UNDERSTANDING THE BANK EROSION-ACCRETION OF PADMA RIVER MULTI-TEMPORAL SATELLITE IMAGES USING GIS AND RS APPROACH

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ABSTRACT

The Ganges-Padma is an important river system in South Asia that 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, produce 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 and accretion. 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 patterns and changing land cover resulting from 51 years of erosion and accretion processes have been observed. These rates of shifting of rivers 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 bankline shifted significantly between 1972 and 2023 and this triggered massive bank erosion and accretion.

Keywords: *Bank shifting; Erosion; Accretion; River dynamics; Padma river; USGS; ArcGIS.*

1. INTRODUCTION

A river flows from upstream to downstream across the countryside and is an important part of the water cycle. By rainfall, surface runoff, groundwater flow and discharge of huge volumes of water which is dropped in natural glacier basins can feed the rivers. But the natural hazards, such as bank erosion, flooding and sideways change also occur with these rivers (Sinha & Ghosh, 2012). 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 triggered by water, sedimentation, tectonic activity and human activity on a diversity of time and time balances (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 unpredictability, leading to channel and design changes(Midha & Mathur, 2014). The rivers have changed their sequences often and therefore there is no actually stable map of bank lines (Bristow, 1987; A. Hassan et al., 1997; Mithun et al., 2012)

The hydraulic and deltaic floodplains of Bangladesh are single in this country which is established by the addition of the Padma, Meghna and Jamuna River (S. N. Islam et al., 2010). These river growths and its dynamics over time have been an interesting subject of study in geomorphology (Petts, 1995). Bangladesh is interconnected by more than 600 rivers, which makes this country's fruitful land (Khan & Islam, 2015). Among them, Bangladesh's big and wide rivers are the study in geomorphology. The Padma, the Meghna and the Jamuna these three major rivers and their distributaries regulate their hydrological and fluvial-morphological behaviours. In fact, rivers vary from each other in their physical features and the assembly of the channels. The Padma River plays an important role in changing morphological behaviors than any new river (S. Hassan & Akhtaruzzaman, 2010). The river's dynamic occupation of the river causes erosion of riverbanks in Bangladesh that causes enormous suffering every year to thousands of homeless and landless people(Elahi, 1991; Hossain, 1993) .

The Ganges river system is one of the biggest river systems in the world and covers an area of 1.09 million kilometers, Originating on the Himalayan Gangotri Glacier. In its 2526- kilometer-long journey over China, Nepal, India and Bangladesh to reach the confluence with the Meghna, creation it a famous worldwide river. India's largest share of the total catchment (79.1%) is, however, just 4.3% (corresponding to 32% of that country's area) is located in Bangladesh (Dewan et al., 2017). Bank erosion is a regulated method which is mostly controlled by river-dynamic. 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 limits of bounded zigzagging channels and the erosion rate depends largely on the features and bank materials of rivers (D. M. N. Islam, 2006). Bangladesh is probably 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-continent. 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 & Jabbar, 1991). The Remote Sensing technique is useful to inspect river channel vibrations across an extensive range. However it has been commonly used to track the movement of river channels (Thorne et al., 1993) and Detect polio-enlarged terrace surface channels. Some studies reviewed necessary change of channels using geospatial methods, such as overlapping a series of historical channel maps. For the checking of river channel changes, anthropogenic moves and movements of land use related actions in Bangladesh the remote sensing data is used. The study area satellite images direct that the rivers consume almost 8500 hectares of arable land annually. The event affects around 1368459 people (Bandyopadhyay, 2007). The main objective of the study area was to calculate the dangerous erosion, accretion and rapid bankline movement of the river Padma at Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna, and Bheramara-Daulatpur, Kushtia at the micro-level. But at present, the Study area is very important as it has significant installations of Bangladesh Government like Ruppur Nuclear Power Plant, Ishwardi EPZ, Bangladesh-India Friendship Power Transmission Station, Bheramara Thermal Power Station, G.K Project, Hardinge Bridge, Lalon Shah Bridge etc. This districts is on the bank of the Padma River; shifting and meandering in this area is very rapid and lastly, most parts are eroded and deposited

recently. A specific emphasis of this research was on inspecting morphological dynamics as well as the effects of erosion and accretion in the study area.

2. METHODOLOGY

2.1 Study Area

The study area focuses on the Padma River is located in Bangladesh is 45km long and its width differs from 4 to 14 km. The study area Bagha-Rajshahi, Lalpur-Natore Ishwardi-Pabna and Bheramara-Daulatpur, Kushtia is located in the north-western part of Bangladesh. It is a part of the Rajshahi and Khulna divisions. It is situated among the latitude 20'12.17 to 24'2.24 and longitude 88'44.96 to 89'2.37. The logical research technique is accepted in this study because this research tries to find out the movement of bank erosion, accretion, and river shifting of the Padma River in Rajshahi and Khulna Divisions. A specific emphasis of this research was on inspecting morphological dynamics as well as the effects of erosion and accretion in the study area. (figure.1)

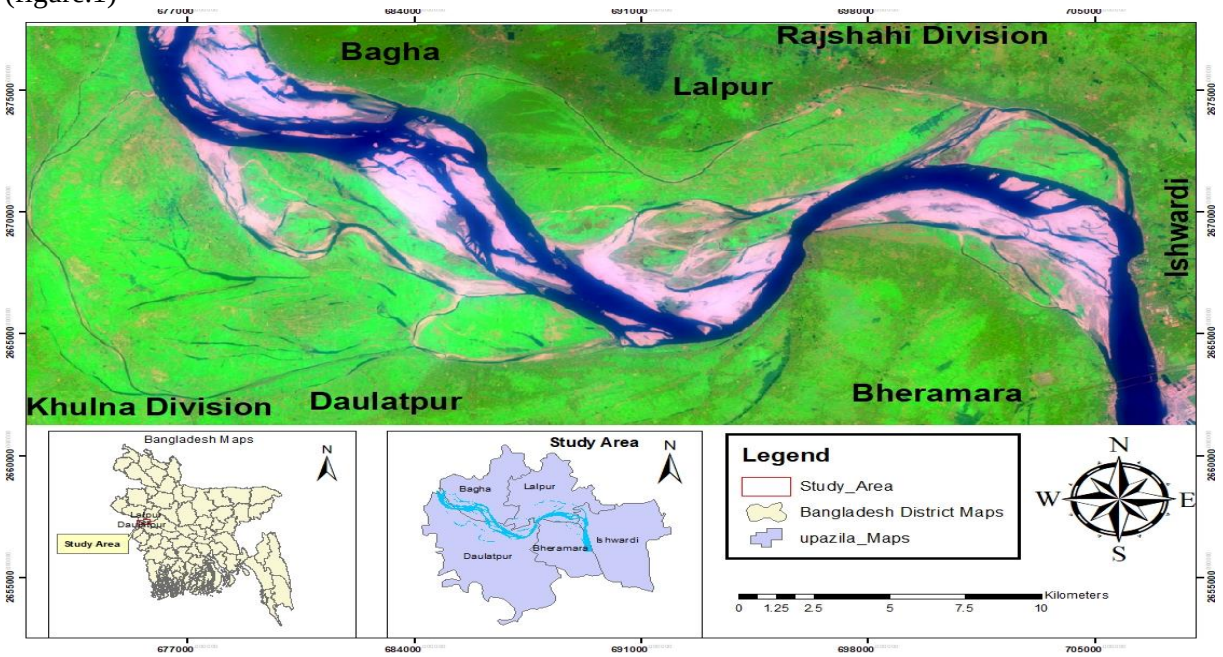


Figure1: Study area location

2.2 Materials and Methods

The Remote Sensing (RS) and Geographic Information System (GIS) methods and other statistical data techniques have been used for the charge of river bank erosion-accretion and identification of bank line shifting design of the Padma River. At first, the vital data were primarily 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 from other maps from LGED, Wikipedia and Banglapedia. 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 intermissions are not the same because of maintaining the equivalent (i.e., quality; cloud coverage) between the images. ArcGIS 10.3 is used to envision, and correct (Geometric Modification; Radiometric Improvement; Atmospheric Correction); Sub setting layer; and Study area's image preparation of Landsat images. Then Landsat images are used for supervised classification. The images are separated into two large classifications, namely water and land. After that, the classified image is transported into ArcGIS 10.3 to effort a reclassify process. Then 11 Section/Reference lines for considering the immigration of river channels are identified. These 11

Section/References lines are accepted provisional on where the highest rate of erosion happened. Finally, ArcGIS' normal measurement tool is used to measure the movement of river channels on the basis of 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: Description of Landsat Select Imageries The Landsat 5 MSS, TM, and TIRS were taken to keep the spatial resolution and maximum band configuration comparable among all images. Some essential articles from the River Research Institute (RRI) library were accessed. Other minor data sources include Banglapedia, Wikipedia, published works, and various online sources. Software and Tools used to outline the work were ArcGIS, Version 10.3, Microsoft Office 2010 Word, and Excel.

Table1: Description of Landsat Select imageries.

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

3. RESULT AND DISCASION

3.1 River bank Erosion Trend

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 kept 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 of land was eroded in this 3-year period. The erosion rate was also higher in the 1972- 1980 years period with 682.56 hectares/year, 5460.48 hectares of land eroded in this 8-year period. In the 1980-1990 time periods, the average erosion rate reduced from 682.56 to 558.32 hectares/year. In the time period of 1990-2000 the erosion rate gradually reduced to 349.77 hectares/year and 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 total 25827.03 hectares of land eroded in this 51-year period. This high rate of erosion triggered unbelievable land loss. Table 2 describes the detailed outcome of the river bank erosion charge in this study area.

Table 2: Details Bank erosion and accretion .

SL No	Period	Duration (Year)	Total Erosion (hectares)	Average Erosion (hectares/year)	Total Accretion (hectares)	Average Accretion (hectares/year)
1	1972-1980	8	5460.48	682.56	4335.48	541.94
2	1980-1990	10	5583. 15	558.32	4840.02	484.00
3	1990-2000	10	3497.67	349.77	5057.64	505.76
4	2000-2010	10	5416.92	541.69	2885.4	288.54
5	2010-2020	10	3009.87	300.99	3552.84	355.28
6	2020-2023	3	2858.94	952.98	3232.35	1077.45
Grand Total		51	25827.03	506.41	23903.73	468.70

3.2 River bank Accretion trend

Erosion and accretion are rapid processes in a river basin. In these 51 years from 1972-2023 the accretion rate in Bagha-Rajshahi, Lalpur-Natore, Ishwardi-Pabna, and Bheramara-Daulatpur, Kushtia districts several meaningfully. Maximum accretion rate found in 2020-2023 period with 1077.45 hectares/year, and total 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. In the period of 1972- 1980 the accretion rate was 541.94 hectares/year with the total 4335.48 hectares of accretion land. And in the period of 1990-2000 the accretion rate was very near 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 outcome of river bank accretion is shown in Figure 2 and Table 2.

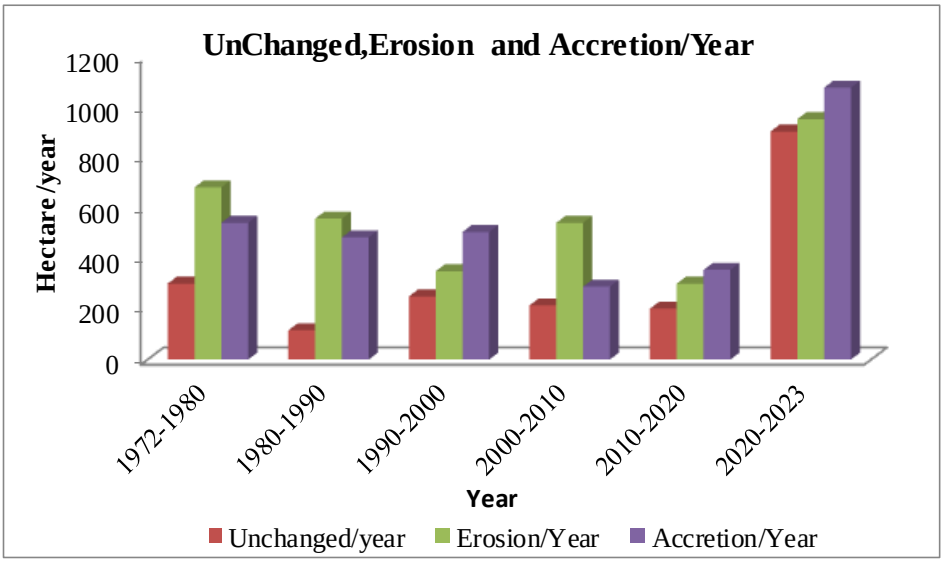


Figure 2: Comparison of Erosion, Accretion and Unchanged area

3.3 Land area changed trend

The Bagha-Rajshahi, Lalpur-Natore Ishwardi-Pabna and Bheramara-Daulatpur, Kushtia districts land area has changed over time as a result of erosion and accretion of the active Padma river. The area of the land falls in the periods 1972–1980 and 1980–1990 and 2000–2010, due to the fact that it was above accretion level and the opposite cycle was convoyed by a rise in the area between 1990–2000 and 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. And 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. (Table 2 and Table 3). The study region covered a total of 25827.03 hectares of land eroded between 1972 and 2023, with a growing deposit of 23903.73 hectares. Over the 51-year period, total land loss was calculated to be 1923.30 hectares with a rate of 37.71 hectares per year (Table 4).

Table: 3 Details Land Area Change by Erosion And Accretion.

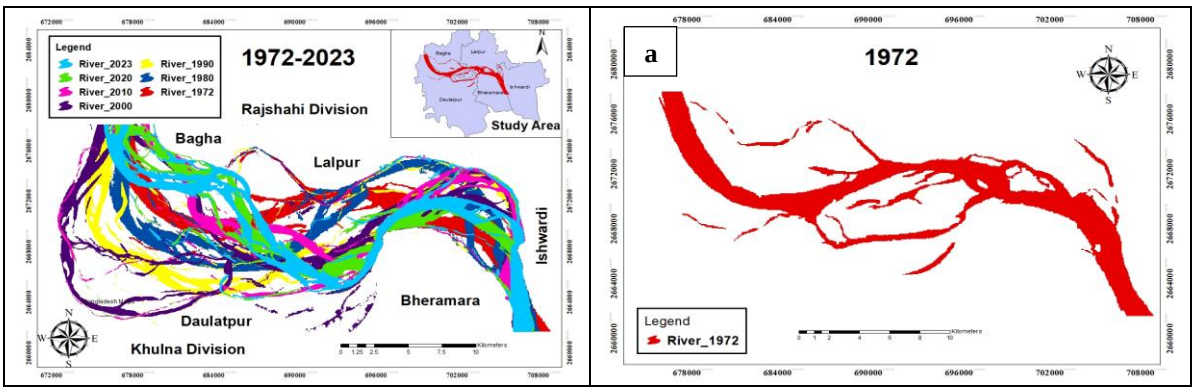
SL No	Period	Total Accretion (hectares)	Total Erosion (hectares)	Duration (year)	Unchanged (hectares)	Change Land area (hectares)
1	1972-1980	4335.48	5460.48	8	2406.6	-1125.00
2	1980-1990	4840.02	5583.15	10	1158.93	-743.13
3	1990-2000	5057.64	3497.67	10	2501.28	1559.97
4	2000-2010	2885.4	5416.92	10	2142.00	-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: 4 Details Land Loss Area.

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

3.4 River bank shifting

Most rivers complete their processes 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 grains, aggregates or blocks) on the 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. Figure.3



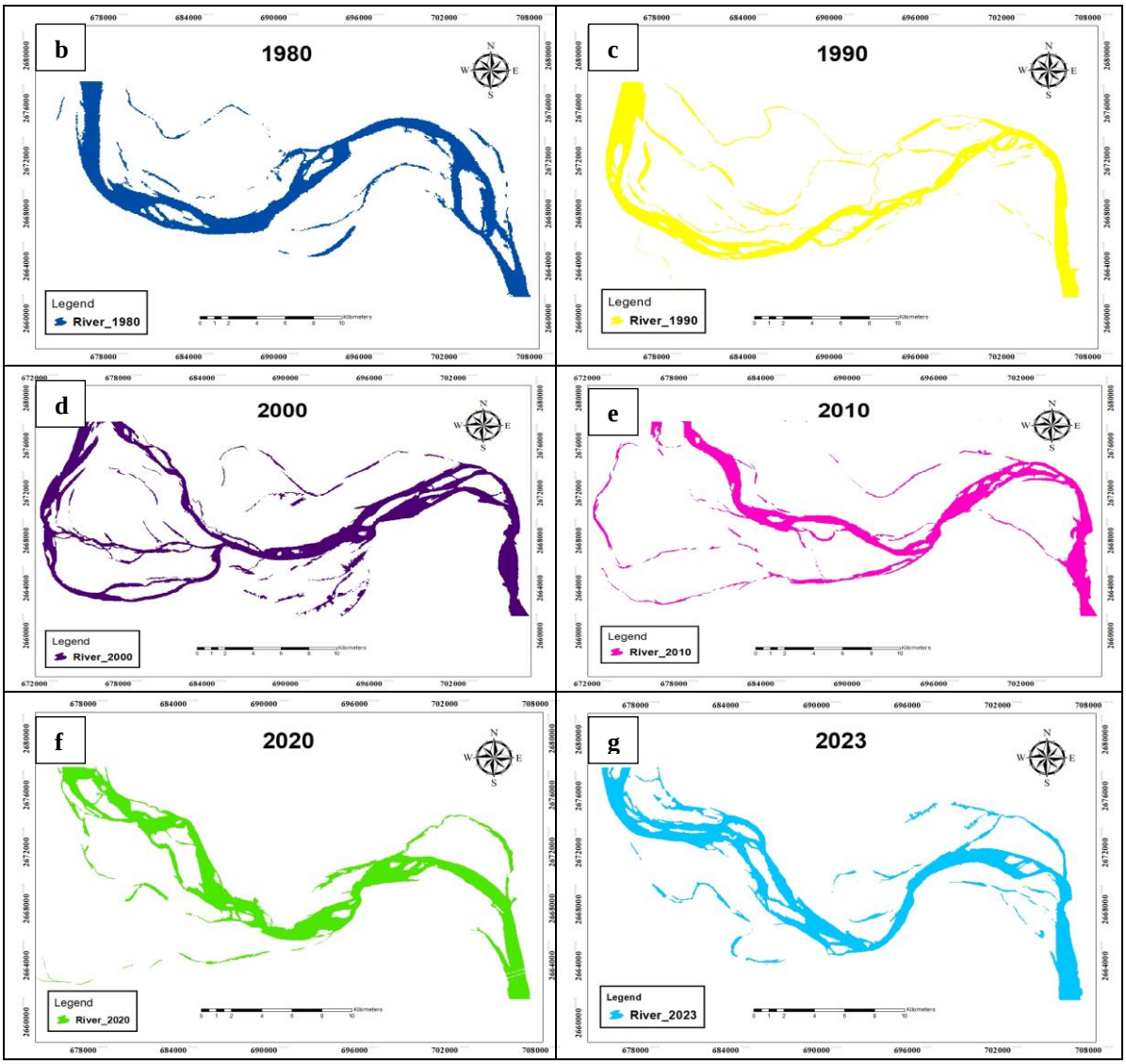


Figure 3: Position of the river since (a) 1972, (b) 1980, (c) 1990, (d) 2000, (e) 2010, (f) 2020 and (g) 2023.

3.5 Shifting nature of Padma river channel

The shifting nature of the Padma River in our study area is a typical fluvial geomorphic phenomenon that can occur anyplace on rivers. This shifting nature is like a swing which occurs along the river's left and right bank. We consider here only one side of Padma River which is arrived in our study area. The maps of the years 1972, 1980, 1990, 2000, 2010, 2020 and 2023 of the Padma Rivers were ready here to show the changing nature of the channel.

Figure: 4-(a):(1972-1980) 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 has changed.

Figure: 4-(b):(1980-1990), it is seen that the main river has eroded further to the south, towards the Daulatpur and Veramara section. 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 narrow 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.

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

Figure: 4 -(d):(2000-2010) shows that the river has shifted upstream to the north-east, 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 narrow and a branch of the river was seen downstream. A little upstream of downstream the river moved somewhat towards the north-east towards the Lalpur-Ishwardi section.

Figure: 4-(e):(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.

Figure: 4-(f):(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 north-east towards the Lalpur-Ishwardi section.

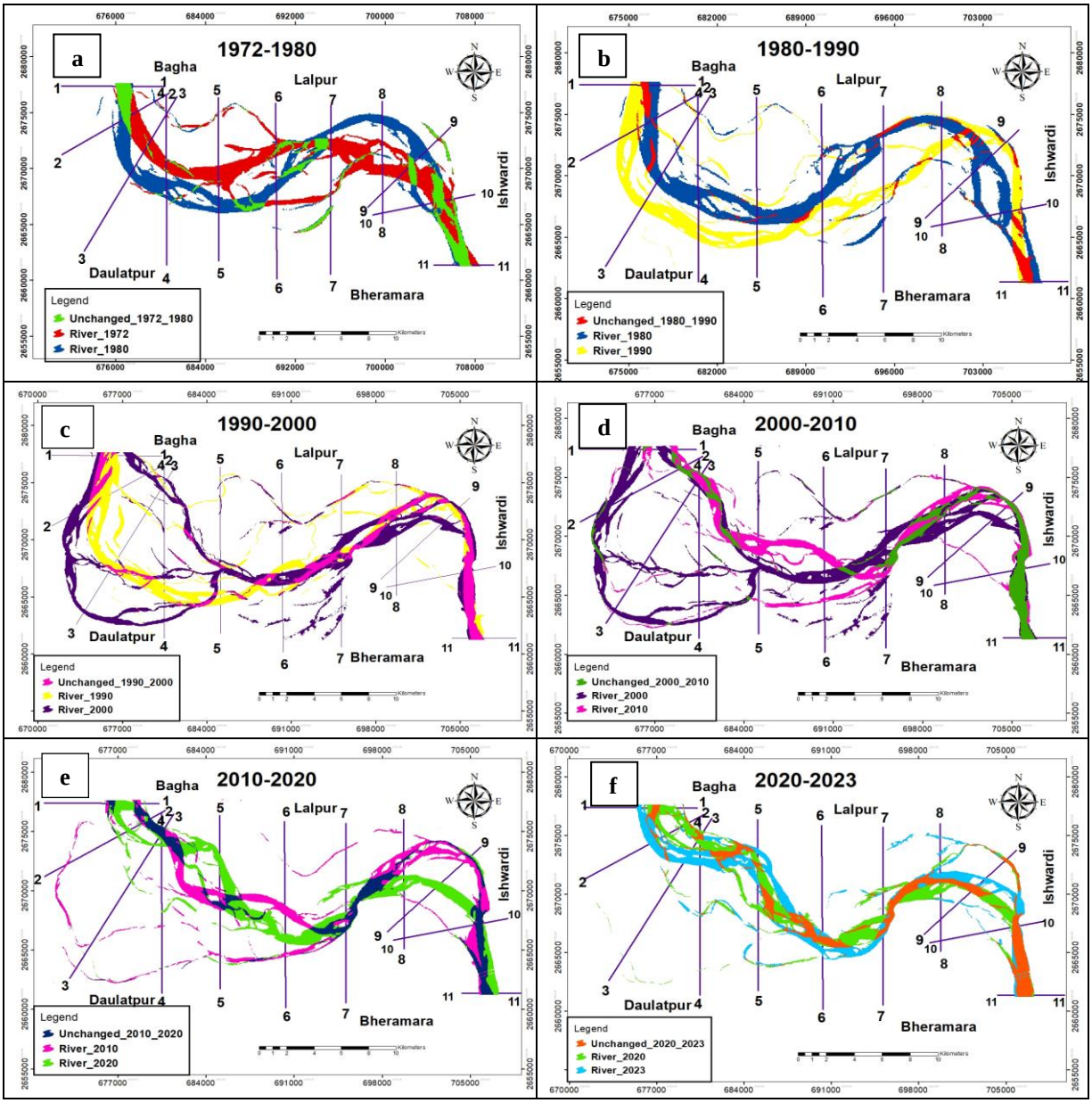
Figure: 4-(g):(1972-2023) shows that the upstream has moved upwards, and the middle position has shifted far south to form a U shape. There was no change downstream of the river. Analyzing the pictures of 1972 and 2023, it can be seen that the river is returning to its previous state. From the mentioned 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 Padma River (metres) at 11 different positions during several periods. Where N, S, E, W, NE, NW, SE, SW indicate north, south, east, west, northeast, northwest, southeast, southwest.

Table 6: Net migration Direction Left to Left Bank (in meter) of Padma river at 11 different location in different period.

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 2545 S	2153 N	210 N	0	4778 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 1363 SW	1680 NE	3185 SW	981 N	1145 NE
10-10	0	832 NE	0	0	0	0	0
11-11	777 W	780 W	0	0	480 E	200 W	1368 E



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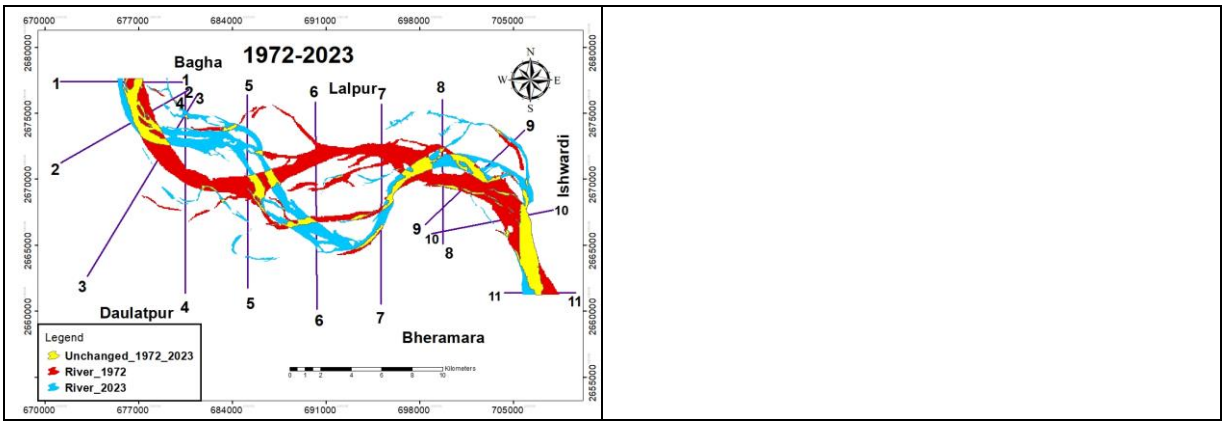

Figure 4: Sequential change of Padma River Bank shifting, (a):(1972–1980), (b):(1980–1990), (c):(1990-2000), (d):(2000–2010), (e):(2010–2020), (f):(2020–2023) and (g):(1972–2023)

4. CONCLUSIONS

The River shifting between 1972 and 2023, an average erosion rate was 506.41 hectares/year and the accretion rate was 468.70 hectares/year during this 51-year. In the period 1972- 2023, a total area casing 25827.03 hectares was worn and 23903.73 hectares was accretion in the study area. The highest erosion rate 952.98 hectares/year occurred 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 individually. In this 51-year period from 1972 to 2023, land loss was estimated at 12937.77 hectares/year. In 1972, the Padma River was almost straight or small in curve, and in 1980 the river was progressively thickened and highest in 2000. In 2000 the development was highly meandered. In this 51-year period compared to 1972 and 2023, the river went winding and massive stretches in the Upper and Middle portion which shifted towards north-south in the mid portion and the lower portion shifted 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.

5. ACKNOWLEDGEMENTS

I prompt enough thanks to S.M Abu Horayra, Honorable DG Sir, River Research Institute, for his support and inspiration. I also want to thank my parents who always inspire me and help me to keep it up. Finally, I want to thank all my friends who encouraged and help me to finish this paper.

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