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APPLICATION OF REMOTE SENSING & GIS FOR CHANNEL SHIFTING: A CASE STUDY OF ATREYEE RIVER, DAKSHIN DINAJPUR DISTRICT, WEST BENGAL, INDIA

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Abstract:
River channel shifting becomes an endemic and recurrent natural hazard. It acts as the relentless transformation of landforms by the two processes like erosion and accretion on river bank areas, especially in alluvial floodplain worldwide. Lateral channel shifting is becoming one of the significant characteristics of the alluvial lower course rivers, and it threatens the channel instability also. One of the advance scientific technologies, Remote Sensing & GIS can be applied to identify such spatio-temporal changes of river channel shifting as well as in the monitoring of changing in land use and land cover in the riverine areas. The present work examines the temporal variation of the lateral channel shifting by adopting the Remote Sensing and GIS techniques, and it explores the quantitative assessment to detect the changes in the areal extent due to channel accretion and erosion in the study area. The present work is based on the datasets combined with field survey and Landsat satellite data of two different years (1973 & 2018). The systematic study of this present work is helpful to evaluate the lateral shift and changes in channel platform of the selected area between Kamdebpur and Fatepur, part of Atreyee River basin areas in Dakshin Dinajpur district, West Bengal. Thus, present work is very significant for focusing the nature of shifting of this lifeline channel Atreyee for the last few decades and providing the knowledge about meandering as well as its impacts on the areal coverage of landscape caused by natural as well as man-made factors.

1.0. Introduction

Shifting of the river channel is one of the relentless transformations of landforms that threatens the stability of the channel, which is also responsible for flooding, the most common of all environmental hazards. Rivers are too much

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sensitive in the natural and man-made environment (Eaton et al., 2010; Rozo et al., 2014). It is true for all alluvial rivers† that river channels change; such as bank erosion, river bed accretion and down-cutting are common natural processes, and these incidents may increase the risk of bank erosion, flood, loss of agricultural land, nearby settlements and developed infrastructures (Zhengyi et al., 2011). However, different human activities such as sand mining from the riverbed, construction of buildings along the riverbank, artificial cut-offs, embankment with boulders, reservoir construction, and land use alterations have modified the natural dynamics of the river (Surian, 1999; Kesel, 2003; Surian and Rinaldi, 2003; Batalla et al., 2004; Vanacker et al., 2005; Wellmeyer et al., 2005). These incidents are responsible for the shifting of the river channel.

Remote sensing data are a perfect tool for monitoring such changes taking place in the riverine landscape, identification of bank erosion (Michalková et al., 2011), effects of vegetation on erosion (Micheli et al., 2004), and development of gravel bars (Hooke & Yorke, 2010.) Because of the likelihood that naturally, as well as artificially regulated or migrated channel flows produce many specific problems, the present study of the lower course of the river Atreyee is very significant. The present work will help to assess the shift of the channel for the last few decades, and it will provide the knowledge about meandering as well as its impacts on the areal coverage of landscape in two ways, i.e., erosion and deposition. The satellite image of the Atreyee River basin is used here to visualize the extent of lateral channel shift, the river flow pattern, and its meandering course in alluvial settings.

This study is significant to identify such changes and to monitor the changes with the help of computer-based knowledge. Datasets like satellite images, topographic sheets are used systematically for the present study. Change detection analysis is used to explain and measure the spatio-temporal pattern of environmental changes quantitatively for a given region of the earth's surface (Das, 2015).

2.0. Objectives of the study

Historical and topographical evidence, as well as local traditions, prove that the river Atreyee has several times altered its course in the past (Master plan for the drainage system, Balurgat Municipality, 2007). Channel shifting has been considered one of the most critical concerns globally in recent decades. These changes are subjected to erosion and deposition to reach the balance condition.‡ The study is useful to identify the lateral shifting between Kamdebpur and Fatepur along the lower course of Atreyee and helps to understand the influence of such spatio-temporal variation on land-use changes caused by the two critical ways erosion and accretion in the study area.

† Alluvial rivers are those, which flow through sandy material, carve their channels through it & carry water & sediment.

‡ Rivers and streams maintain a dynamic equilibrium between discharge, slope, sediment load, and sediment size (Lane 1955).

The present study aims to fulfill the following objectives:

- To examine the variation of river width due to the lateral channel shifting between Kamdebpur and Fatepur by adopting of remote sensing and GIS techniques
- To establish the value of the average score for the measurement of channel stability in the study area
- To detect the change in areal extent quantitatively due to channel accretion and erosion

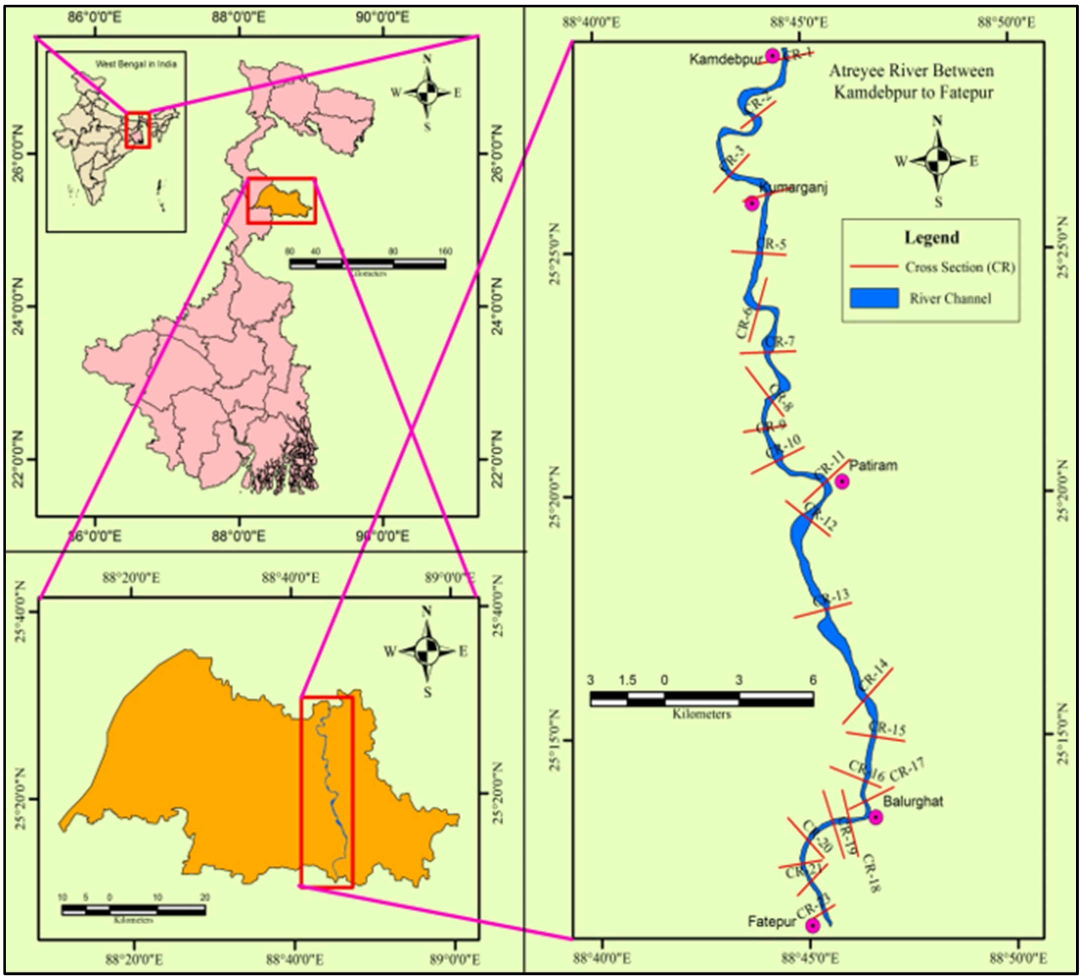


Fig. 1
Location map of the study area (Source: Prepared by the author)

3.0. Study area

The ancient district Dinajpur is believed to have been actively developed with influenced river enriched flood alluvial plain of river Atreyee, Punarvaba, Tangaon, Brahmani, Yamuna, and their many tributaries.§ The Atreyee river is the

§ Dakshin Dinajpur District Profile, Govt.of W.B.(p-13-14)....the area is the part of great barind or plestocene alluvium,which is the largest of the alluvial units of Bengal basin.At the surface,this older alluvium is covered by the floodplains of the river Atrai (Atreyee), Punarbhava,Tangan and Yamuna ...."

part of the Sub-Himalayan river system, consists of a combined catchment area about 8873 square km, which are directly or indirectly connected with the Ganga - Padma river system at downstream where flood acts as the main carrier of huge sediments and other fluvial deposit (Govt. of W.B. Annual Flood Report, 2016).

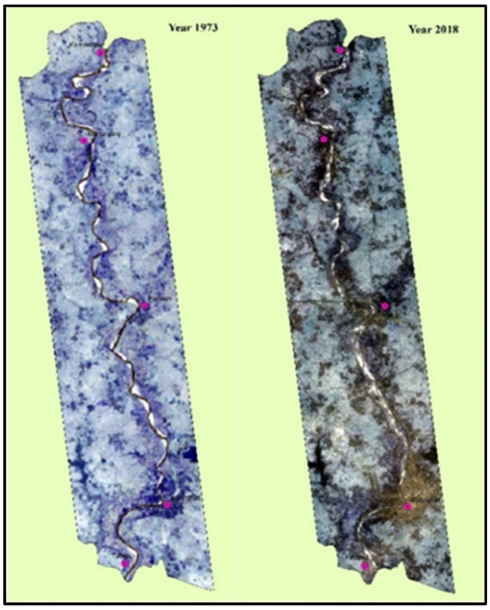


Fig. 2
Satellite images of two different years 1973 (Landsat 1) & 2018 (Landsat 8)
(Source: USGS Landsat Program)

Plate 1
View of Atreyee river bank with accretion
(Source: The author)

Plate 2
View of Atreyee river bank with erosion
(Source: The author)

Balurghat is the headquarter of this district is situated at the left bank of river Atreyee. The part of the study areas of the Atreyee river basin lies between $25^{0}10'$N and $25^{0}30'$N, and between $88^{0}40'$E and $88^{0}50'$E longitudes. The Atreyee River runs across the north to the south direction within this study area. The study area covers an area of about 262.65 sq. km.

The total length of Atreyee is about 340 km, out of which 55 km of its course is within the administrative areas of West Bengal, which is selected for this study. The study area lies between North Kamdebpur (which is the point where the river enters District Dakshin Dinajpur) and Fatepur (where the river again runs towards outside the district and re-enters Bangladesh). A total of 23 reference sites have been selected for the retrieval of field-data covering the entire longitudinal course of the river in the study area (See Fig. 1 and Fig. 2). The entire work of these selected sites is studied for identifying the amount of shifting of channel, variation of channel width, depth, the bank-line accretion, erosion, etc (See plate1& plate 2).

4.0. Database and Methodology

Datasets used in this study are basically the satellite and GIS data, topographic data, field-survey-based data, and socio-economic data. The comprehensive sources of the datasets are given in Table 1. An extensive field study accompanied by topographical data from Survey of India Topographical Sheets and satellite imageries are used for the changing detection of the channel between the two years, i.e., 1973 and 2018. For the identification of the bank line migration and analysis of LULC change within this study area, GIS and Remote Sensing techniques have been used. Arc GIS 10.2 has been used for extracting the channels of the river of different years (1973 and 2018) from the Landsat data and the shifting of channels over time. To analyze the impact on land use/land cover, supervised image classification has been done of these two Landsat data in Erdas Imagine v2014 software using ground control points (GCPs). Fig. 3 shows the flow diagram of the database and methodology for the present study.

Table 1
Datasets collected from USGS, SOI, GOI and other sources for the present work

Data	Sensor/Source	Path/Row	Year	Resolution (m)/Scale
Landsat-1	RBV (Return Beam Vidicon) and MSS (Multispectral Scanner)	149/042	1973	60
Landsat-8	OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor)	138/43	2018	30 (For band 8 resolution is 15 m)
Topographical Map Index 78C	Source- SOI	--	1968-69	1:250000
Topographical Map Index 78C/11	Source- SOI	--	1972	1:50000
Socio-Economic data, District Profile Flood Report	Source-Census Report Govt.of India, BAES (Govt.of W.B)	--	2001, 2011 & 2017	--

(Source: The author)

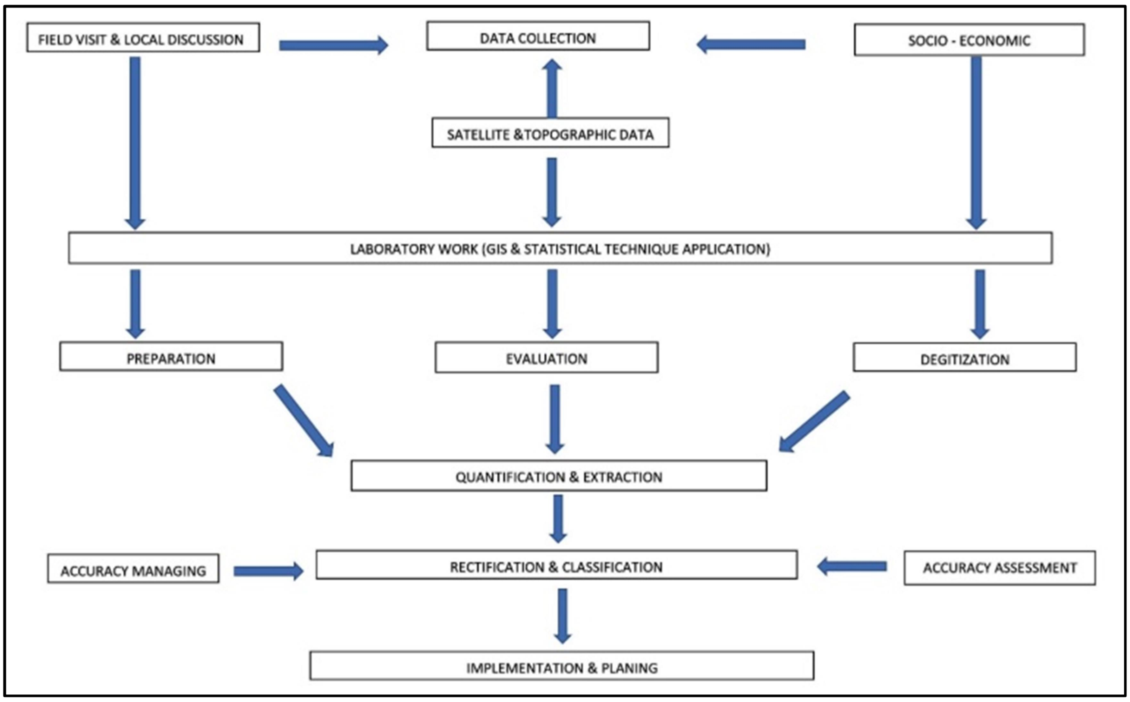


Fig. 3
Flow diagram of methodology (Source: Prepared by the author)

5.0. Results & discussion

The topographic and remote sensing data, as well as field-based data used in the study, offer different information about the nature of the channel movement pattern and existing geomorphological features in the study area. It is found from field visits there are many large longitudinal and transverse bars in the channel, and its courses are changed frequently. Recorded data reveals that the entire course of the old basin of Atreyee has been shifted and changed with the Neo-Tectonic activities as well as massive rainfall-induced flash flood hazards** several times. During the rainy season, the river spreads its enormous discharge and take a meandering course in the downstream. However, in summer and winter, the flow is deficient. According to field survey, the lowest average depth of the channel is in site Patiram (0.6m), and a maximum average depth of the channel is found at the site Safanagar (1.5m) near Indo Bangladesh border area (Fig. 4).

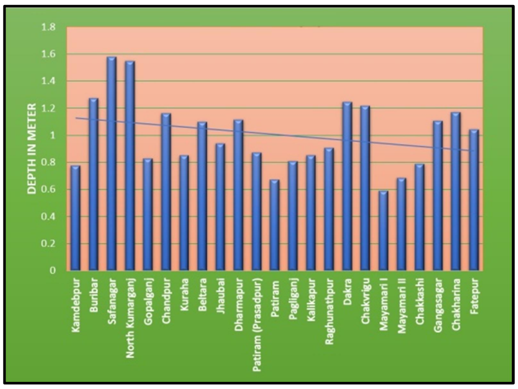


Fig. 4
Average depth of river Atreyee at different site Source: Field Investigator's survey-2019-2020 (Source: The author)

From the field survey, it is observed that different type of anthropogenic activities such as unplanned sand mining from the bed, uncontrolled use of water lifting pumps, the construction of unplanned footbridge within channel bed, agricultural practices along the river bed during the dry season, etc. these all have influenced channel flow pattern as well as channel

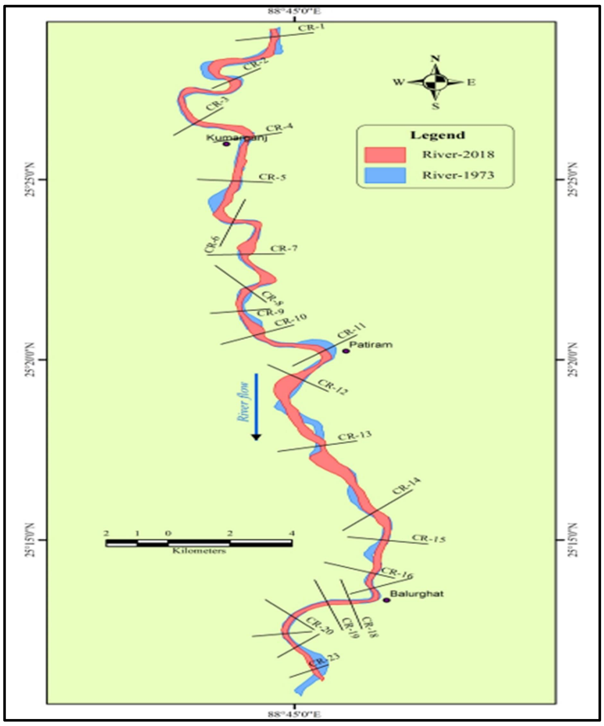


Fig. 5
Lateral channel shift of Atreyee river between Kamdebpur (upperside) & Fatepur (downside) in the year 1973 & 2018. (Source: The author)

** Historical documents on the floods and flood-induced evolution of the sub-Himalayan rivers viz., Bolt, 1772: Buchanan-Hamilton,1810; Dash, A. J., 1947; Furgusson,1770-79; Hunter,1787; Sunder, D. H. E. 1985; Gruning, J.F. 1911; Rennel,1779; Mitra,1964; Sanyal, l969 etc are numerous and fascinating. Record reveals that up to 1787, the river Tista and Karotoya were the same river that flowed through the Atrai-Punarbhaba into the Ganga. Neo-tectonic activity coupled with high intensity rainfall induced flash-flood caused massive shifting of the river. The so-called whale backed subsurface ridge of the Baikanthapur Fulbari became active and the Tista migrated eastwards bifurcating the river Karotoya.

shifting since last few decades (Plate 3). Thus, the river of this alluvial setting is characterized by its continuous changes in channel morphology. So in order to know the variation in channel width, the study is based on two maps of different years and in Fig. 5, the lateral channel migration in the Atreyee river in the study area of two different years has been presented below. Table 2 shows the temporal changes of the channel Atreyee between Kamdebpur & Fatepur.

Plate 3
Voice of various human activities (Source: The author)

Table 2
Variation of channel width along selected sites in study area during 1973 and 2018

Station	1973	2018	Changes in total width (m)	Station	1973	2018	Changes in total width (m)
CR-1	278.74	237.76	-40.98	CR-13	244.03	160.33	-83.71
CR-2	331.14	227.64	-103.50	CR-14	282.67	277.79	-4.88
CR-3	254.46	231.71	-22.75	CR-15	266.55	217.31	-49.24
CR-4	306.30	261.55	-44.75	CR-16	214.92	165.65	-49.26
CR-5	281.18	235.75	-45.43	CR-17	154.60	126.15	-28.45
CR-6	228.81	206.22	-22.60	CR-18	184.13	172.24	-11.89
CR-7	223.87	301.34	77.47	CR-19	184.28	178.27	-6.01
CR-8	304.85	233.58	-71.27	CR-20	263.03	161.98	-101.05
CR-9	201.05	137.26	-63.79	CR-21	187.30	136.61	-50.70
CR-10	241.80	336.79	94.99	CR-22	227.39	149.73	-77.67
CR-11	292.70	268.93	-23.77	CR-23	382.48	165.61	-216.87
CR-12	252.64	450.57	197.93				

(Source: Based on calculation from 1973 and 2018 Landsat Imagery and Field investigator's survey)

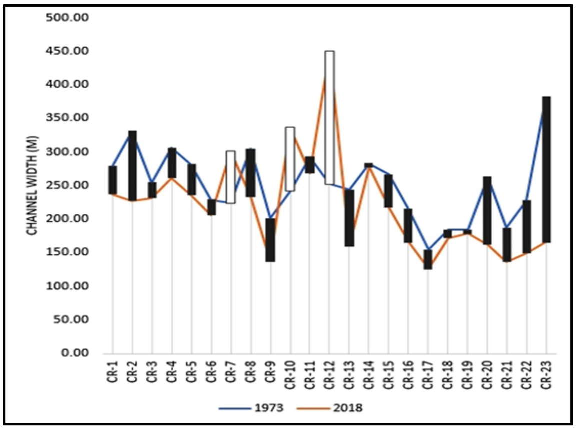


Fig. 6
Graphical representation of temporal changes of Atreyee river width (1973 & 2018). (Source: The author)

It is observed from the data retrieved from the field survey, topographic analysis, and channel migration that there are various changes, e.g., bank erosion, soil loss, vegetation removal, etc., those are caused by the combination between human interferences and nature induced factors. The downstream segment of this channel is most vulnerable to such shift, and human activities within a riverine flood plain. The clearance of vegetation cover for the agricultural practices and artificial channel widening makes this river system most vulnerable to a sudden course change. These factors are responsible for meandering the channel at the northern part of the channel as maximum settlements are found alongside that part of the river.

Fig. 6 shows the graphical presentation of total temporal changes in the channel of Atreyee between Kamdebpur and Fatepur. However, the rate of changes is influenced by many factors, such as average flow velocity, the intensity of turbulence, sediment particle sizes, bed configuration, and of course, the human activities in the study region. Almost every river course has its playfield within which it shows its dynamism.

Table 3
The channel stability condition of selected sites in the study area

Average Score	Site Name	Stability condition	Stability Rank
2.0-2.2	Jhaubai, Raghunathpur, Dakra, Chakvrigu, Mayamari I & II	Relatively Stable	1
2.2-2.4	Buribar, North Kumarganj, Chandpur, Kuraha, Patiram, Pagliganj, Kalikapur, Gangasagar, Chakharina, Fatepur	Moderately Unstable	2
More than 2.4	Kamdebpur, Belterra, Dharmapuri, Patiram(Prasadpur), Chakkashi	Relatively Unstable	3

(Source: Based on the calculation of Raw data from the Field Investigator's survey)

The average score for channel stability can be determined, and it can be used as a flood disaster monitoring tool in order to improve flood analysis. Table-3 shows the average score for the measurement of stability rank of the selected sites, which are considered for this work. Here the method is followed by Rosgen (2001). Raw data directly collected from field surveys for compositing all the variables and site-specific summation of weights of the selected variable has been computed and made it average. Although the channel stability prediction methods involving difficulties and it needs continuous geomorphological assessment for many years.

Here the computed average score is divided into different conditions for stability. The entire study area has been divided into three types of stability, i.e., (i)relatively stable condition having the score 2.0-2.2; (ii)moderately unstable condition with 2.2-2.4 score; and (iii)relatively unstable condition with the score value of more than 2.4. Channel erosion and accretion are related to channel stability, and it is observed that reaches in poorer stability condition prior to the flood, received major damages by the same flow (Rosgen, 2001).

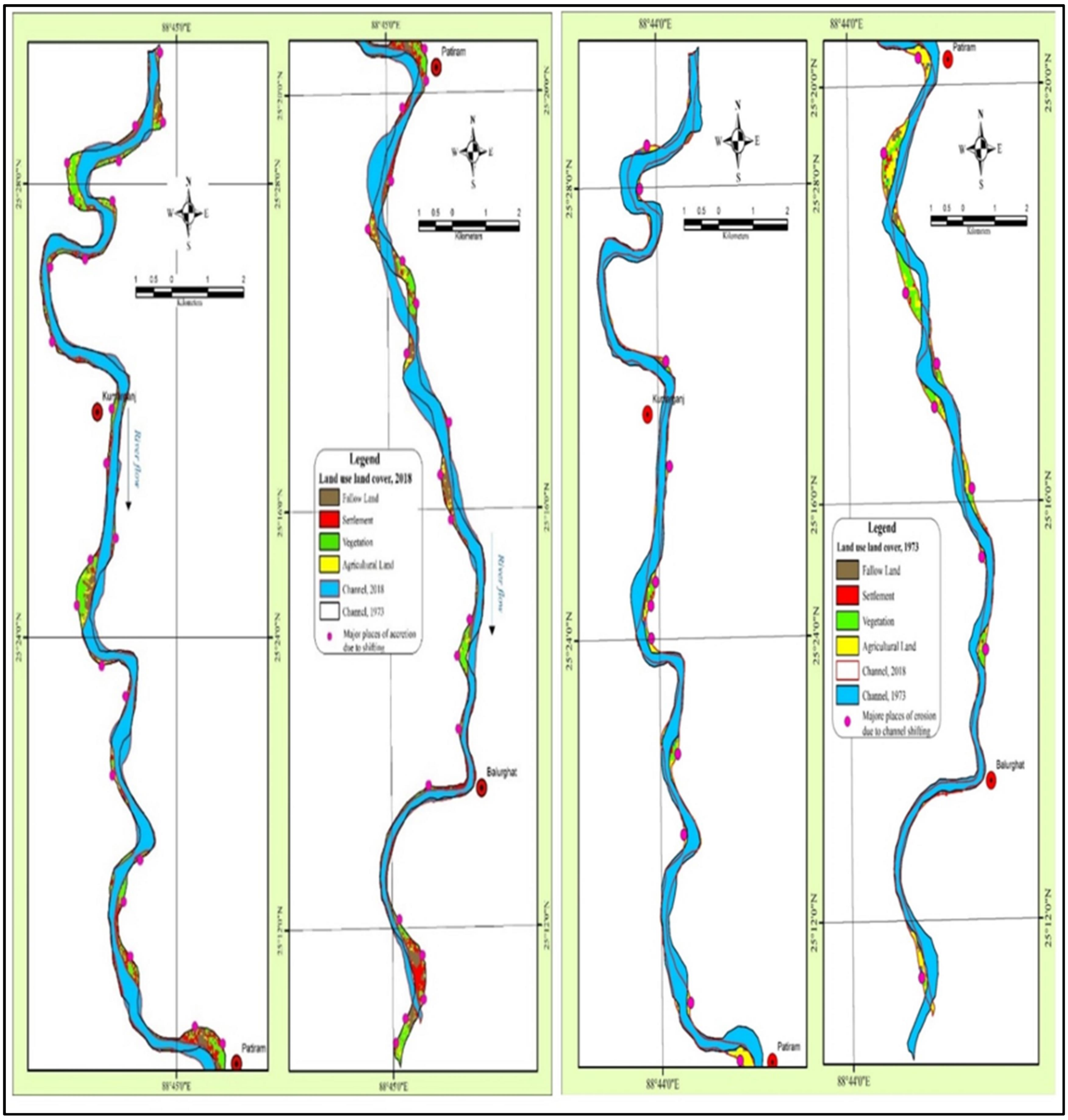


Fig. 7
Different areal coverage of land use due to channel accretion & erosion (1973 & 2018). (Source: Prepared by the author)

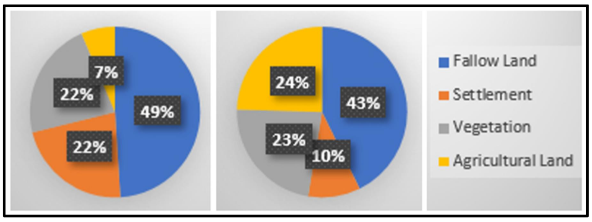
For the analysis of temporal changes in the existing landscape by channel erosion and accretion in the study area along the course between Kamdevpur and Fatepur, the entire area is classified into four different classes. The detailed description of the changed landscape coverage caused by erosion and accretion has been shown in Table 4 and in Fig. 7.

Table 4
Landuse & landcover distribution and change detection in the study

Land use Landcover	The area by Accretion (km²)	The area by Erosion (km²)
Fallow Land	3.96	2.02
Settlement	1.79	0.47
Vegetation	1.81	1.08
Agricultural Land	0.52	1.16
Total	8.08	4.72

(Source: Based on calculation 1973 and 2018 Landsat Imagery and Field Investigator's survey)

Fig. 8
Land use and land cover adjustment after channel accretion & erosion



(Source: Prepared by the author)

Adjustment of temporal changes of the landscape caused by the two processes of erosion and accretion and has been presented graphically in Fig. 8. This work examines what kind of changes have influenced the present distribution of land use. It is seen that the amount of land created by the river accretion (8.08 sq. km) is more than the amount of land created by river erosion (4.72 sq. km) in the study area. There are some places found where channel bed accretion takes place significantly.

These sites are Buribar, Majian, Chak Gangaprasad, Chak Barham, Patiram, Hariharpur, Pollapara, Mahinagar, Dakra, Meria, Chak Bhatshala respectively. Buribar site is one of the sites which is characterized by sedimentation resulting in maximum accretion.

The other twelve sites, Kulahari, Par Sahazadpur, Dhadalpara, Kuraha, Par Patiram, Raipur, Patiram, Rajapur, Parbatipur, Hazipur, Near Tankmore, Fatepur are mentioned here where the shifting has been taking place due to erosional activity within river course.

Based on data adopted for classification adjustment, it can be stated that in the year 2018, the exposed fallow land of the previous year has been converted into growing agricultural cropland. It may be stated that the practice of village orchard is becoming more significant with the growing demand of the population in recent times. On the other hand, due to the accretion of the river bed, the construction of built-up areas near the river plains is becoming very significant. Gradually the problem of water inundation in these low-land areas is quite vulnerable to the flood hazard during the monsoon season.

From the survey as well as statistical calculation, it is revealed that people are encroaching gradually toward the basin of the river due to population growth. However, different human activities, including deforestation, construction of buildings along the river bed, embankment with boulders, temporary reservoir construction have altered the natural flow of this channel in the study area.

6.0. Conclusion

It can be concluded from the present work that the study is useful for identification and analyzation the Spatio-temporal changes of river Atreyee with respect to its lateral shifting and offers significant information to understand a future synoptic view of this river course changes in the study area. The results and database created during this present study will be helpful to focus on the dynamic alteration of landforms structure in the study area for future planning. Remote sensing data and GIS techniques together have been applied successfully in the present study to prepare such temporal variation in river Atreyee for the last few decades. Land use and land cover, including vegetation and non-vegetation parts, describe sustainable planning in the context of human practices. For further research, it is necessary to link fluvial processes with socioeconomic factors in order to predict future stratigraphy, which allows the signature of the dynamic channel movement and will help to interpret such dynamism as the support of disaster preparedness and mitigation activities.

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