023 have been collected. The time intervals are not the same because of maintaining the equivalent (i.e., quality; cloud coverage) between the images. ArcGIS 10.3 is used to envision; correct (Geometric Modification; Radiometric Correction; Atmospheric Correction); Sub setting layer; and Study area's image preparation of Landsat images. Then Landsat images were used for supervised classification. The images are disconnected into two large classifications, namely water and land. After that, the classified image was transferred into ArcGIS 10.3 to attempt a reclassifying process. Then 11 Section/Reference lines for considering the migration of river channels are identified. These 11 Segment/Reference lines are accepted provisional on where the highest rate of erosions occurred. Finally, ArcGIS' standard measurement tool is used to assess the movement of river channels based on two sequential years, i.e., 1972 to 1980; 1980 to 1990; 1990 to 2000; 2000 to 2010; 2010 to 2020; 2020 to 2023 and lastly 1972 to 2023. **Table 1** shows the description of Landsat Select imageries. The Landsat 5 MSS, TM and OLI & TIRS were taken to keep the spatial resolution and maximum band configuration comparable among all images. Some essential articles from the RRI library were accessed. Other minor data sources include Wikipedia, published works and various online sources. Software and Tools used to shape the work were—ArcGIS; Version: 10.3, ArcMap; Version: 10.3, Microsoft Office 2010: Word, and Excel.

Table 1. Description of Landsat Select imageries.

Image No	Acquisition Date	Satellite ID	Sensor ID	Path/Row	Spatial Resolution	Quality	Cloud Coverage
1	23/11/1972	Landset5	MSS	148/043	30 Meter	4	10
2	16/01/1980	Landset5	MSS	148/043	30 Meter	7	10
3	30/01/1990	Landset5	TM	148/043	30 Meter	7	10
4	26/01/2000	Landset5	TM	148/043	30 Meter	7	10
5	21/01/2010	Landset8	OLI &TIRS	148/043	30 Meter	7	10
6	01/01/2020	Landset8	OLI &TIRS	148/043	30 Meter	11	10
7	25/01/2023	Landset8	OLI &TIRS	148/043	30 Meter	11	10

Result and discussion

River bank Erosion trend in the study area

River bank erosion drive in the study area Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna and Bheramara-Daulatpur, Kushtia is the most vulnerable district to the river bank erosion in Padma River. From 1972 to 2023, a 51-year period the erosion was measured. There are seven satellite images reserved to calculate the area of the worn land. Six intermission periods take place for measurement. The interval is 1972-1980, 1980-1990, 1990-2000, 2000-2010, 2010-2020 & 2020- 2023. In 2020-2023 it was made that the erosion rate was highest with 952.98 hectares/year, 2858.94 hectares land was eroded in these 3 years. The erosion rate was also higher in the 1972- 1980 years period with 682.56 hectares/year, 5460.48 hectares land eroded in these 8 years. In 1980-1990 time periods the average erosion rate decreased from 682.56 to 558.32 hectares/year. In the period of 1990-2000, the erosion rate progressively reduced to 349.77 hectares/year and in 2000-2010 the erosion rate increased to 541.69 hectares/year. In 2010-2020 the erosion rate was somewhat reduced to 300.99 hectares/year from the past 10-year time period of 2010-2020. Finally, the average erosion rate was 506.41 hectares/year with a total 25827.03 hectares of land eroded in these 51 years. This high rate of erosion caused unbelievable land loss. **Table 2** describes the detailed result of the river bank erosion charge in this study area.

Table 2. Details Bank erosion in Padma River.

SL No	Period	Duration (Year)	Total Erosion (hectares)	Average Erosion (hectares/year)
1	1972-1980	8	5460.48	682.56
2	1980-1990	10	5583. 15	558.32
3	1990-2000	10	3497.67	349.77
4	2000-2010	10	5416.92	541.69
5	2010-2020	10	3009.87	300.99
6	2020-2023	3	2858.94	952.98
Grand Total		51	25827.03	506.41

River bank Accretion trend in the study area

Erosion and accretion are instantaneous processes of a river basin. In these 51 years from 1972-2023 the accretion rate is significant in Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna and Bheramara-Daulatpur, Kushtia districts. Maximum accretion rate found in 2020-2023 period with 1077.45 hectares/year, and total of 3232.35-hectares land was increased in this frame. And the lowest Accretion rate in 2000-2010 and 2010-2020 with 288.54 hectares/year and 355.28 hectares/year respectively. From 1972 to 1980, the accretion rate was 541.94 hectares/year with a total of 4335.48 hectares of accretion land. From 1990 to 2000, the accretion rate was very close to 1980-1990 which was 484.00 hectares/year. The average accretion rate was measured as 468.70 hectares/year through a total accretion of 23903.73-hectares from 1972-2023 in this study area. The detailed result of river bank accretion is shown in **Fig. 2** and **Table 3**.

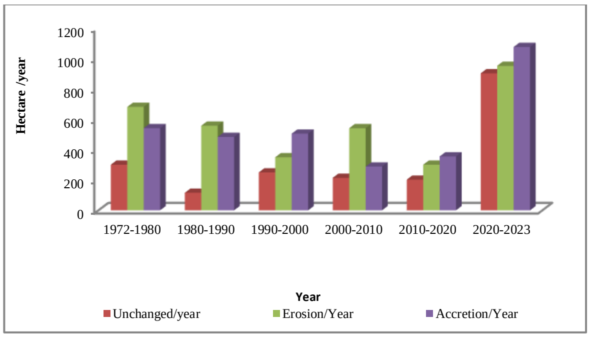

Fig. 2. A chart plot for Erosion and accretion.

Table 3. Details Bank accretions in Padma River.

SL No	Period	Duration (Year)	Total Accretion (hectares)	Average Accretion (hectares/year)
1	1972-1980	8	4335.48	541.94
2	1980-1990	10	4840.02	484.00
3	1990-2000	10	5057.64	505.76
4	2000-2010	10	2885.4	288.54
5	2010-2020	10	3552.84	355.28
6	2020-2023	3	3232.35	1077.45
Grand Total		51	23903.73	468.70

Land area of the study area

The Bagha-Rajshahi, Lalpur-Natore Ishwardi-Pabna and Bheramara-Daulatpur, Kushtia districts land area has changed over time as an outcome of erosion and accretion of the active Padma river. The area of the land falls in the periods 1972–1980, 1980–1990 and 2000–2010, since it was above the accretion level and the inverse cycle was accompanied by a rise in the area between 1990–2000, 2010–2020, and 2020–2023. The most serious period was between 2000 and 2010 across ten-time intermissions; at that time 5416.92 hectares of land were lost. In the period 1990-2000, the largest land accretion happened; there was an increase of 5057.64 hectares of land. During the period from 2000 to 2010, the accretion rate was the lowest, with only 288.54 hectares increased. The specifics are presented in **Table 4** and **Table 5** the study region covered a total of 25827.03 hectares of land eroded between 1972 and 2023, with a cumulative deposit of 23903.73 hectares. Over the 51 years, total land loss was calculated to be 1923.30 hectares with a rate of 37.71 hectares per year.

Table 4. Details Land Area Change by Erosion and Accretion.

SL No	Period	Total Accretion (hectares)	Total Erosion (hectares)	Duration (year)	Unchanged (hectares)	Change Land area (hectares)
1	1972-1980	4335.48	5460.48	8	2406.6	-1125.00
2	1980-1990	4840.02	5583.15	10	1158.93	-743.13
3	1990-2000	5057.64	3497.67	10	2501.28	1559.97
4	2000-2010	2885.4	5416.92	10	2142.00	-2531.52
5	2010-2020	3552.84	3009.87	10	2017.53	542.97
6	2020-2023	3232.35	2858.94	3	2711.43	373.41
Grand Total		23903.73	25827.03	51	12937.77	-1923.30

Table 5. Details Land Area of the study area.

SL No	Year	Total Land (hectares)	Duration (year)	Total Land Loss (hectares)	Land Loss Rate (he/year)
1	1972	128646	8		
2	1980	129771	10		
3	1990	130514	10		
4	2000	128955	10	1923.30	37.71
5	2010	131486	10		
6	2020	130943	3		
7	2023	130570	51		

River bank shifting

Most rivers complete their courses in the wet and sub-humid areas in three phases – young, mature and old. In the old period, during these three stages, the river flowed due to a gentle slope. This causes a side erosion and channel shift in the river valley. A common singularity is bank failure (separation and confinement of bank materials by fluvial, sub-aerial and geotectonic methods in the forms of scraps, aggregates or blocks) downstream of each channel. Padma changes its direction quite frequently. In this analysis, the dynamic change of the Padma River was established over the past few years (**Fig. 3**).

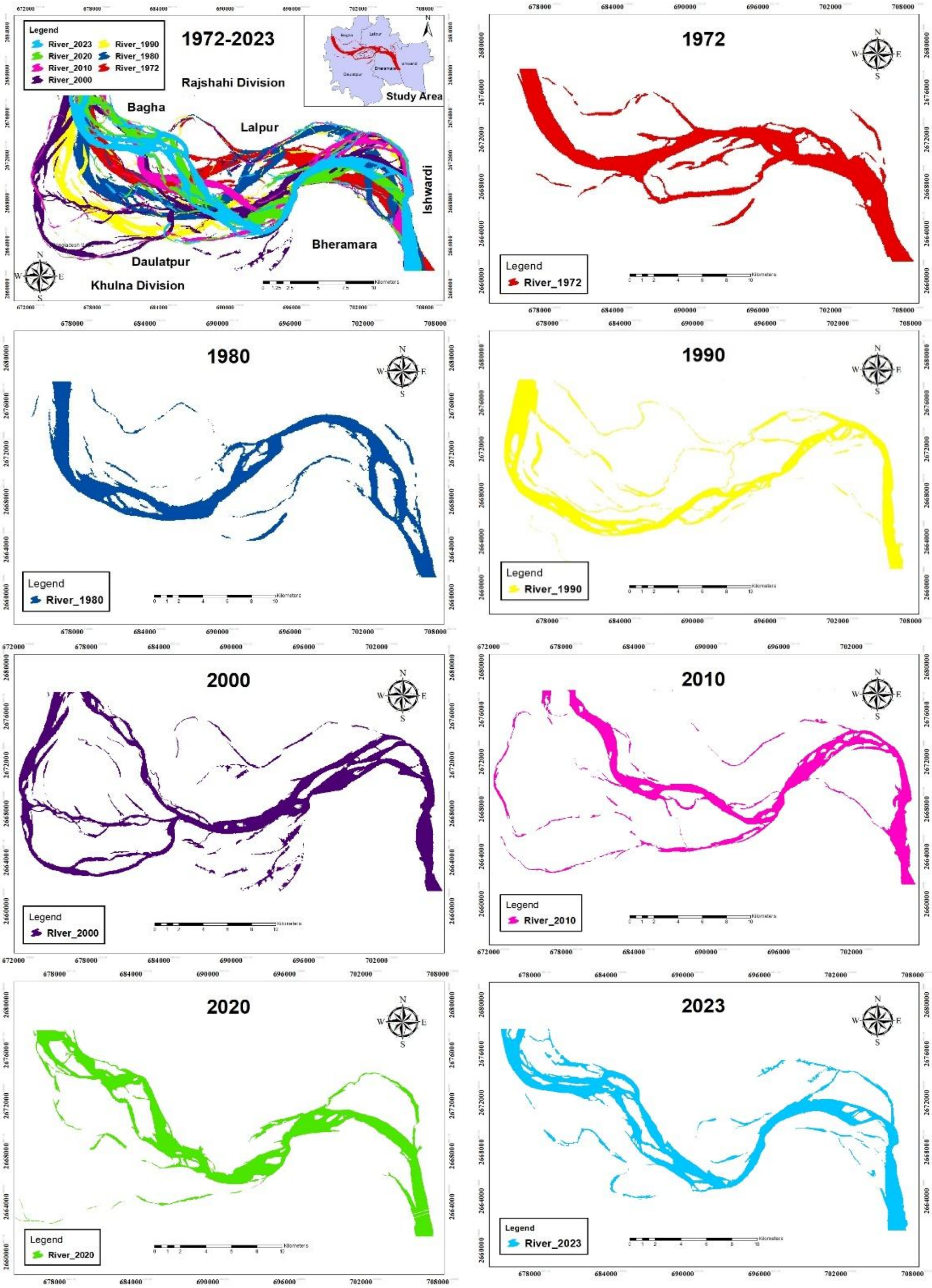

Fig. 3. Position of the river in different years.

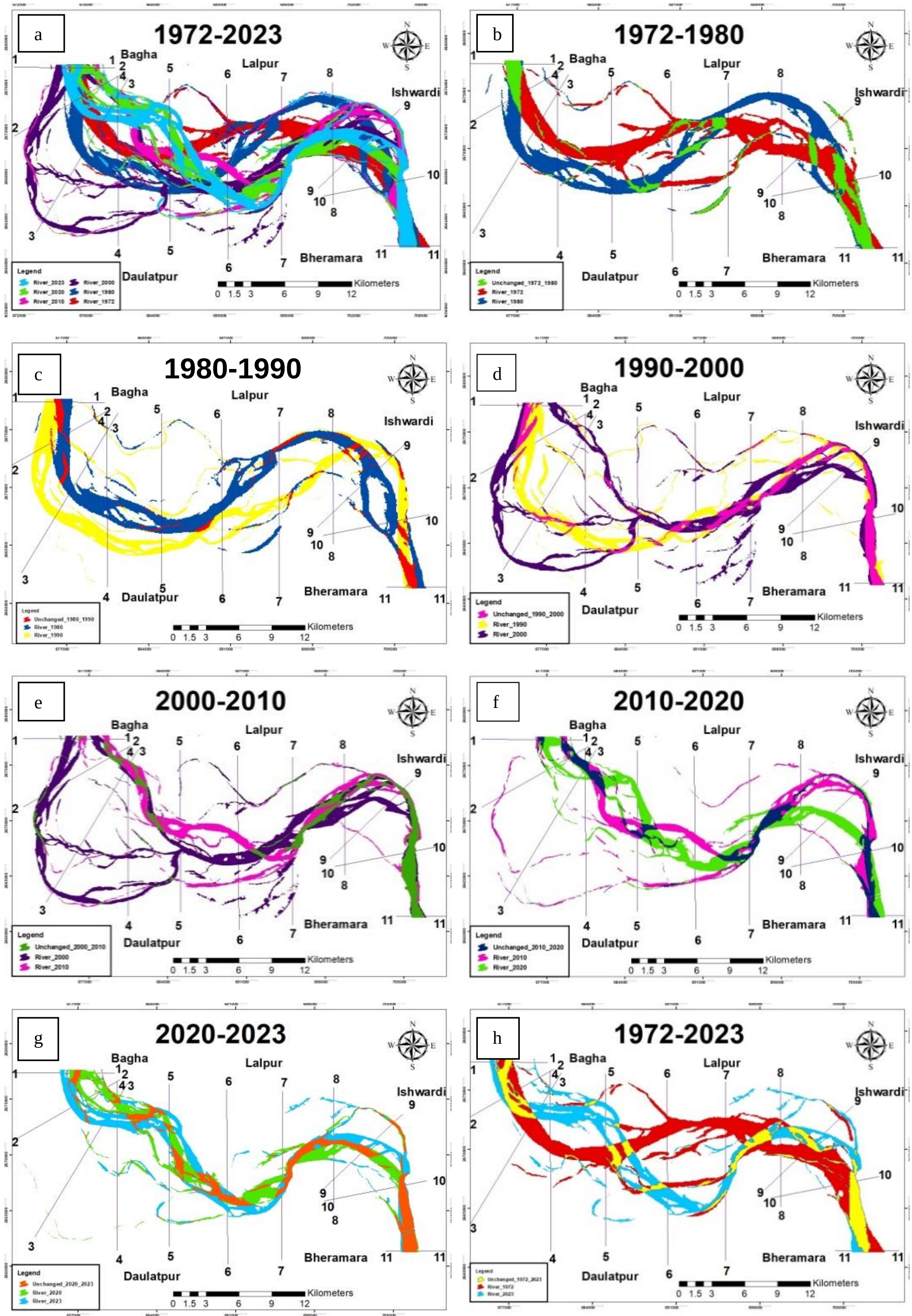

Fig. 4. Sequential change of Padma River Bank shifting, a(1972–1980), b(1972–1980), c(1980–1990), d (1990–2000), e(2000–2010), f(2010–2020), g(2020–2023) and h(1972–2023).

Table 6. Net migration Direction Left to Left Bank (in meters) of Padma River at 11 different locations in different periods.

Section/ Reference line	Net Migration and Direction Left to Left Bank (Meter)						
	1972-1980	1980-1990	1990-2000	2000-2010	2010-2020	2020-2023	1972-2023
1-1	147 W	877 W	1600 E	673 E	200 W	0	114 W
			352 W	3104 E			
2-2	882 SW	1420 SW	3565 NE	0	0	2690 SW	0
			2739 SW	6825 NE			
3-3	3358 SW	2441 SW	8458 NE	0	0	1760 SW	1188 NE
			4876 SW	13300 NE			
4-4	1446 S	3100 S	9370 N	0	0	1850 S	2877 N
			3006 S	12360 N			
5-5	2744 S	1963 S	2716 N	2013 N	3223 N	768 N	3621 N
6-6	4025 S	1087 S	715 S	1754 N	2500 S	450 N	6110 S
7-7	1000 N	4453 S	1361 N	2153 N	210 N	0	4778 S
			2545 S				
8-8	2314 N	1964 S	250 N	596 N	2010 S	574 N	1373 S
9-9	1617 NE	1409 NE	271 NE	1680 NE	3185 SW	981 N	1145 NE
			1363 SW				
10-10	0	832 NE	0	0	0	0	0
11-11	777 W	780 W	0	0	480 E	200 W	1368 E

Shifting nature of Padma river channel

In our study area, the shifting nature of the Padma River is a typical fluvial geomorphic phenomenon that can occur anywhere on rivers. The centrifugal force prevents the river's topmost water surface movement. Moreover, towards the river bottom, the velocities are much less than towards the river top. Enough centrifugal force is not available to counteract the tendency of water at the river top to move inwards. These rotary currents cause the erosion of the concave edge and accretion on the convex side. This shifting nature is like a swing along the river's left and right banks. We consider here only one side of the Padma River. The maps of 1972, 1980, 1990, 2000, 2010, 2020, and 2023 of the Padma Rivers were ready here to show the changing nature of the channel.

Fig. 4-a (1972-2023) shows the maps of all the rivers together, showing that the rivers were spread over an area of 4 to 14 km at different times. The section-wise description of the different two-year rivers of the mentioned rivers is as follows-

Fig. 4-b (1972–1988) of the study area shows that the river was stationary in the tributaries and lowlands. But the 1980 image shows that the main river has eroded and traversed the Daulatpur section to the south. It is also seen that the river crossed in the middle, and in the north, the Lalpur part was much eroded. There was a large char in the middle of the river, but it is not visible in the 1980 photo. In the eastern part of Ishwardi-Pabna, the river was in its original state; no river course had changed.

In **Fig. 4-c** (1980–1990), it is seen that the main river has eroded further to the south, towards the Daulatpur and Veramara sections. The main river moved slightly upstream and downstream to the west. Here it can also be seen that in 1980 the main river was very wide, but in 1990 the river was very thin, and many tributaries and small ones were formed. The 1990 image also shows the river to the northeast By crossing the section, Ishwardi-Pabna moved towards the section.

Fig. 4-d (1990-2000), it is seen that the main river underwent major changes in upstream. The 2000 photograph shows that the river separates to form a narrow channel in the north and another narrow channel in the southwest. The two rivers joined in the middle to form a wide channel in 1990. The figure of 2000 can be seen at that time; many large channels and small channels were created in the river. No significant change was observed on the downstream side of the river, but a little upstream, the river shifted towards the south-Veramara section.

Fig. 4–e (2000–2010) shows that the river has shifted upstream to the northeast, towards the Bagha area. The 2000 image shows three channels upstream, but the 2010 image shows one channel as before. In 2010, the river appeared much narrower, and a branch of the river was seen downstream. A little upstream and downstream, the river moved somewhat towards the northeast towards the Lalpur-Ishwardi section.

Fig. 4-f (2010-2020) shows that in 2020, the river moved upstream to the southwest. Compared to 2010, the river in 2020 was much wider and produced more forage. In 2020, the river moved south towards the Veramara section along the middle. Here it can also be seen that the downstream part of the river has not changed much, but a little upstream, it moved from the northeast to the southwest part of Veramara.

Fig. 4-g (2020-2023) shows that in 2023, the river has moved slightly upstream in the southwest. Compared to 2020, the river in 2023 was much wider, and more char was produced. The river in 2020 did not change much along the middle of the river. Here it can also be seen that the downstream part of the river has not changed much, but a little upstream has moved northeast towards the Lalpur-Ishwardi section.

Fig. 4-h (1972-2023) shows that the upstream has moved upwards in Bagha, and the Daulatpur and Veramara middle positions have shifted far south to form a U shape. There was no change downstream of the river. Analyzing the pictures of 1972 and 2023, it can be seen that the river is returning to its previous state. From the mentioned picture, it is also observed that the river of 2023 is thinner and more formed than the river of 1972.

Table 6 shows the net migration of the Padma River (in meters) at 11 different locations during various periods. Where N, S, E, W, NE, NW, SE, and SW symbolize north, south, east, west, northeast, northwest, southeast, and southwest.

Conclusion

The River shifted between 1972- 2023, a total area casing 25827.03 hectares was eroded and 23903.73 hectares were accretion in the study area. In the period 1972 and 2023, the average erosion rate was 506.41 hectares/year and the accretion rate was 468.70 hectares/year during this 51-year. The highest erosion rate 952.98 hectares/year happened in the period 2020-2023 and the lowest was 300.99 hectares/year in 2010-2020. The highest accretion rate was measured at 1077.45 hectares/year and the lowest was found at 288.54 hectares/year in the 2020-2023 and 2000-2010 periods respectively. In these 51 years from 1972 to 2023, land loss was estimated at 1923.30 hectares with a rate of 37.71 hectares per year. In 1972 the Padma River was almost straight or small in curve, and in 1980 the river gradually thickened and highest in 2000. In 2000 the progression was highly meandered. In these 51 years compared to 1972 and 2023, the river went winding and massive stretches in the Upper and Middle portions which shifted towards north-south in the mid portion and the lower portion shifted Ishwardi north-east, the upper and lower portion remaining almost in the past course. The river moved several times between 1972 and 2023 and this activated erosion and land deposition in this period. In addition to settlement, structural, and economic loss, both physical and mental health of the riverbank people is affected due to frequent migration. Immediate steps through effective river management policy guidelines and implementation are required to adopt a permanent solution.

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