Importance of remotely sensed data to analyze the changing fluvio-geomorphological environment of the uninhabited islands in Indian Sundarbans: special reference to Ajmalmari islands

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Abstract - Lots of researches have been done or being carried on the geographical or socio-economic issues of Indian Sundarbans. Even though, due to the restricted entrance to the uninhabited mangrove islands and unavailability of primary as well as secondary data to carry out a case study or research work, we often depend upon the local people's statements entered or wonder those mangrove. But with the introduction and availability of the satellite imageries, geographers somehow managed and are achieving more and more unknown facts and figures of the ever-mysterious mangrove islands even of the core areas of Indian Sundarbans. The satellite images help a lot to understand and collect the remotely sensed data which might or may lead lots of interdisciplinary works to explore more unknown wealth of the world's largest mangrove delta, the Sundarbans.

This article has tried to focus on the changing fluvio-geomorphological environment of the uninhabited Ajmalmari Reserve Forest along with the dynamic islands and mid-channel bars to the west of it. Author also explains the tidal dynamics in Indian Sundarbans through RS and GIS which hopefully may help carry on more interdisciplinary research works where both primary and secondary data collection is really a challenging one.

Keywords: ***Fluvio-geomorphological environment, mangrove, tidal dynamics, Reserve Forest, BOB, Point bar, Mid-channel bar***

I. INTRODUCTION

There are total 101 islands (both habited and uninhabited) in IndianSundarbans. As per the delineation line drawn by Dampier and Hodges, the Indian Sundarbanconsists of thirteen C.D. Blocks from 24 Pgs.(S)– Gosaba(9), Basanti(2), Canning-I & II(1),Namkhana(5),Sagar(2) Kakdwip(2), Patharpratima(13), Mathurapur-I(1), Mathurapur-II(2), Kultali(1), Joynagar-I &II (in Kultali) and six C.D. Blocks from 24 Pgs. (N) – Minakhan(1), Haroa(5), Sandeshkhali-I(1), Sandeshkhali-II(6), Hasnabad(1), Hingalganj(2). The numbers within the parentheses denote the inhabited islands in each block falling under each region of Indian Sundarbans. Whereas, rest 47 islands are still, for god sake has been left as uninhabited ones.

Almost all the present inhabited islands are either falling in the mature zone or in maturing or say active estuarine zone of the prograding Bengal Delta, the largest in the world. Since historical past, many controversies aroused regarding the formation of this Sundarban delta and still now scholarly researches from different disciplines are going on to search the ground reality of the typical formation and degradation of the mangrove islands decades after decades. But the insufficiency of primary as well as census level data related with the uninhabited parts often becomes an obstacle to analyze the spatio-temporal changes in the fluvio-geomorphological environment all over the Sundarbans. Thus, geographers or scholars from different disciplines have to depend upon the tertiary data or say the remotely sensed data to analyze and interpret the geomorphological processes acting behind the changing nature of this region controlled by the tidal channels, khals and creeks. So, the periodic satellite imageries of this region sometimes become the most important databank to the geographers by which the fluvio-geomorphological attributes can be quantified and can also be analyzed through different morphometric techniques. The Ajmalmari islands under the administrative control of the Ajmalmari Reserve Forest area are also a model area where lots of changes have been rectified which also can represent the natural dynamism of the intangible tides and bores occurring all time modifying the exclusive estuarine deltaic scenarios of the Indian Sundarbans.

Objectives:

I. To find out the locational significance of the study area.

II. To acquire, calculate the quantitative as well as qualitative data and to analyze the data obtained from the satellite imageries of the region of interest.

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III. To year-wise compare the spatio-temporal changes in the fluvio-geomorphological attributes of this area.
IV. To relate the result obtained from the analysis and to represent it as a model one in Indian Sundarbans.

II. METHODOLOGY

✓ **Pre-Phase:**

I. Literature Review – Mainly scholarly articles related to the physical or geomorphlogical studies on Indian Sundarbans in books and journals have been gone through to collect previously published authenticated report about the problem area.
II. Collection of - NATMO Map, Toposheet No.s - NF 45-8 and NF 45-8 Series U502 with R.F. 1:250k, F45Q9 and F45K12 with R.F. 1:50k) and Satellite Imageries (IRS LISS-III,2009-2016) from https://www.bhuban.nrsc.gov.in.

✓ **Phase of Data Processing:**

I. Geo-referencing the selected Toposheets (Raster layers) and digital processing of the different bands in the same CRS through Arc GIS and Google Surfer-16 software.
II. Digital Classification of the satellite imageries through supervised and unsupervised techniques.
III. Extraction of different physical and cultural attributes.
IV. Calculating the number (point), Length (line), Area (polygon) of the vector layers.

✓ **Post-Phase:**

I. Comparing the fluvio-geomorphological data extracted both from Toposheets and Satellite Imageries from 2009 to 2016 (IRS LISS-III images downloaded from https://bhuban.nrsc.gov.in).
II. Analyzing and Interpreting the data to make them a secondary source (Through Mapping and articles) to the interdisciplinary research works where primary and secondary data are not available.

Location of the study area: Geographically the study comprises three prominent islands of Indian Sundarbans extending between the 88.58˚E to 88.67˚E longitudes and 21.79˚N to

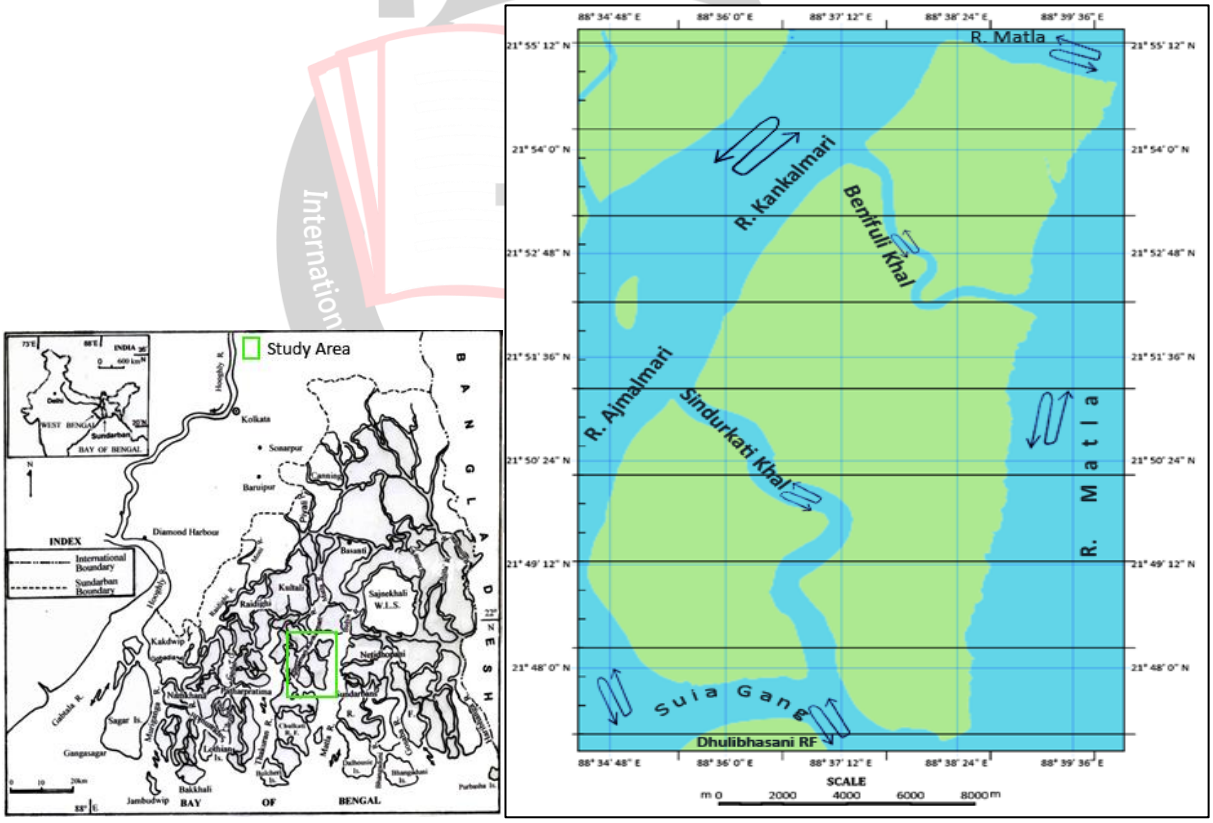

Fig.1: Location of the study area in district of 24 Pgs. (S), West Bengal, India

21.92˚N latitudes covering an area of ± 74.23 km² land area. The islands are mainly delineated by the confluence of Matla River and Bidyadhari River to the north, Matla River to its east, the Suia Gang, an interlinking tidal channel (between the Dulibhasani Reserve Forest and Ajmalmari Reserve Forest) connecting the Matla River to the Ajmalmari-Kankalmari Rivers to the south and the Ajmalmari River, Kankalmari Rivers to its west. Geomorphologically these are mangrove islands which are the formed due to the continuous deposition of silt and clay (O'Malley, 2009), by the River Matla and that of the tidal creeks bearing the saline marine water of Bay of Bengal (BOB) which is ± 45.71 km (heading 179.74 degree) away from its southernmost tip. It has a very typical estuarine locational significance in the central part of the prograding Indian side Sundarban Delta.

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Administratively this mangrove islands fall under the administrative jurisdiction ofKultali C.D. Block in South 24 Parganas, West Bengal. The study area covers about 24.24% area of the total block area (306.2km²). The islands of Gosaba and Basanti C.D. Blocks lie to the east to the north respectively. These islands are still the uninhabited ones and are under the control of the Ministry of Sundarban Affairs, Govt. of West Bengal. So, it is also having an administrative importance as these are uninhabited but a tourist attraction also. The three island compartments under the Ajmalmari Reserve Forest used to serve as the steamer signaling area during the British colonial period in Bengal. The SOI Toposheets of 1924 of this region (NF45-08 and NF45-12, SERIES U-502) reveal the fact that this area had four *Steamer Signals*, particularly at the confluences of Kankalmari River and Sindurkati Khal, at the confluence of Kankalmari River and Benifuli Khal and along the right bank of Matla River along its northern border (Fig.1). Still today, these islands are uninhabited and the homeland of rare mangrove and endangered animal species.

Relief and Climate: The Ajmalmari mangrove islands within the specific coordinates as stated earlier are mainly the active estuarine parts of the Bengal Delta (Indian side) and are the tidal riverine depositional products. The maximum elevation of the islands is ± 5.0 m and minimum ± 0.25 m above MSL (from the DEM analysisC1_DEM_16B_2006-2008_v1_88E21N_f45q) and from the altitudinal analysis by Surfer-16 (Fig.2 & Table 2).

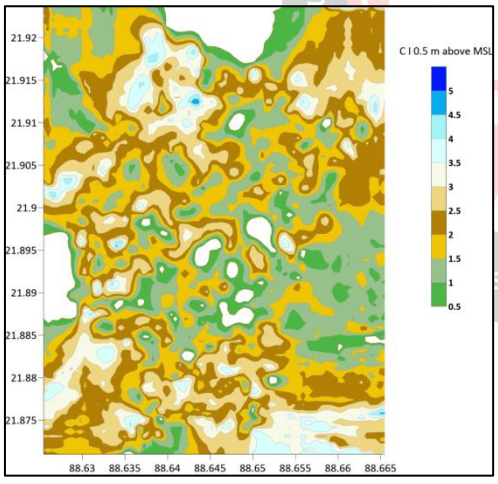

Fig.2: Relief Map of the north compartment part of the Ajmalmari-Kankalmari Mangrove Islands (2018)

From this, it's very much clear that this intertidal area is very much prone to submergence during the high tides or during tidal bores particularly during cyclonic conditions when the tidal river water level rises more than 5 m.

Climatic and Soil Characteristics: The study area is located in the central zone of the Indian Sundarbans. So, likewise the climatic condition prevailing over the South 24 Parganas, West Bengal in India, the Ajmalmari Islands also experience the Tropical Monsoon type of climate mostly influenced by the BOB (about ± 45km away). The annual average temperature is 25˚C-30˚C with maximum of 40˚C in summer (May/June) and minimum of 10˚C. The three mangrove islands experience an average annual rainfall between1200 mm to 1900 mm. The nearness to Bay of Bengal and frequent formation of depression, cyclone and cyclonic storms sometimes play a major role in the tidal water level and temporarily accelerate the riverine activities. Closeness to the BOB keeps the relative humidity more than 80% during the wet season (March-September) and 50-70% during dry season (October-February).

In general these three islands are made up of fine silt and clay with finer alluvium. The tide water laden suspended load often help in the formation of point and mid-channel bars around the islands and along the tidal channels and creeks draining them twice a day.

Geological set up the Bengal Delta: Marine transgression on the Bengal shelf occurred locally during late Cretaceous and widely during Eocene. During Miocene, only the eastern parts of the Bengal shelf were under marine influence.Slow subsidence of the shelf area during late Cretaceous when brackish to lagoonal deposits accumulated on the Bengal shelf. During Pliocene, with the regression of the sea, estuarine and fluvial conditions of deposition prevailed in most parts of the Bengal (Bagchi, 1945).

Fluvio-geomorphological Environment in Ajmalmari Islands in Indian Sundarbans:

The study area as is an estuarine deltaic part of the Indian Sundarbans is mainly of sedimentary depositional landform in origin (Paul, 2005). The sediment load borne by the River Matla and Bidyadhari has been playing a major controlling factor behind the formation of the study area envisaging three major and one minor estuarine deltaic island with some creeks. Besides, settling of the suspended particles, coming from the incoming tidal waves of the Bay of Bengal (BOB) for some decades, also helped or is helping in the accreditation processes particularly in this location. Same locational significances can be correlated to the location of Haliday Island just to the south of these islands (± 45km). Geomorphologically the study area is made up of fine silt and clay with uneven surface although the relative altitude ranges between 0-4.5m in the north compartment, 0-5m in the central island part and 0-1m in the southern island part.

The Relief Map (Fig.2) of the north compartment part among the three macro island system of the Ajmalmari-Kankalmari Islands (interfluvial area between Kankalmari River-Ajmalmari-Suia Gang and Matla River) also indicate that the contour heights (clamped to ground) are relatively higher in the northern section of the north compartment part bordering the Kankalmari River, whereas, the rest portions (particularly the SE section) are having relatively lower altitudes. The probable reasons found from the analysis of the satellite imageries of the said study area are –

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I. The Matla River after taking the huge amount of suspended sediment load from Bidyadhari River flow down towards the BOB and bypass through the Kankalmari River-Ajmalmari, a distributary tidal channel of Matla River which actually bifurcates into three interlinking tidal channels and creeks as following –

(a)A narrow tidal creek i.e. Olian Nala linking the Thakuran River to the Matla River

via Ajmalmari River and Kankalmari River.

(b) A narrow tidal channel viz. Suia Gang, an interlinking channel between the R.

Ajmalmari and Matla River, and

(c) Benifuli Khal and Sindurkati Khal, the interlinking tidal creeks ply the tidal

dischargeof Kankalmari River, Ajmalmari River and Matla River (Fig.1).

II. As the Matla Riverstartsnarrowing from the Herobhanga Is.(to the east) and Kaikhali Abad (to the west) up to Canning and flows down almost in linear alignment with sluggish flow during the ebb tides, so, it accumulates most of the sediment load at its southern most passage, particularly in the confluence zone of Kankalmari River-Ajmalmari and Matla River. Thus, the zone, just south of the Herobhanga Is., is a meeting of three loads bearing tidal channels viz. Matla River, Bidyadhari River and Kankalmari River-Ajmalmari. The peculiar fluvio-geomorphological environment helped in the formation and aggradation of the Ajmalmari islands in Indian Sundarbans.

III. The abandoning of the Matla River in its catchment area as well as the increase in the suspended load year after year have combined impact over the formation of lots of point and mid-channel bars along both side banks of Matla River (Das, 2006). But, as all the tidal rivers flow with higher velocity during ebb tides along their right bank towards the BOB rather than the left banks along which the incoming lighter tidal bore flow with higher velocity, the left banks become least affected by the undercutting processes by the river water.

Besides this, from the digital analysis of the satellite imageries of the study area it has also been found that these three islands also passed through spatio-temporal changes in areal

Table 1: The erosional and depositional activities in Ajmalmari islands (2009 to 2016)

2009 (Year of Base Layer)			2016 (Year of Last Layer)	Result	Remarks
Sl. No.	Island Compartments	Area (km²)	Area (km²)	Area (km²) Deposited or Eroded	
1	North	14.125607	13.88430781	-0.241297	Loss
2	Middle	38.05688498	38.02678344	-0.03010154	Loss
3	South	15.98951756	16.07012016	+0.0806024	Gain

Source: Result from digital processing of the satellite imageries

coverage since 2009 to 2016. The spatio-temporal changes in the amount of suspended sediment load in Matla River, Bidyadhari River, Kankalmari River-Ajmalmari, Benifuli Khal, Suia Gang has also shown a shown that there is a loss of 0.241297 km² and 0.03010154 km² land area in the northern and middle islands respectively during this period. Whereas, the southern part among those three islands of Ajmalmari RF area has shown a gain (0.0806024 km²) in areal coverage (Table 1). Although the amount of land and loss is negligible but the factor behind the depositional activities in the southern part (towards the mouth of Matla River) can draw an inference. Hence, it is quite a common phenomenon caused by altering erosional and depositional activities by the shifting tidal channels particularly in the estuarine deltaic zone of the Indian Sundarbans (Mukhopadhyay and Mukhopadhyay, 2005).

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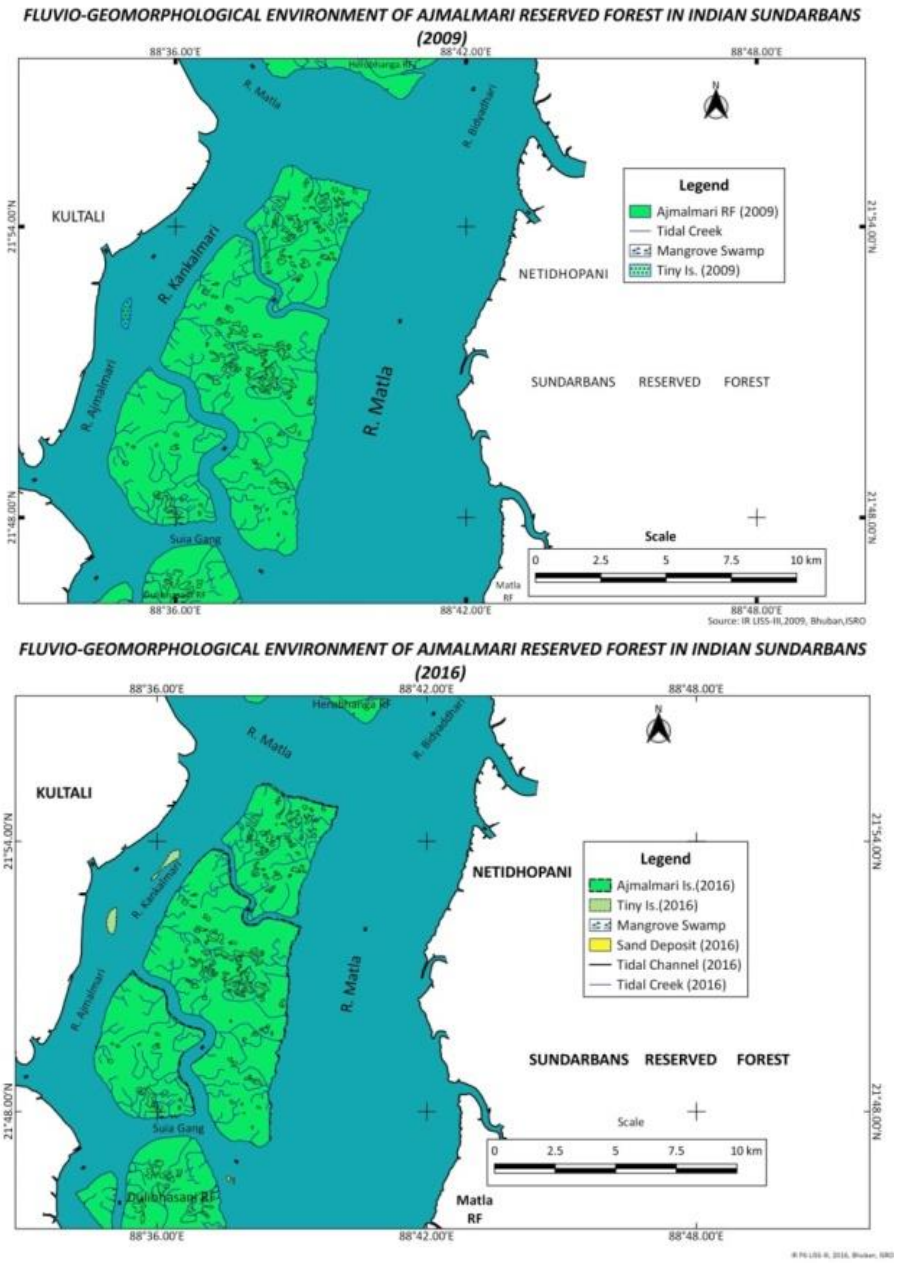

Fig.3: Spatio-temporal changes in the fluvio-geomorphological environment in Ajmalmari islands since 2009 to 2016.

The reasons behind the maximum loss of land area in the northernmost island as noticeable are –

a) Formation of helical flow at the junction of the Matla, Bidyadhari, Kankalmari Rivers around and along the northern part (just south of Herobhanga Is.).
The sharp bending and meandering of the Matla River also accelerate the changing erosional and depositional rate depending upon the seasonal amount of discharge

Table 2: The probability (%) of submergence of the Ajmalmari islands during high tides

Island compartment	Tide Water Level increase/decrease (in m)	Submergence (%) under Tidal Waves
North	0.65m	HTW enters
	0.80m	50%
	0.96m	99% submerged
Middle	0.47m	high tide water enters
	0.96m	99% submerged
South	<0.50m	50% submerged

Source: Digital analysis with 3D modeling through Google Surfer 16

*BOB- Bay of Bengal, HTW- High tide water

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Noticeable changes in the fluvio-geomorphological environment in the Ajmalmari islands along Matla River during 2009 and 2016. A newly forming mid-channel bar covering an area of ± 0.42 km² area (as in January, 2016) and sand deposits can also be noticed along the Kankalmari River and at the confluence of Suia Gang and Matla River during this period (Fig.3). and varying amount of sediment load. As the Matla bends and bifurcates through the Kankalmari River-Ajmalmari maximum sediment load as found from the imageries, use to be brought down along the bed of Kankalmari River-Ajmalmari link channel and northern part of Ajmalmari island system is very much affected by the erosional works by the Matla River.

b) The eroded materials mainly borne by the Kankalmari River which ultimately due to its sluggish flow help in settling down the load along its bed. This process has helped and helping in the formation of marsh and swamp in the north-west tip of the Ajmalmari Is. (Fig.3) and helping in the formation of a tiny mangrove island (covering an area of 0.35 km²)and a growing mid-channel bar (not formed before 2009). In recent future, if the same process persists without any drastic natural change in the upstream and downstream discharge and drastic decrease or increase rate of sediment deposition(Gour, 2012) by Matla River in this intertidal zone of Indian Sundarbans, these islands seems to be merged with the eastern part of Kultali Block around eastern bank of village Kishorimohanpur.Same conditions are expected to occur in the zone between village Baikunthapur and Paschim Sripatinagar in Kultali block where extension of the areal coverage of the marsh or swamp is observed during the analysis within the stipulated period (2009-2016).

Epilogue: From the above study and interpretation it can be opined that temporal formation and washing out of the point and mid-channel bars are quite common phenomenon. But sometimes, some point and mid-channel bars may survive and can give birth of a new tiny mangrove island in this deltaic region of Indian Sundarbans. Thus, continuous depositional work have helped in the formation of lots of islands in the estuarine parts in earlier times, side by side, frequent shifting of the tidal channels do not create suitable fluvio-geomorphological environment for the formation of a new stable land area along or within the tidal river beds. So many factors control spatially and temporarily like-seasonally varying amount suspended sediment load and tidal water discharge, sudden increase in the volume, velocity and height of the tidal waves during any severe cyclonic conditions, continuous decrease in downstream discharge with high turbidity at identical locations etc. control the formation and diminishing of estuarine part or parts of the islands in Indian Sundarbans. The formation of a new mid-channel bar and sand deposits along the Matla River around the Ajmalmari islands may not promise to be a stable one to be settled because it may again be eroded at any violent situation like what happened to the New Moore Is. Thus, even if there is unavailability of primary or secondary data we must go through the satellite imagery analysis from time to time to identify the changing fluvio-geomorphological environment occurring silently in the intra and intertidal zones of the Indian Sundarbans.

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