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Research Paper

River shifting trend and landcover change by River Padma over four decades (1979-2019) : A case study at Naria *Upazila* of Shariatpur District

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Abstract

River channel morphologies are defined by riverbank accretion and erosion and how they change landcover over time. This study has examined the change of natural landcover of Naria *upazila* by the River Padma through analyses of satellite images using ERDAS Imagine 2019 and ArcGIS 10.8 software. Landcover maps were generated to monitor morphological changes caused by Riverbank erosion. Imageries from 1979 to 2019 at ten-year intervals from Landsat's Operational Land Imager and Thermal Infrared Sensor (for 2019), Enhanced Thematic Mapper Plus (for 2009 and 1999), Thematic Mapper (for 1989) and Multispectral Scanner (for 1979) were used. After identification of shifting of river course using unsupervised and supervised image classifications, landcover maps at ten-year intervals were generated with eight land use classes viz., river, water channel, inland water, forest, vegetation, *char* land and settlements. During the period of 1979 to 1999, river channel area in Naria *upazila* increased from 29.42 km^2 to 44.34 km^2 and between 2009 and 2019, river area decreased from 37.51 to 30.4 km^2. In the period of 1979 to 2019, river area decreased from 11% to 10% and settled areas increased from 6 to 7%. The most significant change was for forest cover, which went down from 33% to only 6%. The study highlights four-decades of the River Padma's shifting trends and its effects on Naria *upazila's* landcover by riverbank erosion for the first time. This research has the scope of incorporating into the long-term morphological changes in the river as supportive research for future initiatives to adapt plans and policies for the vulnerable communities' life and livelihood.

Keywords: Remote sensing, image analysis, landcover change, river shifting, trend analysis.

1. Introduction

Riverbank erosion affects thousands of people living along the riverbanks in riverine Bangladesh. Erosion causes damage every year by destroying farms, homestead land, and standing crops. The hazard of erosion is not fixed to any location and moves along the banks of Bangladesh's major rivers and their tributaries. Riverbanks move from 60 to 1600 m annually in Bangladesh due to erosion and accretion.

The unpredictable nature of erosion processes is not offset by accretion. The lives of those who reside there are dramatically affected by these processes as well. A study concluded

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in 1991 reported that out of the 462 *upazilas*[2] in the country, 100 were subject to some form of riverbank erosion, of which 35 *upazilas* were seriously affected impacting about one million people on a yearly basis. In Bangladesh, rivers erode about 10,000 ha of land each year. (WARPO, 2001).

There is no clear process in place to determine the degree of damage in this continuous catastrophe and river erosion results in significant property loss every year. One million individuals are affected yearly. Among them, half a million become displaced and the rest never get appropriate accommodation Each year the river systems engulf 9,000 ha of fertile land from the deltaic plain of the country (IFRCS. 2001).

As of 15 September 2018, up to 5,000 people of Naria *upazila* have become homeless due to erosion of the bank of the River Padma. There was severe erosion at at least ten points along a 7 km stretch on the banks of the Padma in Shariatpur District including Naria Municipality, Kedarpur Union[3], Moktarer Char Union, Nawa Para Union, Charatra Union and Gharisara Union. At least 200 businesses at Sadhur Bazar and 200 shops in the Wapda Bazar area were encroached by the river as well. On 7 August 2018, a large part of the Sadhur Bazar Launch Station collapsed due to sudden erosion that washed away 29 people. As of 15 August 2018, 19 people were rescued, and one body was recovered, but the rest were still missing (Start Fund Bangladesh, 2018)

In 2018, Naria *upazila* of Shariatpur district faced acute riverbank erosion which had a large impact on human lives and properties. Shariatpur is listed in the *National Plan for Disaster Management 2010-15* (DMB, 2010) as an area prone to risks of cyclone, flood, and riverbank erosion. Shariatpur district faced devastating floods in 1996, 2012 and 2019 (EM-DAT, n.d.).

The River Padma's average width increased from 5.7 km in 1984 to 7.1 km in 1993, corresponding to a widening rate of 159 m/year. Its left and right banks eroded 121 m and 38 m per year respectively (Rahman, 2013). Trend analysis of riverbank erosion can indicate the future initiatives that need to be taken to adapt plan and policy for the betterment of vulnerable communities' life and livelihood. Understanding the patterns, changes, and interactions between human activities and natural occurrences in the landscape is essential for effective land management and better decision-making. Observations made by satellites are presently especially relevant to and beneficial for research on land use and landcover change (Yuan et al., 2005).

Research recommends integrating remote sensing, GIS, and cartography approaches to develop an accurate landcover layer at any scale for a region where the landcover elements are varied and complicated (Rujoiu-Mare & Mihai, 2016).

Several studies have been conducted on the shifting of the River Padma but this study is particularly focused on the physical impacts on landcover of the Naria *upazila* in Shariatpur district and its changing geography. What also sets this study apart is the use of digital change detection methods for determining the landcover type and location

[2] Upazilas or sub-districts are the second lowest tier of regional administrative units in Bangladesh. There are 495 upazilas in 64 districts of the country.

[3] Unions are the lowest tier of administrative units in Bangladesh. Each union consists of several villages and has elected representatives in the Union Council.

change (Rawat& Kumar, 2015). The term "landcover" encompasses a range of elements that exist on the earth's surface. This study is intended to identify the trend of shifting course of the River Padma and its impact on landcover change.

Research Objectives

- To identify the riverbank erosion trend of the Padma at Naria *upazila* in Shariatpur district.
- To track the change of landcover due to riverbank erosion and find out ways to minimize the adverse effects.

2. Materials and methods

2.1 Study setting

Naria *upazila* is located in an erosion prone area on the bank of the River Padma between 23°14' and 23°25' north latitudes and 90°18' and 90°30' east longitudes in Shariatpur district of Bangladesh. It covers an area of 240.02 km^2 that is subdivided into three parts by the River Padma. Naria *thana*[4] was founded in 1930 and in 1983 it was upgraded to an *upazila.* (Bangladesh National Portal, 2023). The main rivers' continuously changing courses in the active alluvial plains cause both riverbank erosion and the formation of new land (accretion) (Haque & Zaman, 1989). Figure 1 shows the location of Naria.

2.2 Data collection and analysis

Ten-year interval images of the Padma, specifically from 1979, 1989, 1999, 2009 and 2019 were obtained by downloading them from the USGS website. Images for 1979 were from Multispectral Scanner (MSS) (path 137, row 44), for 1989 images were from Thematic Mapper (TM), for 1999 and 2009 they were from Thematic Mapper Plus (ETM+), and finally, the 2019 images were from Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS).

Four reflective bands for the year 1979, seven reflective bands for the images of 1989 to 2009, and for 2019, eleven reflective bands were considered for image classification. Images used are from the dry season, collected between December and March. The change analysis was done with ERDAS Imagine 2014 and GIS analysis was done with ArcGIS 10.8.

Remote sensing software was used to create a false colour composite for each year (as described in section 2.3) to identify river shifting and landcover change. To visualize the delineation of the riverbanks, seven layers of imagery from Landsat data from 1979 to 2009 and eleven layers from Landsat images of 2019 were stacked via the ERDAS Imagine software's subset tool, and the study area was delineated. Both supervised and unsupervised classification techniques were used to analyse the imageries for separating the land features from the water. The quality of the downloaded cloud-free Landsat imageries was upgraded by using histogram equalization algorithm. Each year's shape files were produced using iso cluster supervised classification in ArcGIS 10.8. To measure

[4] Thana is the erstwhile nomenclature for upazila.

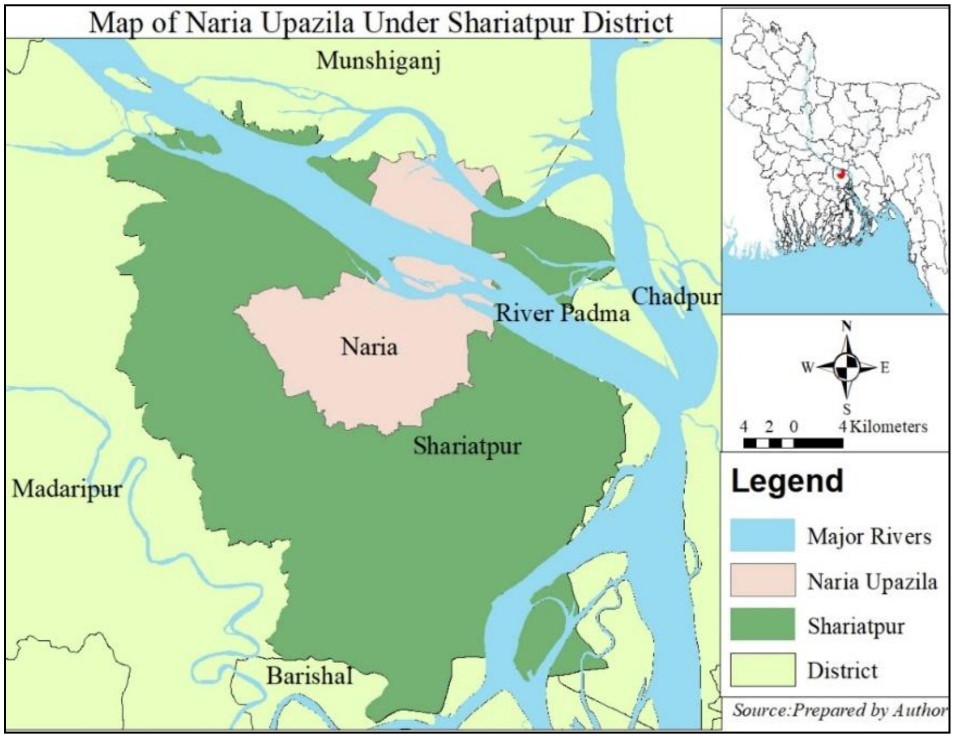

Figure 1. Location map of Naria *upazila*.

the area of the two banks of the Padma River and extract river boundary manually digitization was done to monitor dynamic changes over the 40-year period. The base map was the unsupervised classified image from 1979 and classified images of all later years were examined to extract river area over those years. Figure 2 presents the conceptual diagram of data processing for river course change followed in this study.

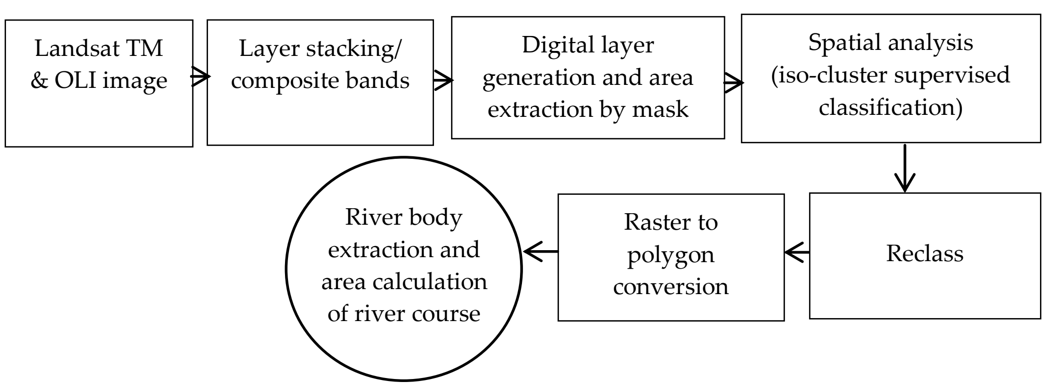

Figure 2. Conceptual data processing of river course change.

The GIS tool Area of Interest (AOI) was used in this study for visual data analysis, validated by reference data. As a result, the analytical landcover classes well represent actual landcover. Supervised image classification enhanced the quality of the investigation for calculating landcover change results. Figure 3 presents the conceptual data analysis diagram of landcover change detection followed in this study.

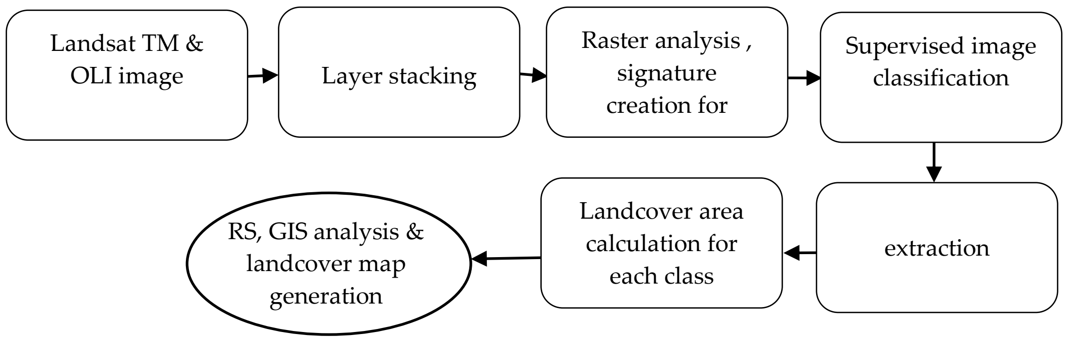

Figure 3. Conceptual framework for landcover change detection.

2.3 Remote sensing data preparation

The study was based on quantitative data used to analyse the overall scenario of riverbank erosion at Naria *upazila*. The data came from the Landsat satellite's OLI & TIRS, MMS, TM, and ETM+ sensors for five distinct years.

Band combination 4, 3, 2 is standard for false colour composites. Vegetation appears in reddish hues and soils range in colour from dark to light brown. Urban areas are cyan blue, ice, snow, and clouds are white or light cyan (Quinn, 2001).

The specifications of the images and bands used for mapping in this research are shown in Table 1.

Table 1. Remote sensing image acquisition years.

Period	Year	Image	Landsat Sensor	Band Combination of Colour Composite
Dry	2019	Landsat 8	Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	5, 4, 3
Dry	2009	Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	4, 3, 2
Dry	1999	Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	4, 3, 2
Dry	1989	Landsat 4	Thematic Mapper ™	4, 3, 2
Dry	1979	Landsat 2	Multispectral Scanner (MSS)	6, 5, 4

Table 2 presents the bands of Landsat imageries used in this study.

Table 2. Band combination of Landsat data.

Bands	Landsat Sensors			
	Landsat 8 (OLI) and (TIRS)	Landsat 7 (ETM+)	Landsat 4 (TM)	Landsat 2 (MSS)
Band 1	Coastal aerosol	Blue	Blue	-
Band 2	Blue	Green	Green	-
Band 3	Green	Red	Red	-
Band 4	Red	Near Infrared (NIR)	Near Infrared (NIR)	Green
Band 5	Near Infrared (NIR)	Shortwave Infrared (SWIR) 1	Near Infrared (NIR)	Red
Band 6	Shortwave Infrared (SWIR) 1	Thermal	Thermal	Near Infrared (NIR)
Band 7	Shortwave Infrared (SWIR) 2	Shortwave Infrared (SWIR) 2	Shortwave Infrared (SWIR)	Near Infrared (NIR)
Band 8	Panchromatic	Panchromatic	-	-
Band 9	Cirrus	-	-	-
Band 10	Thermal Infrared (TIRS) 1	-	-	-
Band 11	Thermal Infrared (TIRS) 2	-	-	-

Source: USGS (n.d.a).

3. Results and discussion

The analysis of Satellite images from 1979 to 2019 demonstrate the dynamic character of riverbank and channel migration. The river channel experienced extremely high and changes between 1979 and 2019. The river's course changes throughout the periods of 1979–1989, 1989–1999, 1999–2009 and 2009–2019 are presented in subsequent year-wise maps.

The river channel in 1979 was divided in two main branches with a 73 km perimeter having a large *char*[5] land in its middle. The Padma shifted in the middle *char* land in 1989 with several channels that representing riverbank erosion resulting in a perimeter increase to 139 km. Again, after ten years, in 1999 the river channel flowed in two main streams with accreted *char* land in the middle covering 69.174 km. In 2009, the river flow was divided into three streams, with a perimeter of 113 km and a river area of 37.51 km^2, which allowed land accumulation under bare soil and *char* land within the river periphery. In comparison, the river's perimeter expanded to 148 km in 2019 within a 30.4 km^2 area, which also indicates land accretion had taken place. Table 3 represents the summary of river area and perimeter changes for different years.

[5] Chars are riverine silt and sand land masses raised by accretion.

Table 3. River area and perimeter change from 1979 to 2019.

Year	Month	River Area (km^2)	River Perimeter (km)
1979	February	29.425	73
1989	January	44.256	139
1999	November	44.341	69
2009	December	37.513	113
2019	March	30.404	148

3.1 River erosion and landcover change in 1979

Landsat 2 MSS images of 1979 encompasses the four bands 4, 5, 6, and 7 and have a pixel resolution of 60 meters. Thermal infrared band 6 has a spatial resolution of 120 meters but was resampled to 30-meter pixels (USGS, n.d.b). The scene spans 170 km from north to south and 183 km from east to west. After stacking the four bands, a false colour composite of bands 3, 2, and 1 were created and the study area was extracted for classification. Raster classification was done to delineate river areas for the year 1979. The raster layer was then converted to a polygon layer (shape file). River area and perimeter were calculated with the field calculator tool, which are 29.43 km^2. and 73 km respectively. Figure 4 presents the classified map and extracted river channel for the year1979. The channel in 1979 was divided in two main streams with a large *char* land in the middle.

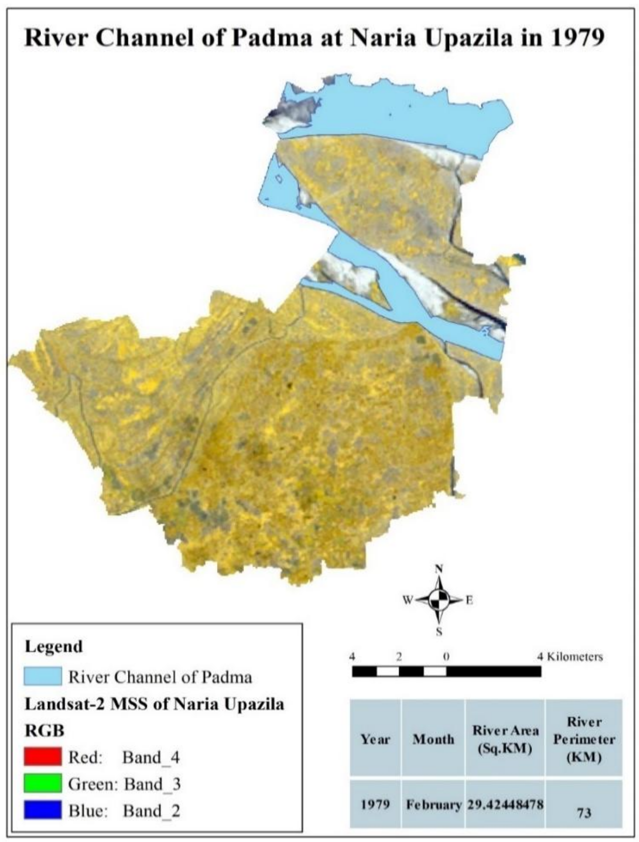

Figure 4. River area at Naria in 1979.

3.2 River erosion and landcover change in 1989

Landsat 4 TM images of 1989 contains seven spectral bands. Bands 1 to 5 and 7 have 30 m spatial resolution. Thermal infrared band 6 has a spatial resolution of 120 m but was resampled to 30-meter pixels. The scene spans 170 km from north to south and 183 km

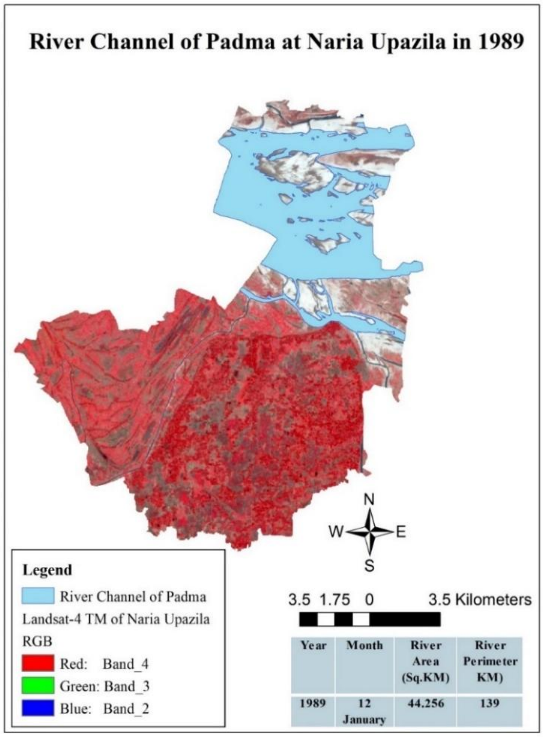

Figure 5. River area at Naria in 1989.

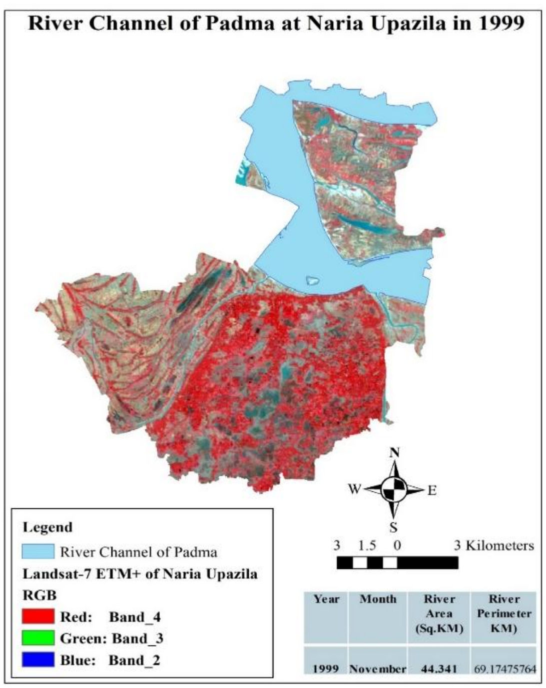

Figure 6. River area at Naria in 1999.

from east to west. After stacking the seven bands, a false colour composite with bands 4, 3, and 2 were created and then **the** study area was extracted for classification. After raster classification, the layer was exported as a shape file. The river area was found to be 44.256 km^2 in area with a perimeter of 139 km. Figure 5 presents the classified map and extracted river channel for the year 1989.

3.3 River erosion and landcover change in 1999

Thematic Mapper instruments that were onboard Landsat 4 and Landsat 5 have been upgraded and now Landsat 7 carries ETM+ sensor onboard. Landsat 7 provides 8-bit imageries with 256 grey levels. Landsat 7 (ETM+) images for 1999 comprise of eight spectral bands where bands 1 to 7 have 30 m spatial resolution and the panchromatic band 8 has a 15 m resolution. Band 6 assembles both high and low gain for all scenes, while the other bands can only collect one of the two gain settings (high or low) for greater radiometric accuracy and contrast ratio. Scene dimensions are roughly 170 km north-south by 183 km east-west.

Layer stacking of the eight spectral bands completed with a pan and thermal band and a false colour composite with bands 4, 3, and 2 were created. Then the study area was extracted for classification. After conducting raster classification, the layer was exported as a shape file. River area and perimeter were calculated with field calculator in the exported river shape file for the year 1999 which were found to be 44.341 km^2 and 69.175 km respectively. Classified image and shape file revealed the decrease of river area and siltation of land in this decade. Just after the devastative flood of 1998, classified imagery of 1999 shows river area's significant increase from the year 1979 and slight increase from 1989. In contrast, classified image of 1999 shows land accumulation between two main river channels. Figure 6 shows the supervised image classified map and extracted river channel for the year 1999.

3.4 River erosion and landcover change in 2009

The 2009 Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery consists of eight spectral bands, with panchromatic band 8 has a 15 m spatial resolution and bands 1–7 have a 30 m spatial resolution. Band 6 assembles both high and low gain for all scenes, whereas the other bands can only collect one of the two gain settings (high or low) for improved radiometric accuracy and dynamic range. The scene spans 170 km in the north- south and 183 km in the east-west.

After stacking bands 4, 3, and 2 they were combined to generate a false colour composite to extract the river area. After raster classification, the layer was exported as a polygon shape file. The river's area was calculated to be 37.51 km^2, and its perimeter to be 113 km. Just after the devastating flood of 2008 the silting up of land and reduction in river area during the past decade shows in the classified image of 2009. Figure 7 shows the supervised image classified map and extracted river channel for the year 2009 derived from the study.

3.5 River erosion and landcover change in 2019

Landsat 8 OLI and TIRS imagery for 2019 contain 9-nine bands where bands 1 to 9 having 30 m spatial resolution, except for Panchromatic Band 8 which has a resolution of 15 m. TIRS image also consist of two spectral bands, band 10 TIRS1 and band 11 TIRS2, and the resolution of these bands is 100 m. Surface water can be observed with

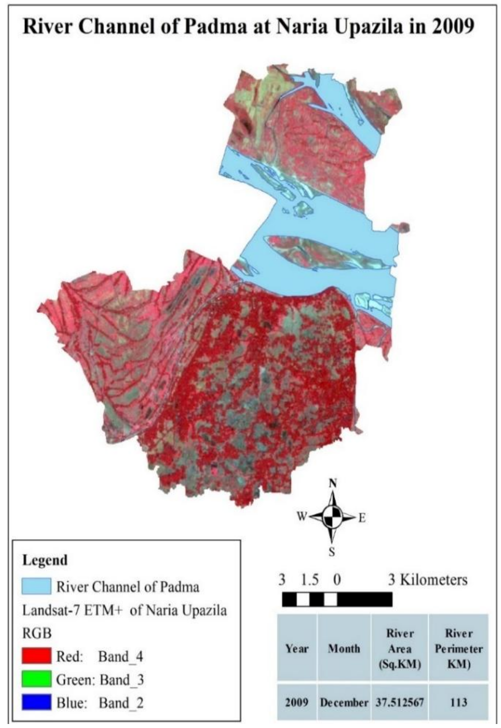

Figure 7. River area at Naria in 2009.

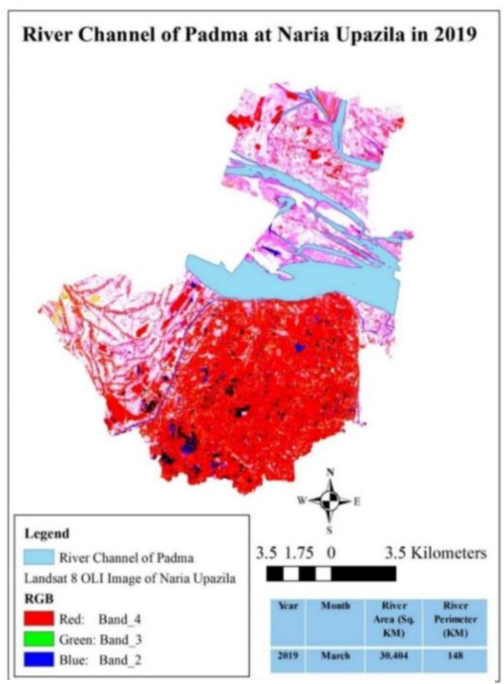

Figure 8. River area at Naria in 2019.

Landsat 8 Band 1 Coastal and Aerosol (USGS, n.d.c). The supervised image classification of year 2019 done and the nine bands were stacked, and a false colour composite with bands 4, 3, and 2 was created. The study area was then extracted for classification and exported as shape file. The river was found to have area of 30.40 km² and a perimeter of 148 km. The 2019 map shows a decrease of river area and increase of land area from 2009. Figure 8 presents the supervised image classified map and extracted river channel for the year 2019.

3.6 Trend analysis of river channel change

The Padma in Naria *upazila* changed its total coverage a lot in the last 40 years. During 1979 to 1989 the area increased from 29.42 km² to 44.25 km². That indicates a large amount of land erosion at the riverbank. On the other hand, in the year 1999 the river area increased slightly to 44.34 km² which also indicate land erosion, but in 2009 and 2019 the river area decreased to 37.51 km² and 30.4 km², respectively. During this 20-year period, there was net land accretion. Figure 9 shows the trend of river channel during the period of 1979 to 2019.

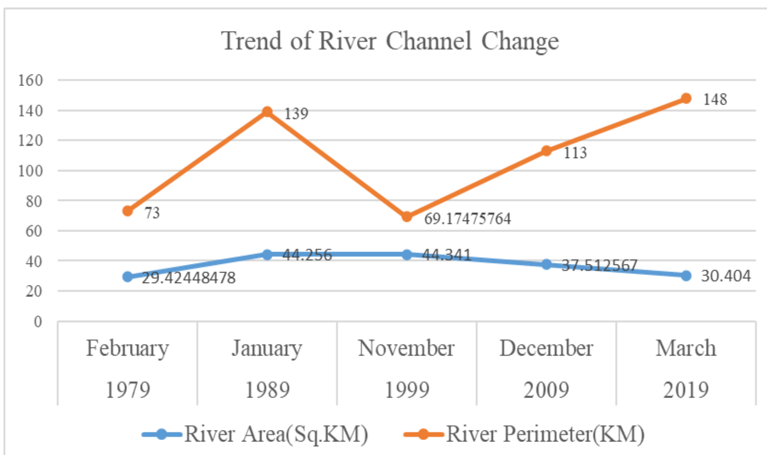

Figure 9. Analysis of trend of river channel.

3.7 Landcover of Naria *upazila* from 1979 to 2019

Using supervised image classification, landcover was detected for the eight types of land use classes, viz., river, water channel[6], inland water, forest, vegetation, *char* land and settlements. A raster layer was generated, and the area of each landcover type was calculated. After layer stacking and band changing, signature file was created by selecting different class to complete landcover classification using ERDAS IMAGINE. Each landcover area was calculated using field calculator in ArcGIS by multiplying the cell area with the cell count.

In 1979, river cover was 11% of total land and *char* land was 9%. From 1979 to 1989 river area and *char* land increased from 11 to 15% and from 9 to 13% respectively. That

[6] A water channel is a natural route, visible trench, or connection between two bodies of water that contains regularly or occasionally flowing water (Channel, 2021).

suggests that riverbank erosion and accretion both occurred during this period. Figures 10 and 11 show the maps of landcover for 1979 and 1989 respectively.

From 1989 to 1999, the river area increased to 19% of total land and *char* land area also increased from 13 to 25%, which means erosion increased river from 34.24 to 43.41 km^2 and land accretion raised *char* areas from 29.40 to 59.28 km^2. Figure 12 shows the landcover for the year 1999.

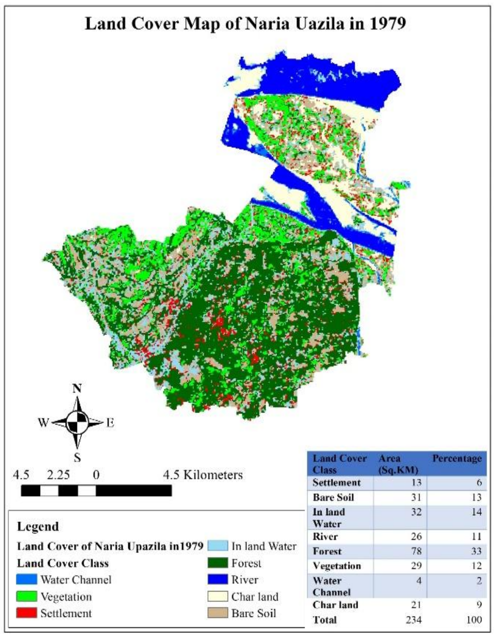

Figure 10. Map of landcover in 1979

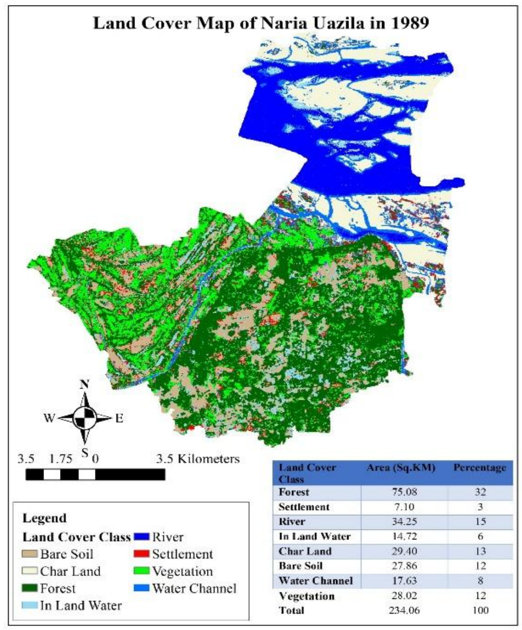

Figure 11. Map of landcover in 1989.

From 2009 to 2019, the river area decreased from 13% to 9.69% of the total land area and *char* land area also increased from 6 to 5.84%. That means river area was reduced from 31.43 to 22.70 sq. km and land erosion in *chars* reduced the area from 14.50 to 14 sq. km.

Figures 13 and 14 present the classified maps of landcover for 2009 and 2019 respectively.

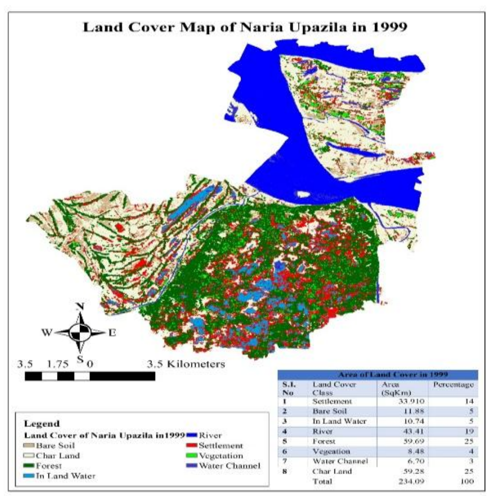

Figure 12. Map of landcover in 1999.

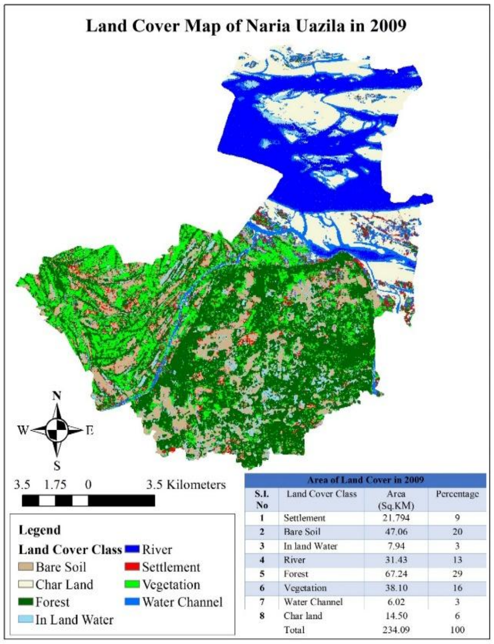

Figure 13. Map of landcover in 2009.

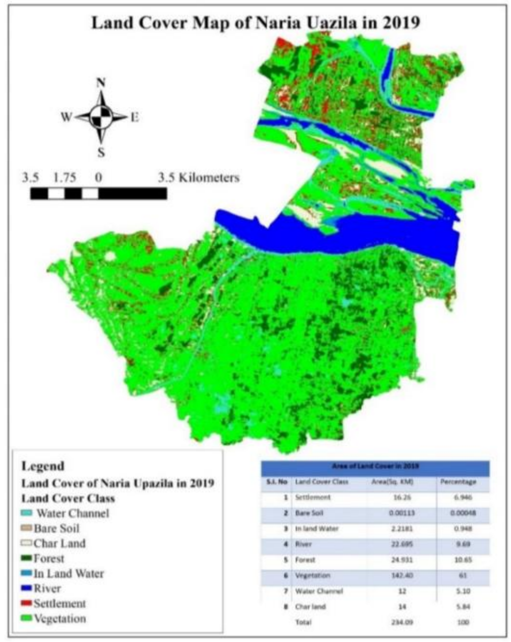

Figure 14. Map of landcover in 2019.

Table 4 shows the summary of image analysis results from 1979 to 2019.

Table 4. Landcover change (in km^2) from 1979 to 2019.

Landcover Area	1979	1989	1999	2009	2019
Settlement	13.00	7.10	33.91	21.79	16.26
Bare Soil	31.00	27.86	11.88	47.06	0.001
In land Water	32.00	14.72	10.74	7.94	2.22
River	26.00	34.25	43.41	31.43	22.69
Forest	78.00	75.08	59.69	67.24	24.93
Vegetation	29.00	28.02	8.48	38.10	142.40
Water Channel	4.00	17.63	6.70	6.02	12.00
Char land	21.00	29.40	59.28	14.50	14.00
Total	234.00	234.06	234.09	234.09	234.50

In 2019, Naria *upazila's* landcover of river was 19% while the *char* land also reached the highest share of 25%. It suggests that shifting river course also causes land accumulation to create *char* land, which had an impact on the peak percentage of settlements over the forty-years of period. There is another significant change in forest landcover from 33% to 11% between 1979 and 2019. Table 5 shows the summary of landcover change in percentage for different years.

Table 5. Landcover change in percentage.

Landcover	Year				
	1979	1989	1999	2009	2019
Settlement	6	3	14	9	7
Bare Soil	13	12	5	20	0
In land Water	14	6	5	3	1
River	11	15	19	13	10
Forest	33	32	25	29	11
Vegetation	12	12	4	16	61
Water Channel	2	8	3	3	5
Char land	9	13	25	6	6
Total	100%	100%	100%	100%	100%

Landcover change of river from 1979 to 2019: River area increased gradually from 1979 to 1989 from 11% to 15%. Finally, river area reaches its highest landcover ratio 19 % in the year 1999 which decrease in the year 2009 and 2019 correspondingly 13 and 10 %. Figure 15 presents river landcover percentage from 1979 to 2019.

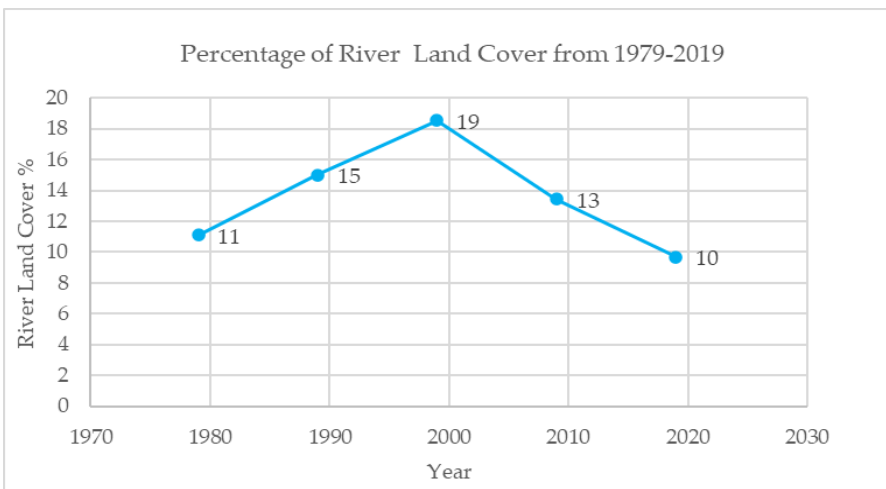

Figure 15. Landcover change of river from 1979 to 2019.

Landcover change of settlements from 1979 to 2019: Settlements coverage increased in a significant way in the year 1999 but it decreased as a result of river erosion afterwards. Figure 16 presents the trend of settlement landcover percentage from 1979 to 2019.

Landcover change of *char* land from 1979 to 2019: The increase and decrease of *char* area cover represent land accretion and erosion. In the year 1999 *char* land class had the highest share over the study period. Figure 17 presents the trend of *char* land share of *upazila* landcover from 1979 to 2019.

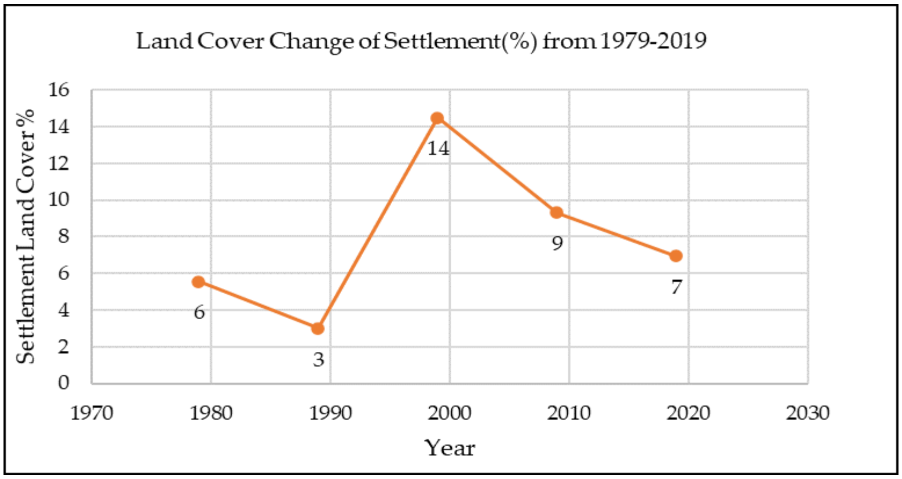

Figure 16. Landcover change of settlements from 1979 -2019.

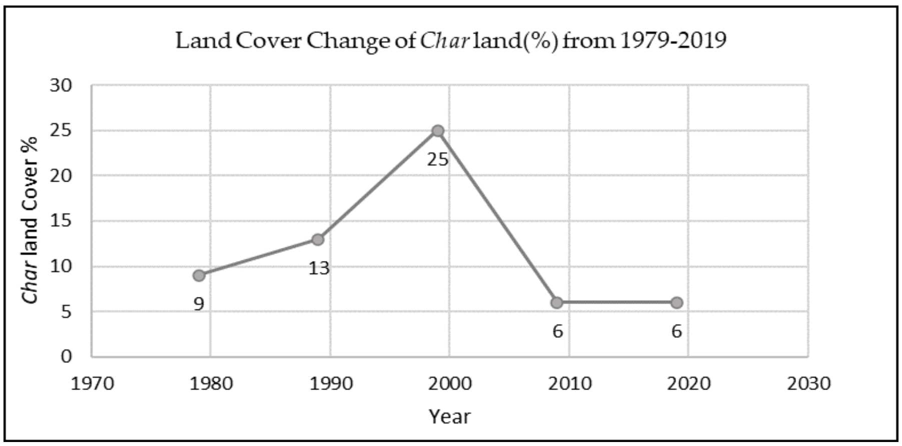

Figure 17. Landcover change of *char* land from 1979 to 2019.

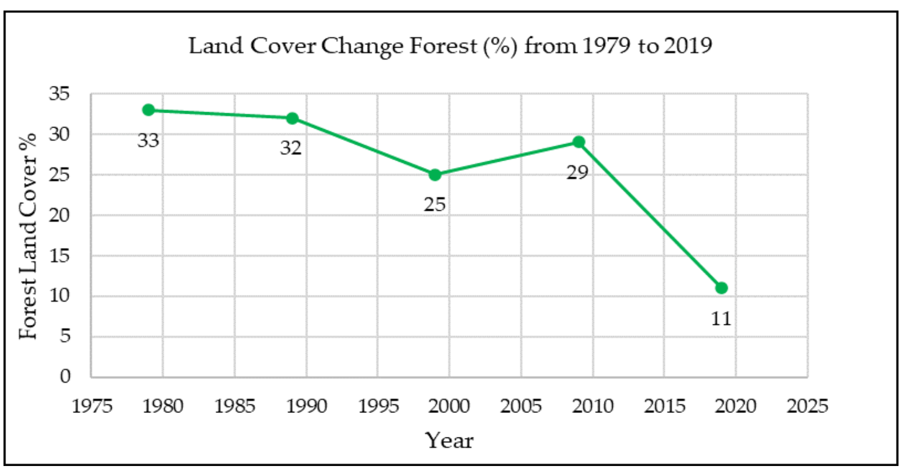

Figure 18. Forest cover change from 1979 to 2019.

Change of forest landcover from 1979 to 2019: The fact that the forest cover has decreased from 33% of the total area in 1979 to 11% in 2019 may be the reason for the significant change in landcover. Figure 18 presents the change of forest landcover in percentage from 1979 to 2019.

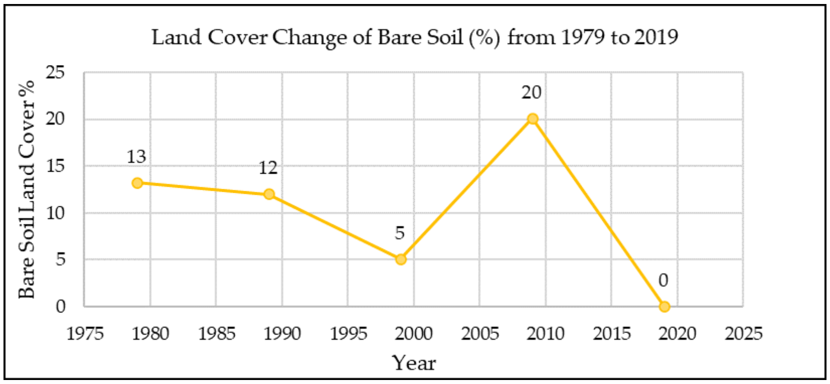

Figure 19. Landcover change of bare soil from 1979 -2019.

Change of bare soil landcover from 1979 to 2019: In 2009, bare soil class had the highest share of land in forty years. In 2019 bare soil cover is almost non-existant (0.00113 km^2). This may be due to the fact that the image for 2019 was from March when there may be rains and more vegetation while earlier images are from the dry season (between November and February). Figure 19 shows the change of bare soil landcover in percentage between 1979 and 2019.

This study shows the river shifting trend, riverbank erosion, and land accretion, and how they transformed the landcover of the study *upazila.* The landcover change detection over the period of 40 years is significant to identify the growth of area. Usually, remote sensing is used for morphological modelling which can be effective for river management. But this study views the process from a different perspective to identify growth pattern and trend which can be useful for further study of social and economic impacts of river shifting.

4. Conclusion

Remote sensing techniques were used in this study to identify the trend of river channel shifting and Naria *upazila's* landcover change. After analysing satellite imageries, the study indicates that decrease of river area and increase of perimeter increases are inversely related to land accretion. In 1999, the river area, settlements and *char* landcovers reached their maximum levels which were 19%, 14%, and 25% respectively. Additionally, it shows that, in forty years, the Padma shifted from the northern side of the *upazila* to the southern part and two river streams changed to three river streams in the year 2019. It showed that GIS may be an extremely useful tool in the process of identifying and visualizing river shifting and bank erosion This investigation has demonstrated that remote sensing data can yield useful results to landcover change analyses. One of Bangladesh's most devastating hazards, riverbank erosion, has great impact on economy and life. Strategic measures can be taken to mitigate the effects of those problems in the long run. It is essential to manage landcover scientifically by analysing past trends and monitoring current landcover change. Studies like this can be useful in that respect. This study used 10-year interval data to detect long term changes; to study at a lower temporal resolution, more closely spaced data may be used.

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