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A STUDY ON PATTERN IDENTIFICATION OF BANK SHIFTING AROUND PADMA-UPPER MEGHNA CONFLUENCE USING MULTI-TEMPORAL SATELLITE IMAGES

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ABSTRACT

Padma-Upper Meghna confluence is widely acknowledged as an important geomorphological node that controls the downstream routing of water and sediment to the Bay of Bengal through Meghna Estuary. The present study aims at pattern analysis and forecasting of bank shifting around Padma-Upper Meghna confluence with spatial and geographic co-ordinate system based approach using GIS; and a deep learning approach based on long short-term memory (LSTM) network using MATLAB. Comparisons between different approaches are also divulged. Satellite images (LANDSAT MSS, TM and IRS) covering the period of 1973 to 2018 has been used to carry out the investigation. Maximum rate of bank migration has been found 59.25m/year for the left bank and 81.64m/year for the right bank for study reach of Padma River. Similarly, maximum migration rate for left bank is 8.17m/year and for right bank is 9.35m/year for the study reach of Upper-Meghna River, and the maximum migration rate for the Lower-Meghna reach is 64.39m/year for left bank and 146.55m/year for the right bank over 45 years.The present morphology at the confluence of Padma and Lower Meghna River is such that the width of cross-sections increases considerably at upstream of the confluence, leading to a decrease of stream velocity and consequently the generation of large chars elsewhere. Left bank of the Padma River is severely affected by erosion. Accretion was a dominant process from 1978-2002 in the Lower-Meghna but from 2002 erosion started to dominate and the net result is found to be accretion as dominant in the last 45 years.

Keywords: *Padma-Upper Meghna confluence, Satellite image, GIS; Bank shifting, Erosion-accretion.*

1. INTRODUCTION

In Bangladesh, river erosion is considered as one of the worst catastrophes to affect the country, almost on an annual basis, as it destroys productive land, livelihood and much needed infrastructures permanently. The present study, however, aims its analysis on the confluence of the Padma and the Meghna River and its downstream river reach of the Lower Meghna River. The vibrant morphological and hydrodynamic natures of such two large rivers make this region one of the most unstable and erosion prone area of the country. In fact, the erosion in the left bank of the lower Meghna River at Chandpur and further downstream has become a serious issue over the year. Bangladesh Water Development Board (BWDB) has taken several mitigation projects against this erosion problem including construction of embankments on the left bank of Lower Meghna River and developing hard point at Chandpur. On the other hand, as for being morphologically unstable and dynamic river like Padma and Lower Meghna, the islands and bars (locally called chars) in these rivers are changed its shape and size every year. Some of them are gone under severe erosion while some of them got deposited during monsoon and post-monsoon season. The huge amount of sediments coming from upstream (particularly sediments carrying by the Padma River flow) and the sediments formed by local scouring are deposited right bank of Lower Meghna River. Therefore, the very consequence of protecting the left bank from erosion and the curvature of the left bank of the Lower Meghna River upstream of Chandpur itself diverts the flow towards the right bank and the huge amount of sediment that this flow carrying deposits on that bank. As such during the last four decades the river at this location has lost it conveyance area considerably.

Previously Pegg and Galay (1974), Ali(1975), Rahman (1978), Ahmed (1989) studied the confluence shifting, movement of bank line of the Padma-Upper Meghna Confluence. Khan and Matin (1986) found that the Ganges carries about 30 percent of the suspended load as sand load, whereas, 90 percent of the suspended load of the Brahmaputra is sand, whose combined effects have influence on the morphology of Padma and around Chandpur Confluence.

Three approaches have been considered to realize the bankline shifting pattern in this study. Firstly, a common sinuous equation is introduced for different reaches which is based on spatio-temporal distances.Secondly, regression equation is evaluated based on geographic co-ordinate system. Finally, Recurrent Neural network (RNNs) namely, LSTM (Long-Short Term Memory) is considered to understand the bankline shifting pattern. Comparison between these studies have been discussed to make a better understanding of approaching on bankline shifting pattern.

2. METHODOLOGY

2.1. Study Area

The study area covers part of the Padma, the Upper Meghna, the Lower Meghna .The study area is considered from Mawa to Dighirpar of about 40km of Padma river reach, from Satnol to Chandpur of about 27.5km of Upper-Meghna River reach and From Chandpur to Haimchar of about 27.5km of Lower-Meghna reach (Figure 1). The Meghna joined at the present confluence about 150 years ago. The Lower Meghna had to adjust to carry the combined discharge of the Jamuna, Ganges and Meghna rivers, one of the largest rivers in the world, which conveys the combined discharge and sediment load of the three major rivers of Bangladesh into the Bay of Bengal.Over the past three decades, Padma river has changed from a relatively narrow, straight line to meandering to braided and most recently back to straight.Upper-Meghna river shows a meandering behaviour while Lower-meghna is straight, occasionally braided.

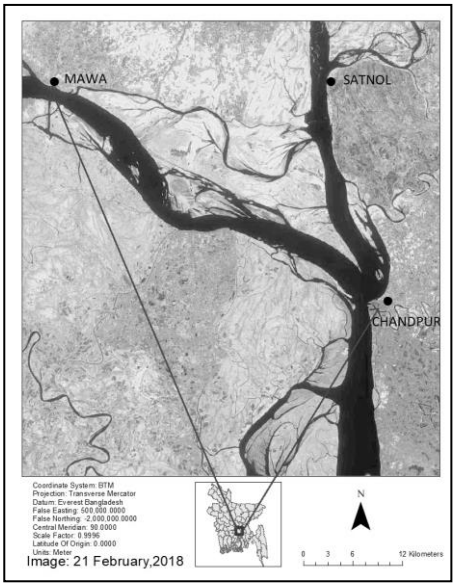


Figure 1: Location map of study area

2.2 Data Collection and Processing

A time-series satellite images of dry season for the Padma-Upper Meghna confluence have been collected from the website of United States Geological Survey (USGS). For this study, satellite images types of Landsat MSS,Landsat TM and IRS,LISS covering the period 1973-2018 were collected. The study has conducted diiferent steps which are given below:

- For estimation of erosion/accretion rate of bank line and identification of the pattern of bankline shifting, Padma river, Meghna river and Lower-Meghna river have been divided with four, one and two sections respectively which is imposed on image of 1973 (Figure 2).
- The Shifting of each point from bankline of 1973 to the bankline of specific year is estimated through the attribute table of ArcMap 10.3 and the data were processed for the further study.
- This study is based on three different approachs for bankline shifting observation: regression based analysis and geographic coordinate system based analysis are performed with Microsoft EXCEL, LSTM based study is performed with the help of MATLAB2018a.
- The developed equations from the regression and geographic coordinate system based analysis are used to forecast for the year of 2020 and also comparison between three approaches are observed appropriately..

3. RESULTS AND DISCUSSIONS

3.1 Bankline shifting analysis

In total, seven sections (P1, P2, P3, P4, M1, ML1 and ML2) are imposed on the Padma, Upper-Meghna and Lower-Meghna River where the sections are almost at 10 km interval. Considering 1973 as the base year, magnitude of left bank and right bank shifting has been determined (2 years interval) using GIS technique. The value of shifting is considered positive, if the digitized bank line of the specific year is in left side of the bank line of 1973 according to the flow direction. Similarly, the shifting value is considered negative, if the digitized bank line of the specific year is in right side of the bank line of 1973. Then all the values have been plotted in a graph for each section to observe the shifting pattern which is shown in figure 3.

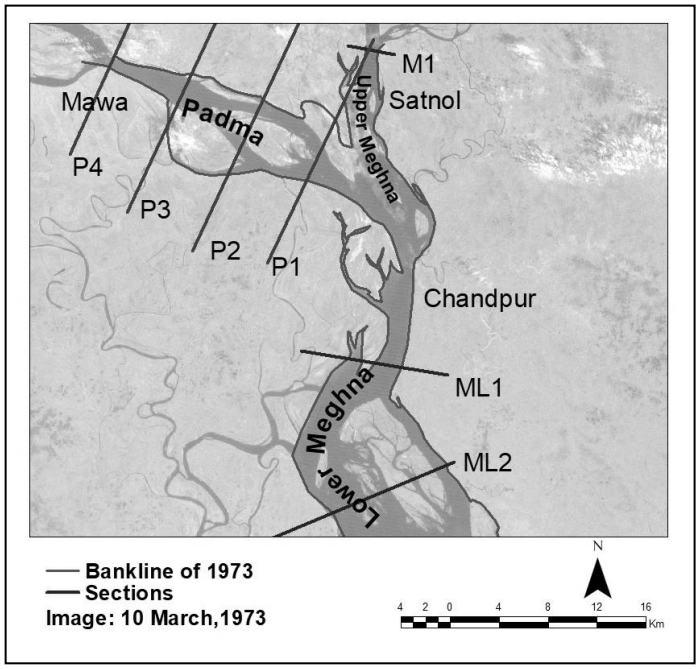


Figure 2: Sections imposed on 1973 image

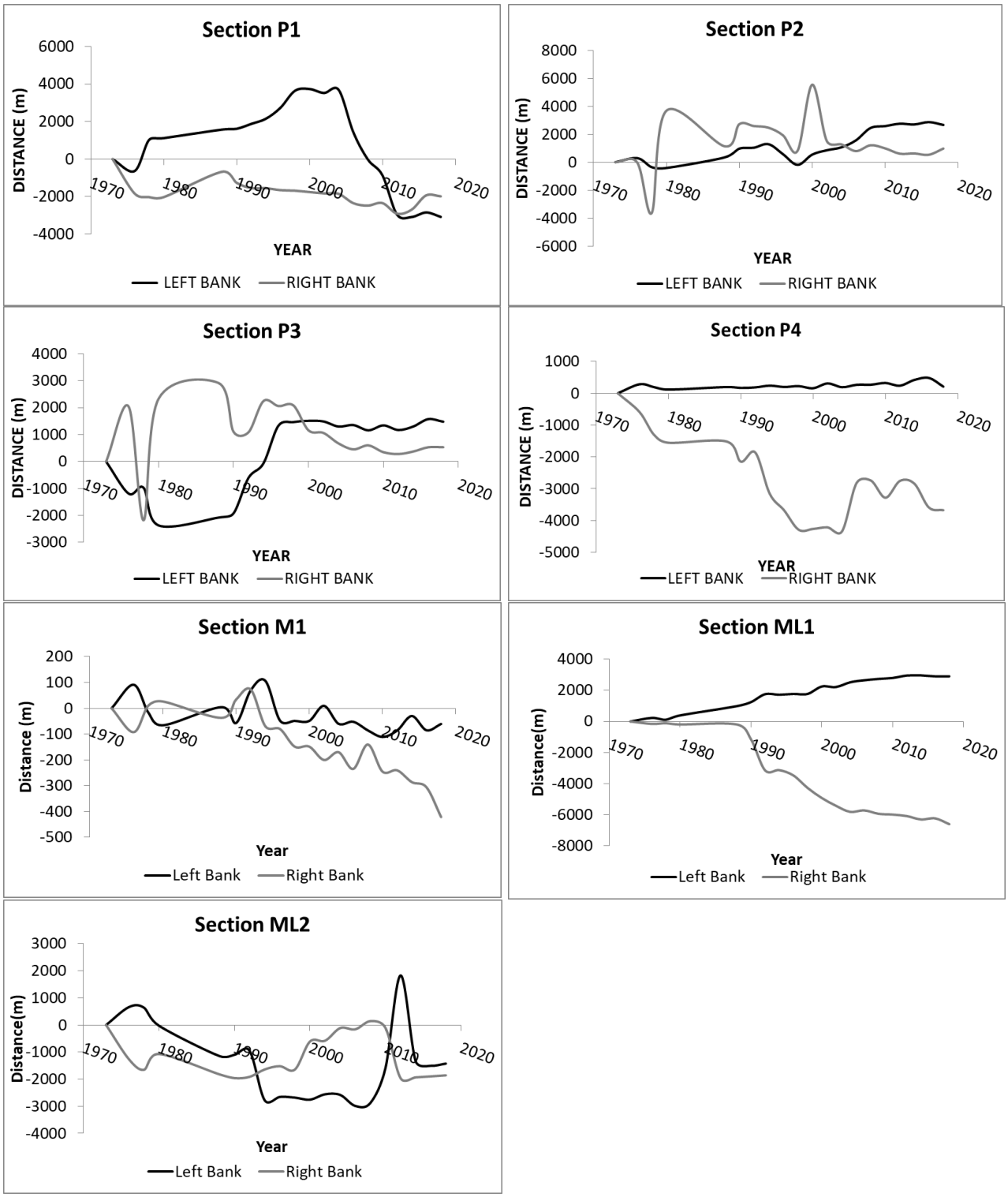
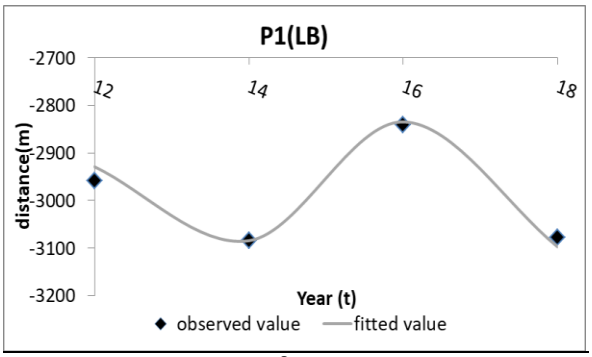


Figure 3: Bankline shifting from 1973 to 2018

3.1.1 Regression Based Analysis

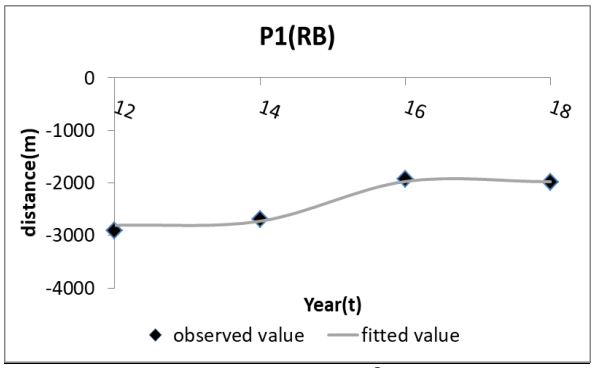
To understand the pattern of bank shifting for the recent years, a sinuous equation $D= [(a_1\sin(b_1t+c_1) +a_2\sin(b_2t+c_2)+d)]$ is evaluated where D is the distance between the bank line of 1973 and the specific year and t is considered to be the last two digits of the corresponding year (e.g. 2012 is considered as 12) to avoid complexity. Regression analysis is done for the last 10 years for these seven sections.

Polynomial equations are derived for the sections who mismatched with the criterion. The regression equation and R^2 values are shown in Figure 4.



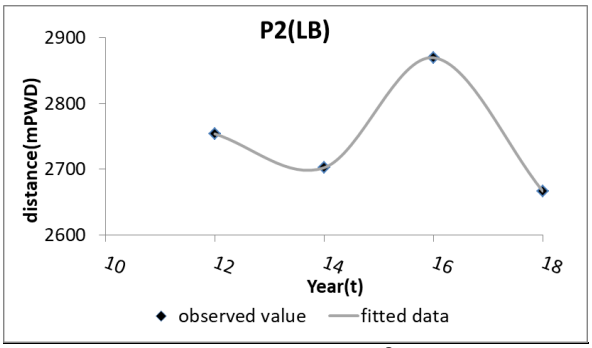
$D=a_1*\sin(b_1*t+c_1)+d$, $R^2=0.981328042$

a_1	b_1	c_1	d
140	-1.86	0.899	-3100



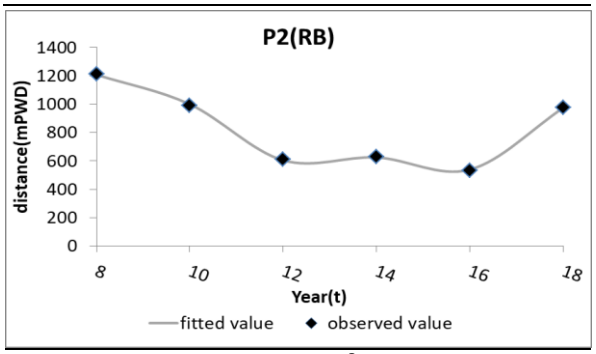
$D=a_1\sin(b_1t+c_1)+a_2\sin(b_2t+c_2)+d$, $R^2=0.9874760$

a_1	b_1	c_1	a_2	b_2	c_2	d
600	-40	1.305	70	80	0	-3150



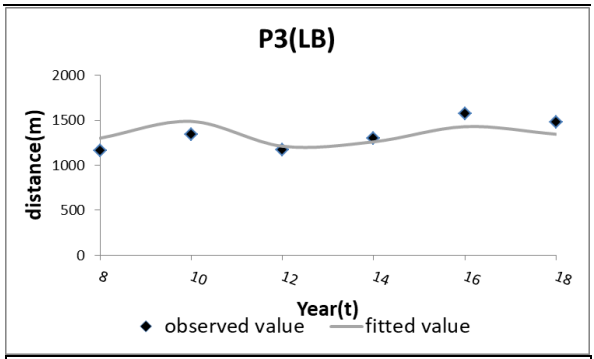
$D=a_1\sin(b_1t+c_1)+a_2\sin(b_2t+c_2)+d$, $R^2=1$

a_1	b_1	c_1	a_2	b_2	c_2	d
1533.73	0.123	442.7	183.02	0.834	442.7	442.74

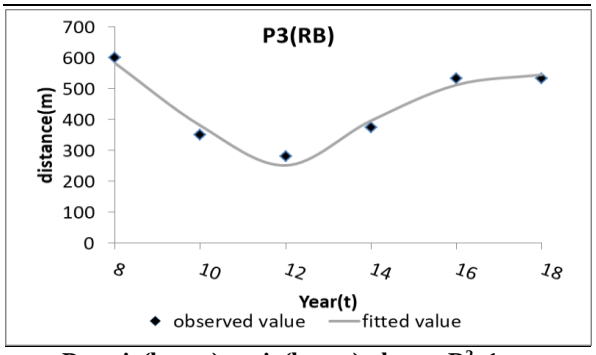


$D=a_1*\sin(b_1*t+c_1)+d$, $R^2=0.999619635$

a_1	b_1	c_1	d
479.2544	0.3313174	1025.6912	0

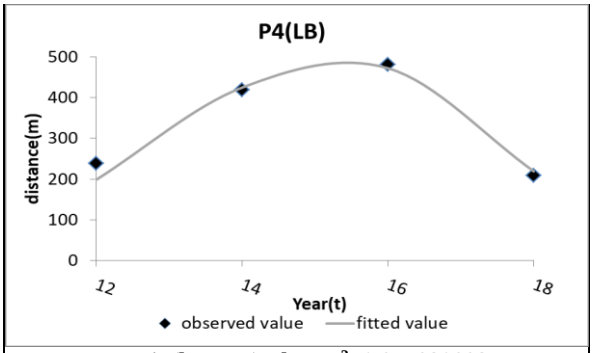


$D= -23.306x + 29.902$,
$R^2 = 0.8917$



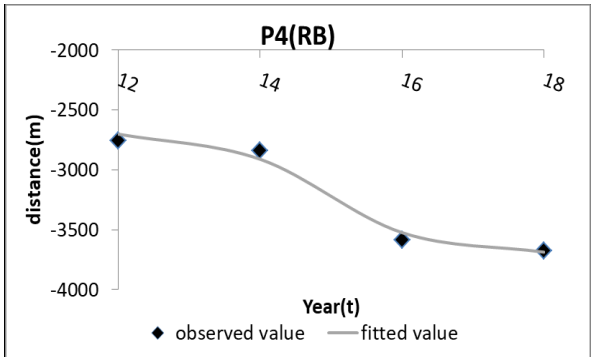
$D=a_1\sin(b_1t+c_1)+a_2\sin(b_2t+c_2)+d$, $R^2=1$

a_1	b_1	c_1	a_2	b_2	c_2	d
188.61	0.383	502.83	68.76	0.945	1.000	0



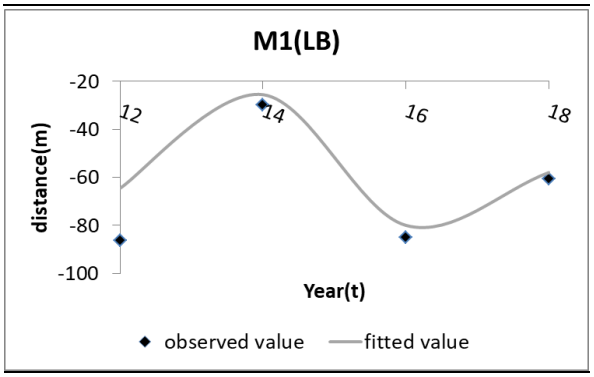
$D=a_1*\sin(b_1*t+c_1)+d, \quad R^2=0.974820992$

a_1	b_1	c_1	d
158.7897	0.93	355	0



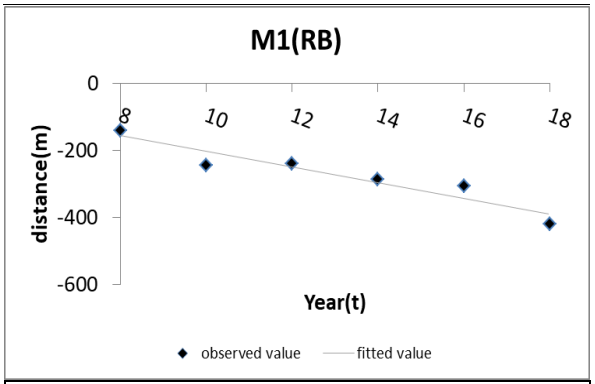
$D=a_1*\sin(b_1*t+c_1)+d, \quad R^2=0.983743638$

a_1	b_1	c_1	d
-520	-0.631	-3200	0

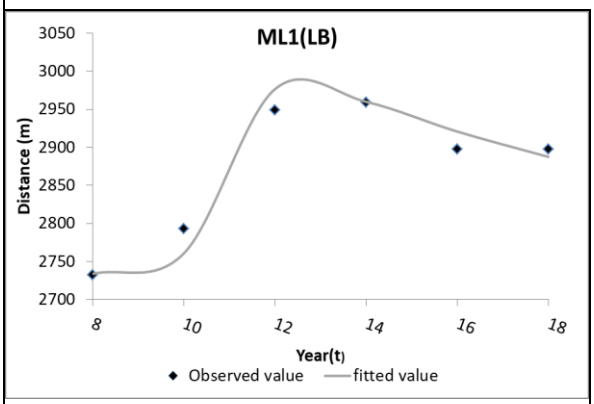


$D=a_1\sin(b_1t+c_1)+a_2\sin(b_2t+c_2)+d, \quad R^2=0.893483424$

a_1	b_1	c_1	a_2	b_2	c_2	d
-22	1.31	1.5	24	0.983	13.84	-45

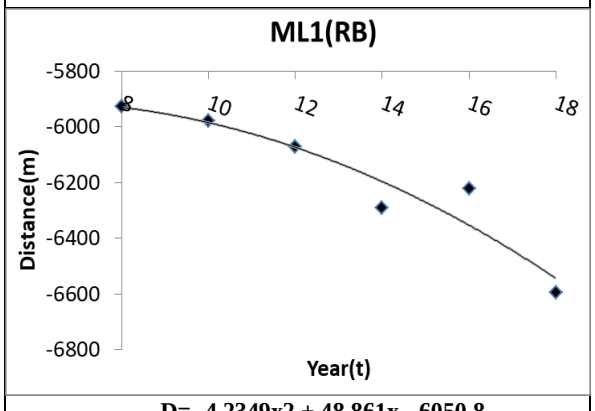


$D= -23.306x + 29.902,$
$R^2 = 0.8917$

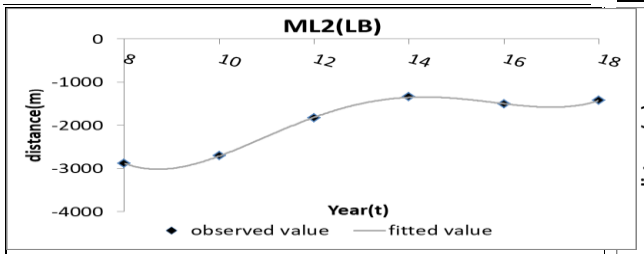


$D=a_1\sin(b_1t+c_1)+a_2\sin(b_2t+c_2)+d, \quad R^2=0.943180163$

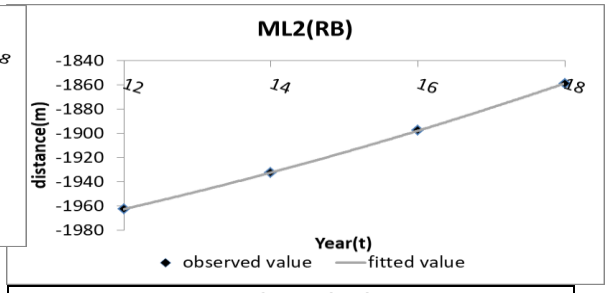
a_1	b_1	c_1	a_2	b_2	c_2	d
104.6	0.5522	27.55	60	1.1559	-0.9999	0



$D= -4.2349x2 + 48.861x - 6050.8$
$R^2 = 0.9038$



$D= -20.748x2 + 701.67x - 7320$
$R^2 = 0.9155$

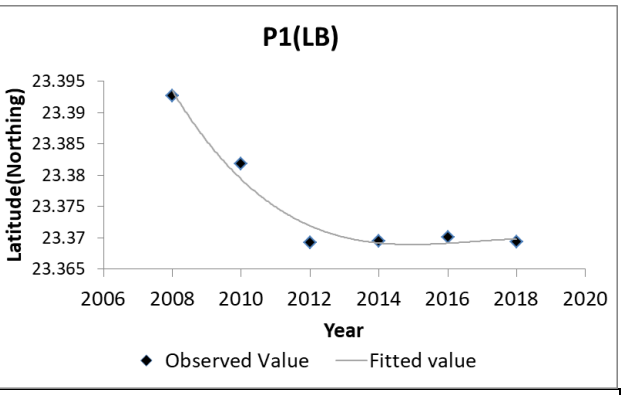


$D= 17.314x - 2172.5$
$R^2 = 0.9966$

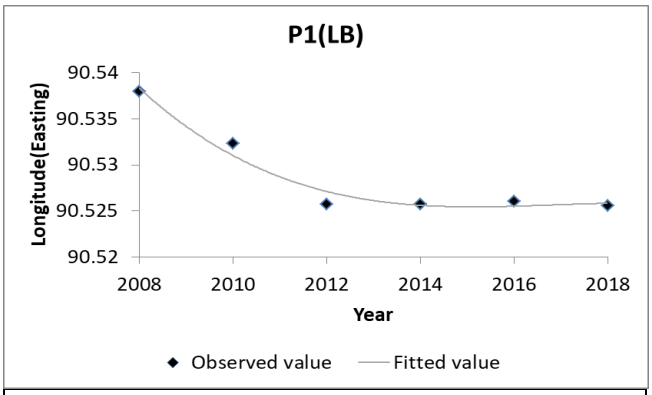
Figure 4: Rgression based analysis

3.1.2 Geographic co-ordinate system based analysis

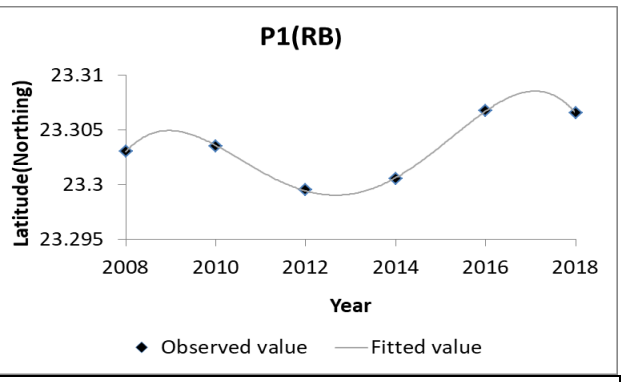
The spatio-temporal analysis is based on the base year of 1973. So, the coefficients of the equations derived from this study may vary if the base year is changed. Considering this consequence, a geographic coordinate system based study is evaluated in which the changes of latitude and longitude with respect to time can be brought under a pattern. Two sections of Padma, one section of Upper-Meghna and one section of Lower-Meghna is used to behold the study (figure 5).



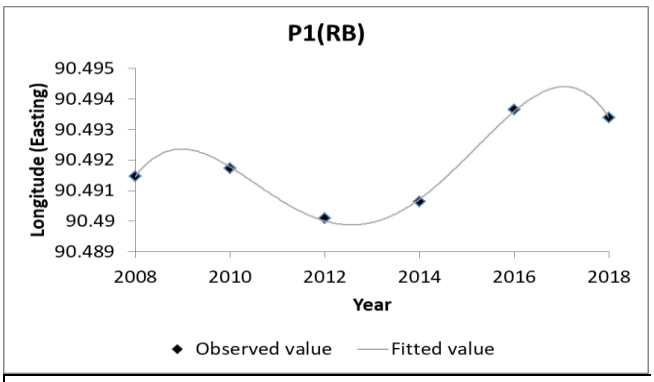
N = -4E-05x3 + 0.2495x2 - 503.18x + 338281
R^2 = 0.9683



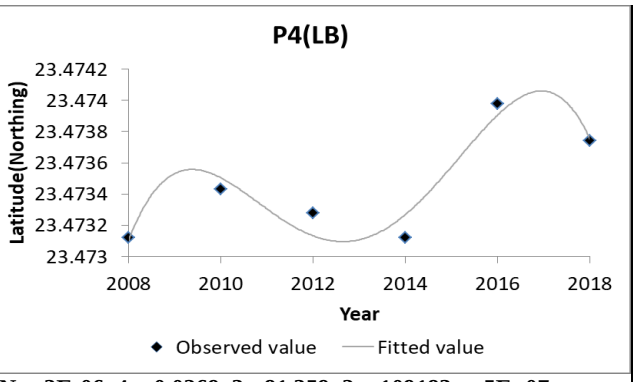
E = -4E-05x3 + 0.2495x2 - 503.18x + 338281
R^2 = 0.9683



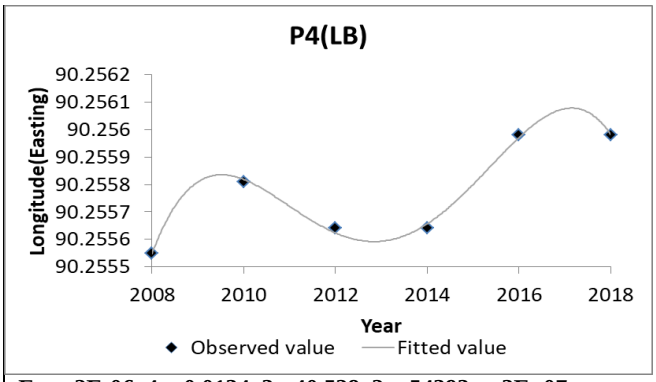
N= -3E-05x4 + 0.2227x3 - 672.34x2 + 902237x - 5E+08
R^2 = 0.9994



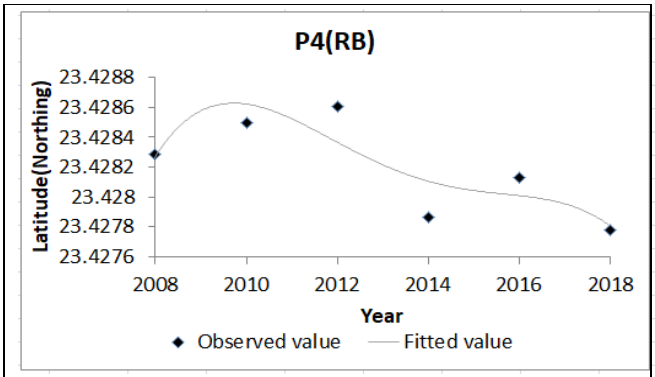
E = -1E-05x4 + 0.1032x3 - 311.47x2 + 417961x - 2E+08
R^2 = 1.0023



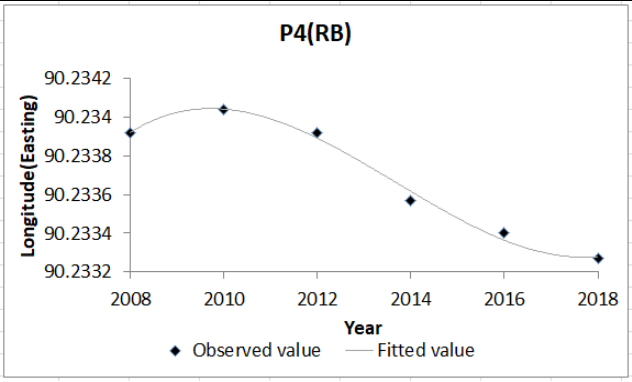
N= -3E-06x4 + 0.0269x3 - 81.359x2 + 109183x - 5E+07
R^2 = 0.9176



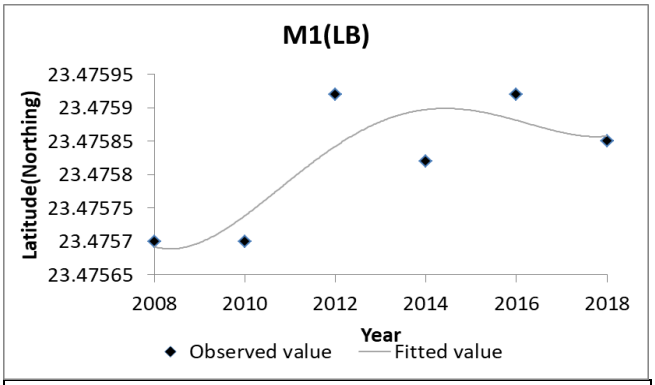
E = -2E-06x4 + 0.0134x3 - 40.528x2 + 54393x - 3E+07
R^2 = 1.2049



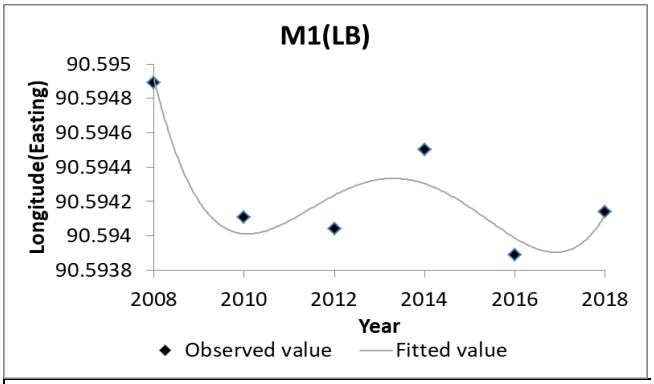
N= -3E-06x4 + 0.0269x3 - 81.359x2 + 109183x - 5E+07
R^2 = 0.9176



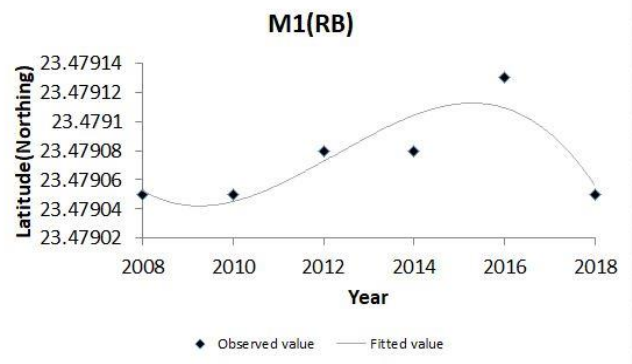
E = 3E-06x3 - 0.0184x2 + 37.03x - 24766
R^2 = 0.9977



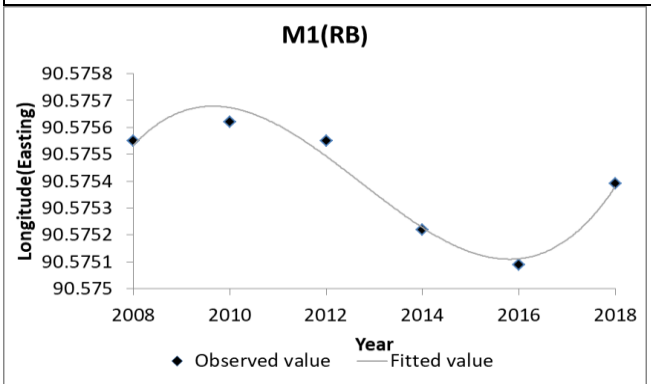
N= 2E-07x4 - 0.0018x3 + 5.3845x2 - 7227.8x + 4E+06
R^2 = 0.8598



E = 3E-06x4 - 0.0221x3 + 66.826x2 - 89699x + 5E+07
R^2 = 0.9488



N= -6E-07x3 + 0.0039x2 - 7.8734x + 5304.6
R^2 = 0.764



E = 5E-06x3 - 0.0296x2 + 59.5x - 39828
R^2 = 0.9763

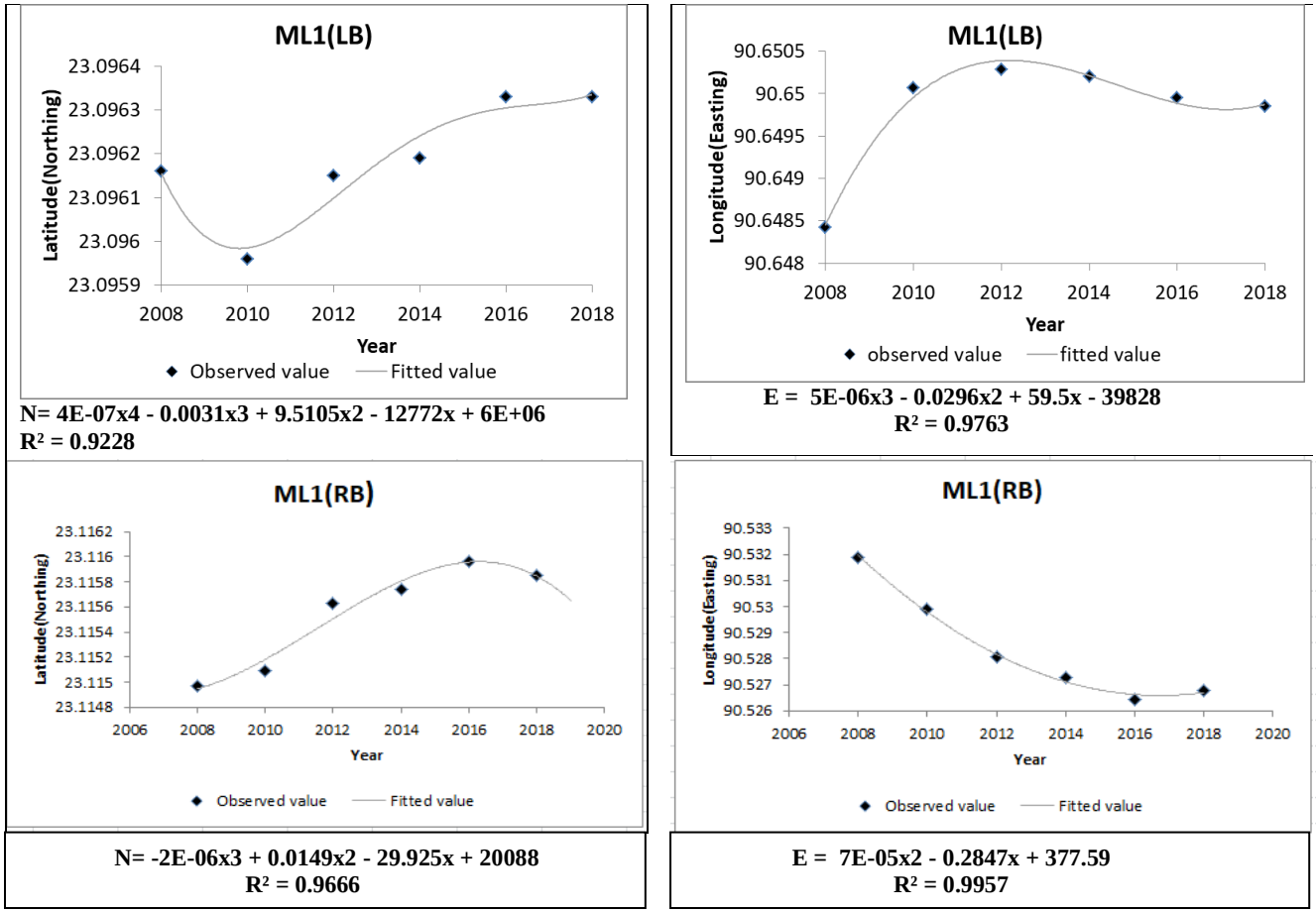


Figure 5:Geographic Coordinate system based analysis

3.1.3. Lstm based analysis

The LSTM program is implemented in MATLAB. The dataset is partitioned with 80% for training, 20% for the testing. The analysis is used for four sections only. The hyper-parameters used to train are carefully tuned and are given in Table 1 and the obtained Predicted value for 2018 and RMSEs (Root Mean Square Value) are shown in Table 2.

Table1. Dataset Partition, Parameters and Hyper-Parameters

Parameters and Hypermeters	Case study
Train data set	4 (80%)
Test data set	2(20%)
Max Epochs	250
time elapsed	4 sec
Initial learn rate	0.005
Gradient Threshold	1
Learn Rate Drop Period	125
Learn Rate Drop Factor	0.2
Verbose	0
Optimizer	Adam

Table 2: Results Obtained from LSTM

Sections	Observed value	Predicted value	RSME
P1LB	-3077.031832	-2.86E+03	164.7068
P1RB	-1982.172877	-2.43E+03	432.1116
P4LB	209.171909	213.3962	189.6368
P4RB	-3673.930572	-3.70E+03	81.4506
M1LB	-60.776865	-67.1754	13.4419
M1RB	-421.104105	-310.4744	66.7011
ML1LB	2897.367771	2.93E+03	29.0464
ML1RB	-6594.58581	-6.24E+03	199.2874

3.2 Comparison Between Approached Methods

The three methods described; Regression based study, Geographic Co-ordinate system based study and LSTM based study have shown their own predictions for different sections of the study area. All of them have shown satisfactory results.Regression based analysis has given the best results as it shows the least error. But LSTM based study has shown greater error because of the small amount of data sets. The error(%) obtained from the three methos are shown in figure 6.

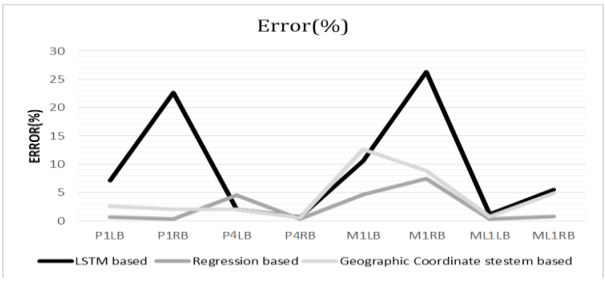


Figure 6: Error(%) from described three methods

3.3 Forecast

Using the regression equations described above, banline shifting for 2020 is forecasted with the regression based study and the geographic co-ordinate based study. It is shown that The results from both of the methods are nearly close to each other (figure 7).

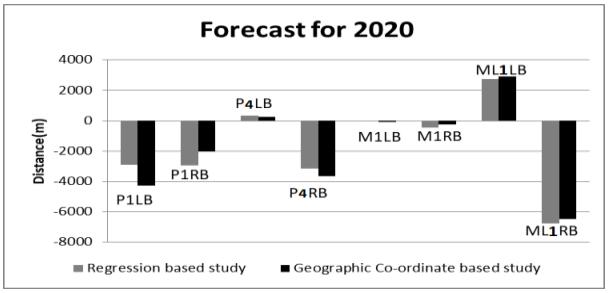


Figure 7: Forecast for 2020

4. CONCLUSIONS

The present morphology at the confluence of Padma and Lower Meghna rivers is such that the width of cross-sections increases considerably at upstream of the confluence, leading to a decrease of stream velocity and consequently the generation of large chars elsewhere. From the analysis of satellite images, it can be realized that major floods occurred in 1974, 1988, 1998 and 2004 impacted on char development and bank shifting of the whole area of interest.

- Over 45 years (1973-2018), the maximum erosion rate for both left bank and right bank are given in table below.The erosion rate is decreased over the last 10 years compared to the last 30 years.

	maximum erosion rate (m/yr)	
River	**Left Bank (m/yr)**	**Right Bank (m/yr)**
Padma	59.25	81.64
Upper-Meghna	8.17	9.35
Lower-Meghna	64.39	146.55

- From the bank line shifting analysis by regression, it is tried to evaluate a specific pattern of shifting, which follows a sinusoidal equation D=[(a1sin(b1t+c1)+a2sin(b2t+c2)+d)].This study is quite satisfactory as the R^2 value varies between 0.8 to 1, showing a little error.This analysis is quite suitable for small amount of data.

- The Geographic co-ordinate system based approach seems satisfactory too, as the R^2 values are in the range of 0.7-0.99.But the magnitude of latitude and longitude are very delicate to measure from the satellite images,nevertheless the analysis shows enough suitability.

- The LSTM based analysis also worked well enough to predict the bankline shifting process.But this process showed much error because of small amount of data. This process is highly helpful with a huge amount of data sets when regression based analysis is not very helpful.

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