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Analysis of the Morphological Changes of the River Padma Along Naria Upazila through Supervised Classification of Satellite Images

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Abstract: **This paper analyzes the morphological changes of the Padma River along Naria upazila, which was severely affected by river erosion in 2018, analyzing the satellite images of last 42 years. Five satellite imageries of 10-year interval were used. Various software such as Google Earth Pro, QGIS 3.8, Adobe Illustrator, etc. have been used for image processing. The land cover changes under four classes as water, built-up, vegetation and bare soil were identified using the method of Supervised Classification. Surface thermal emissivity was also detected and the impact of the changes in land cover to the surface temperature has been investigated. The results show that during the past 42 years, the rate of sedimentation has been increased significantly, river become braided in nature, average surface temperature decreased and intensive river training works performed at both sides. Some parts of the study areas have been found to be unaffected by erosion for long time too. Based on these information, probable causes of recent Naria erosion is discussed, however, further analysis is needed with bigger domain of Ganges catchment. The study is considered to be of great importance because of its close vicinity to the largest infrastructure of the country Padma bridge.**

Keywords: Satellite Images, Supervised Classification, Riverbank erosion-deposition, Surface emissivity

I. INTRODUCTION

Naria, located along one of the mighty rivers Padma, has been severely affected by river erosion in 2018, causing colossal damage to life and properties [1]. Bangladesh is one of the most fertile countries in the world with more than 600 rivers intersecting it [2], consequently every year it experiences hazards like flood, riverbank erosion, salinity intrusion etc. Among them riverbank erosion is the worst [3]. Sudden channel shifting and unpredictable bank erosion of river in the floodplain areas displaces many people, destroys a large scale of cultivable land, settlement, health and educational institutions, markets etc. in the blink of an eye. Therefore, this issue needs to be regularly monitored and controlled. This study thus focused to understand the reasons behind riverbank erosion and to find the vulnerable areas through studying previous and present satellite images.

Padma is one of the three main rivers in Bangladesh. Bangladesh is situated in the Bengal delta also called the



Fig. 1 Recent incident of severe riverbank erosion in Naria

Green delta which was developed by three mighty rivers i.e., the Ganges, the Brahmaputra and the Meghna. The amount of sedimentation in this GBM basin is the highest in the world. Over siltation causes the river configuration to be adjusted frequently and to shift the river main channel repeatedly. High sedimentation also causes the navigability problem in ferry routes. These phenomena are responsible for fluvial flood and riverbank erosion in the country [4]. On the other hand, bank erosion itself is a major source of sediment deposition [5]. The other factors that affect river bank erosion are changes of shear strength, shifting of river course, characteristics of erosion prone bank and bed materials, pressure imbalance at the bank face, rapid drawdown, poor vegetation at the bank, obstacle in the streams etc. [3]. Human actions are also a major cause for bank erosion too, i.e. by disturbing the natural course of water through construction of hydraulic structures or river training work [6].

Following the rule of meandering river, considering the position of the river, usually the major erosion occurs along the left bank of the River Padma. But, during the most recent Naria tragedy in 2018, Padma also eroded in its right bank severely. It is of great importance to study the incident because, one of the country's greatest communication structure, the Padma Bridge, is located just at the upstream of the erosion site.

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Fig. 2 Map of Bangladesh showing the study area

II. RELATED WORKS

There have been several studies on the detection and prediction of riverbank erosion considering the changes of bank line, vegetation, settlement, built up and soil condition [6], [7]. But there has been little attempt to determine the influence of the change in mean surface temperature, changes in land cover, obstacle in the stream or river training work on the riverbank erosion. These factors should also be focused for identifying vulnerable areas. A study [8] indicates that the downstream flow and sediment delivery can be disrupted by large dams, which induces channel change and may extend hundreds of kilometers. Another study [9] showed the effect of the diversion of water into the Bhagirathi–Hooghly at Farakka. Due to the diversion, the dry season flow and the dry season sediment load are effectively reduced as that sediment is confined behind the barrage. During the wet season when the sluice gates are opened, that sediment is then realized in a great amount. Again, [10] assessed that increase in global temperature leads to increase in Precipitation which has impact on climate change and ultimately on Earth's water cycle. Another study [11] revealed the influence of thermal factor of soil and water in erosion studies.

Most of the studies related to this work mainly emphasized on the identification of channel shifting pattern using one or two hydraulic factors [12]. Statistical tools like Logistic Regression (LR) technique, BSTEM, ARIMA modeling etc. are being used to determine the riverbank erosion probability [13], [14]. However, the accuracy of these methods needs to be improved. Moreover, measuring the channel shifting, using the traditional way is difficult. Remotely sensed data especially the satellite images can play very important role for examining the overall changes of a large surface area. Few approaches are there to indicate the reasons behind these changes.

For example, [15] has shown an overview of the trends of bank lines movement of Padma river and the quantification of the morphological changes in both channels in the last three decades in Munshiganj, Madaripur, Shariatpur districts. Also, [16] calculated the amount of riverbank erosion and the accretion of land along the Padma river using GIS and RS methods to analyze satellite image data. In [17], the authors assessed the trend of river bank erosion at Chandpur, Bangladesh. But none of these used any classification operation to show the land use/land cover changes. However, [18] performed a supervised classification with maximum likelihood algorithm in ERDAS imagine to notice land use/cover changes (LU/LCC) in Mandavi river basin, Kadapa district, Andhra Pradesh, India using multispectral satellite data. But this study doesn't show any link between the landcover changes with surface temperature and their impacts on riverbank erosion. The authors of [19] and [20] examined the relationship between land use land cover (LULC) and land surface temperature (LST). But these studies were conducted in other countries and mainly for urban planning. Less attention has been paid on the land cover change and its impact on the surface temperature which is responsible for the regional climatic changes and may cause river erosion. In addition, no study has assessed the rapid erosion of the Padma river at micro-level over any region of Bangladesh especially at Naria.

III. STUDY AREA

The study area is located in the Southwestern region of Bangladesh. Shariatpur district is one of the four districts through which the Padma river has passed. Naria upazila is situated in Shariatpur district. It lies between $23^0 14'$ and $23^0 25'$ north latitudes and between $90^0 18'$ and $90^0 30'$ east longitudes. The length of the river in this study area is about 24 km. The total study area is about $185 km^2$. About $2-4\ km^2$ area at both banks were analyzed. The river flow direction is Northwestern to Southeastern.

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Fig. 3 Around 185 km^2 study area marked with orange color on satellite image

IV. METHODOLOGY

A. Material

Five multispectral satellite imageries of 5 different time periods (of last 42 years, 10 years interval) have been used for the assessment of channel shifting and other classification tasks. A multispectral image consists of several bands of data. For visual display, each band of the image may be displayed one band at a time as a grey scale image, or in combination of three bands at a time as a color composite image. The United States Geological Survey (USGS) website was used for downloading the images. The data obtained was in a GeoTIFF format for each individual band. Each image covers 1825 $sq. miles$. The details of the images are in TABLE I. Open source software QGIS 3.8 was used for image processing. At first, images were stacked by combining all the bands. Then area of interest has been chosen and a vector shapefile which is a polygon has been created. Then it has been used to clip the area of interest from the stacked images. After performing these tasks for all the imageries, classification operation has been performed and thermal emissivity has been measured accordingly.

TABLE I: DETAILS OF THE LANDSAT SATELLITE IMAGES USED IN THIS WORK

Satellite	Sensor	Date of Acquisition	WRS_PATH, WRS_ROW
Landsat 2	*MSS*	*1977-02-08*	*137, 44*
Landsat 5	*TM*	*1989-11-04*	*137, 44*
Landsat 7	*ETM*	*1999-06-29*	*137, 44*
Landsat 7	*ETM*	*2009-03-24*	*137, 44*
Landsat 7	*ETM*	*2019-05-07*	*137.44*

B. Classification and Thermal Emissivity

A supervised classification algorithm called Spectral Angle Mapping has been used for the classification task. This algorithm works by calculating the spectral angle between the image pixels' spectral signatures and the training spectral signatures. The method uses only the direction of the spectra, and not their length. Hence it is insensitive to the unknown gain factor and illumination differences like topography, light source, sensor etc. Other algorithms like Supervised Maximum Likelihood classification can't provide sufficient accuracy of land use/land cover map when performed only on original bands due to the overlap of spectral signatures and effect of topography [18]. Moreover, Spectral Angle Mapping algorithm is a fast and easy approach with comparability of image spectra with lab spectra.

Four main categories for classification were counted. These are Water, Built-up, Vegetation and Bare soil. At first, different training data were created by defining the Macro Classes (MC) and Classes (C). Regions of Interest (ROIs) were selected for each Class. Each ROI is identified by the Class ID (C ID) and assigned to a land cover class. Each land cover class is identified by a Macroclass ID (MC ID) which is a group of ROIs with different Class ID. This process helps to classify materials with different spectral signatures in the same land cover class. For example, forest and grassland can be identified as vegetation by assigning the same MC ID and different C ID. For vegetation, MC ID=1 and for forest, C ID=1 and for grassland, C ID=2. Using all these data, classification was performed and the chosen algorithm compared the spectral characteristics of the reference land cover classes to the spectral characteristics of each pixel and classified the whole image. The area covered by each class can be measured using Classification Report. TABLE II shows the classification report. To estimate emissivity, Reclassification of the land cover classification to different emissivity values has been performed. Emissivity varies from wavelength to wavelength. For instance, water has higher thermal emissivity and remains cooler hence is in blue color. The overall classification accuracy was 80%. Accuracy was evaluated using the Semi- Automatic Classification Plugin (SCP) for QGIS. After the classification process, the images have been converted into Single band Pseudo color images for better visual comparison. Here, the water appears in orange, built-up in yellow, vegetation in green and bare soil in blue.

TABLE II: LAND COVER CLASSIFICATION

Category	Area covered in 1977 (km^2)	%	Area covered in 1989 (km^2)	%	Area covered in 1999 (km^2)	%	Area covered in 2009 (km^2)	%	Area covered in 2019 (km^2)	%
Water	*47.64*	*25.49*	*91.27*	*48.86*	*110.03*	*58.90*	*94.35*	*50.51*	*82.58*	*44.20*
Built-up	*68.56*	*36.68*	*50.81*	*27.20*	*31.22*	*16.71*	*27.93*	*14.95*	*62.69*	*33.56*
Vegetation	*53.57*	*28.66*	*16.07*	*8.60*	*35.71*	*19.11*	*20.25*	*10.84*	*37.85*	*20.26*
Bare soil	*17.14*	*9.17*	*28.67*	*15.34*	*9.85*	*5.27*	*44.29*	*23.71*	*3.69*	*1.98*

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V. RESULTS and DISCUSSION

Results show that the overall width of the Padma River in this study area has varied significantly during the last 42 years. The channel moves at different directions in different times. The river got meandered and braided from almost straight channel in the study period.

A. Images After Classification

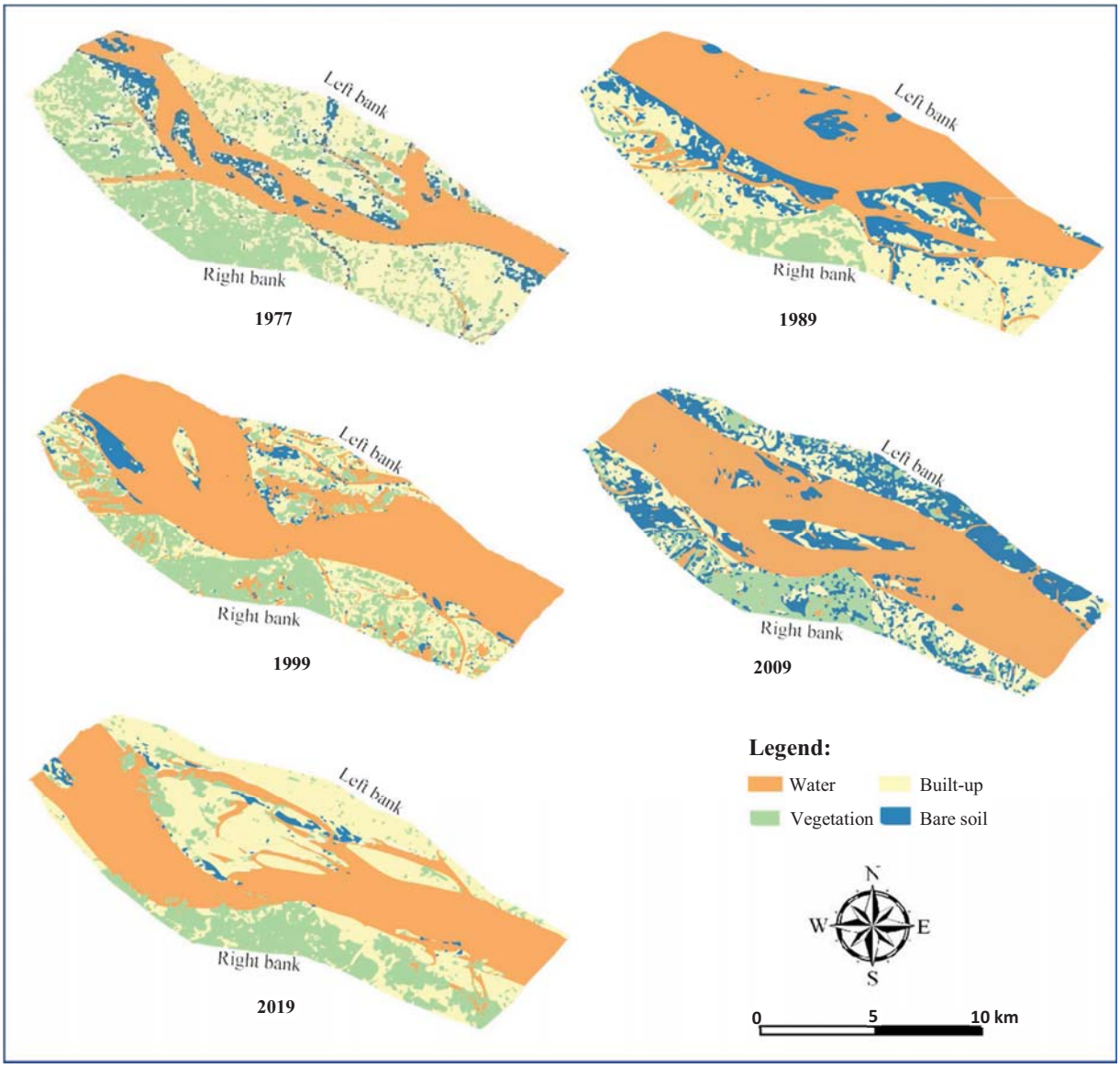


Fig. 4 Changes of landcover in the study area 1977-2019

During the recent decade, it has shown braided nature in this area probably due to the high rate of mid channel sedimentation. The bank line shifting is also not stable. From 1977-1989, it eroded the left bank significantly and the maximum amount of channel shifting occurred during this time. The amount of water increased from 25.49% to 48.86%. After that, it started shifting southwards (towards the right bank). Interestingly, till 2009, the western part of the right bank wasn't eroded, but in the recent decade the channel has migrated towards westward significantly. This is an unusual incident and alarming for the inhabitants of the study area. The evaluation of the Land cover/use change reveals that the poorly vegetated areas are mostly the erosion prone areas. Fig. 4 clearly shows that the river eroded the bare land or built- up areas mostly than the healthy vegetated areas. It is also found that there is a decrease in green vegetation over Naria, which may be a probable cause for it being erosion prone.

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B. Estimation of Thermal Emissivity of the study area

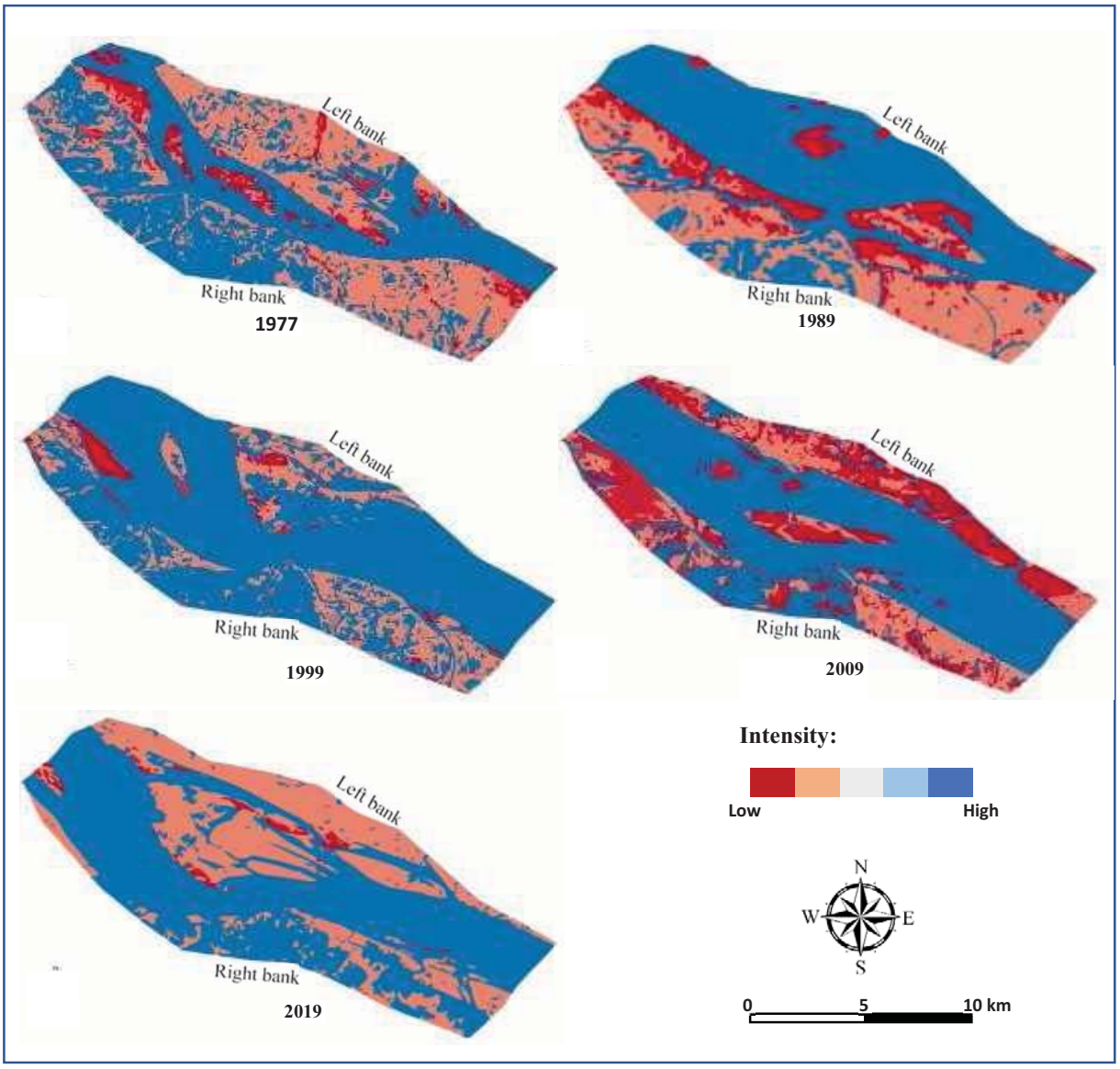


Fig. 5 Surface thermal emissivity changes in the study area 1977-2019

The changes of land surface temperature reveal that the surface temperature has increased in those areas which were transformed from vegetative area to settlement or bare land. The highest rate of increase in temperature is observed in 2009. The study demonstrates that, increase in non- evaporating surfaces and decrease in vegetation have increased the surface temperature and regulated the temperature of the study area. In this period, the much hotter land air at both banks with the narrowing trend of river indicates the reduced chance of rainfall which affects the erosion process. Reduced rainfall mayreduce the volume of water and increase the sediment deposition rate. The overall temperature of the right bank is reduced due to the large-scale erosion in 2019 since decrease of land surface temperature is observed when any land transforms into water body. An interesting observation is that, Padma could hardly erode one place 'Sureswar' during this 42 year. This area lies near Chandpur and about 10 km eastwards from the eroded area of Naria. May be this place is formed by soil with relatively less erodible characteristic which works as a natural resistance to erosion. This also indicates that the bank material of Naria has no such natural control. However, impacts of many other factors like water discharge (any irregularity), wind speed, rain fall, water and soil temperature history, detail anthropogenic activities etc. are yet to be investigated. As mentioned earlier, the biggest engineering structure of the country, Padma Bridge has been started to construct by 2014 [21]. For the protection of the bridge, extensive river training and bank protection work has been done there, which may have changed the natural regime of the flow channel at the downstream too. Further research is however, needed covering a larger catchment area for confirming the cause-effect relation of the erosion nature of the river in that place.

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VI. CONCLUSION

This study analyzed the morphological change nature around the place Naria, a highly vulnerable part of the river Padma, one of the three largest rivers in Bangladesh. Satellite data has been found to be an excellent resource for analysis of riverbank erosion, monitoring and prediction purposes. This study was successfully able to analyze satellite images for estimation of riverbank erosion as well as deposition nature of the area. It also examined other changes of land and atmospheric conditions and tried to relate them to bank erosion. It could be concluded that the channel shifting trend is now southwards and the eastern part will turn its direction by bending eastward. The erosion rate is lower than the sediment deposition. The high sediment deposition indicates the low velocity at that place. The cause may be due to the upstream withdrawal of water along the Padma river at Farakka. However, recent river training work due to the construction of Padma Bridge at about 22 Km upstream from Naria, might have changed or increased the flow path of the river so that it affected the bank at the Naria part of the river. As the study area is newly facing this much erosion, more research is still needed to predict and control this disaster. Surface temperature can be calculated in degree Celsius or Fahrenheit for which band 10 information is required. Since all the images with band 10 couldn't be managed, only the emissivity has been shown. Further study is needed with greater coverage of catchment area, more parameters like rainfall history, river flow parameters, river training work, and soil characteristics as well.

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