Changing Behavior of Tidal Channels and its Impact on Fluvio-Geomorphological Environment of Indian Sundarbans: A Geographic Overview

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Abstract
Sundarbans has been the playfield to the tidal channels since its very origin. Tides and ebbs configure the shapes and sizes of the islands from time to time. The British government during their colonial period in India tried to tame the free movements and control the natural tidal drainage networks by different means for their own economic benefits. Till today, full-fledged embankment building processes in this mangrove delta are being carried out to protect the riverside villages from bank erosion during or during post cyclonic storms. Often, these newly constructed and reconstructed embankments are leading to more devastation here from an agro-economic point of view. The paper aims to identify the causes and effects of unscientific and forceful changes in the natural tidal drainage systems in Indian Sundarbans and recommends some eco-friendly remedial measures to bring back the age-old natural fluvio-geomorphological environment of Indian Sundarbans.

Keywords: Sundarbans, Tides and ebbs, tidal drainage network, mangrove delta, embankment, bank erosion, fluvio-geomorphological environment

Introduction: Sundarbans spreads over India (4200 sq km of Reserved Forest) and Bangladesh (6000 sq km approx. of Reserved Forest) and geospatially extends between 21°30′40′′N-22°03′3′′N latitudes and between 88°04′3′′E-91°14’00”E longitudes. The Total Geographical Area is 9630 km² (including 102 islands) which has been declared as a World Heritage Centre in 1987 by UNESCO, Biosphere Reserve in 1989 and Ramsar Site in 2019. It is the only mangrove in the world where Endangered Flora like Golpata, Kankra, Garan, Keora, Sundari, Passur, Ohundhal are still found and nurture the Endangered Fauna like Estuarine Crocodile, Gharial, Olive back Loggerhead Turtle, Common Batagur, Gangetic soft-shelled Turtle, Water Monitor, Yellow Monitor, Indian Monitor, Python, Olive Ridley (Source: IUCN & SDB). Administratively it covers 13 blocks of South 24 Pargana and 6 blocks of North 24 Pargana districts of West Bengal in India. Drained by major like- Hooghly, Matla, Bidyadhari, Thakuran and Saptamukhi etc., this region has been reclaimed and transformed from wild area to habitable areas by modifying the natural drainage system of the deltaic islands. Defying the natural tidal mechanism, several projects have been taken to rescue the reclaimed island dwellers of Sagar, Namkhana, Pathar Pratima, Kultali, Basanti, Gosaba blocks etc. and their agricultural lands from saline water intrusion during cyclonic storms and cyclones since the British colonial rule in undivided Bengal (Paul, 2002). The maximum temperature reaches to about 42C in summer and minimum of 9.2C in winter seasons and humidity remains about 82%. According to the report of Sundarban Development Board, the Sundarbans may be divided into two zones based on salinity i.e., northern low salinity zone (up to 8 PPT), southern high salinity zone (8 PPT- 20 PPT) having soil types of Ganga alluvium andSalinized alluvium.

Side by side, a report published by the Expert Committee of government of West Bengal in July 2021 stated that the 'Global Mean Sea Level has been rising @ 3.6 mm/year between 2006-2015. The sea level off the coast of Bengal is rising @4.04±0.44 mm/year. The impact of sea level rise in Sundarban is further accelerated due to slow subsidence of land @2.9 mm/year.'...and the 'embankments were built along 3500 km.-long river bank but now the length of effective embankments is not more than 1800 km.' Under these circumstances, this study aimed to incorporate the impact of the ENSO cycle and the effects of meteorological parameters which are changing the behavior of the tidal range in Sundarbans also.

Objectives: The major objectives of this research work are-

a. To search for the importance and hydro-geomorphological influence of tides in configuring the Sunderban Delta.
b. To find out the spatio-temporal changes in tidal behavior since last decades.
c. To give some propositions on the basis of results obtained.

Methodology: For the convenience of discussion, the entire spectrum of methodology has been categorized into (a) Pre-Field Work, (b) Field Work and (c) Post-Field Work.

(a) Pre-field Work: For the appraisal, the present scholar went exhaustively through library materials including previous publications, historical records, maps etc. in the pre-field stage. For the measurement and analysis of fluvial landform features the necessary SOI Topographical Maps bearing No. 79 B/10, 79 B/11, 79 B/12, 79 B/15, 79 B/16, 79 C/9 and 79 C/13 of R.F. 1: 50,000 and the Toposheet of Putney, Khula (1924) of R.F. 1: 2, 50,000 has been consulted in the research work. Administrative delineation of the study area and Bangladesh (through Bangladesh Govt. Portal) has been done. Selection of objectives oriented fluvio-geomorphological environmental properties and land use themes to be stressed during field and post-field works. Determination of hydro-morphological and land use parameters for two ways impact assessment between the fluvial-geomorphological environment and land use in the research area. Consultation of mathematical, statistical techniques to be applied. Framing of rules to conduct both field work and post-field work analysis.

(b) Field Work: Door to door survey has been done to collect the Primary Data of the study area in the Indian side. Questionnaire for perception study has been done accordingly. Detailed field surveys over the entire area have been done to collect the present status of the research area. Careful field investigation has been done incorporating the measurement of the height and depth of the riverbeds, embankments, locational attributes of the settlements, spatio-temporal changes in the courses of tidal rivers, channels, khals (locally found natural or artificial narrow streams), creeks, spatial extension or shrinkage of forested and bils' area, increase or decrease in the back swamps, marshy and swampy areas, identifying waste lands, charas (bars), bheris (local pools or ponds for pisciculture), along with the present land use pattern.

(c) Post-Field Work: To show the valley form and river patterns, large numbers of cross-sections have been done from the top to the mouth of this region. Apart from the field investigations, the land use/land cover data has been consulted from the respective offices and the published sources. Village level land use/land cover maps of different morphological regions has been prepared, based on present Cadastral maps, Census Maps, Revenue Survey Maps of District 24 Parganas, Govt. of West Bengal (1925-26) and NRSC and USGS Satellite imageries of IRS P6 LISS-III of 2019-2016 to show the variations of land use/land cover in relation to changing fluvio-geomorphological environment of the Matla-Bidyadhari interfluve. Different Statistical methodologies like- Mean, Standard Deviation, Frequency distribution, Drainage Frequency etc. have been applied. In the Cartographic methodologies- diagrams, maps have been prepared with the help of Bar-Diagrams, Multiple-Bar Diagrams, Line-Graphs, Pie-Diagrams, Proportionate Pie-Diagrams, Choropleth Maps etc. with the aid of Microsoft Excel and other GIS software like- QGIS and ArcGIS.

Fluvio-geomorphological background of the study area: On the basis of hydrological parameters, the Bengal Delta is divided into (Mukherjee, 1976) –

(a) Moribund Delta- where land building has practically ceased and drainage channels became functionally inoperative. E.g. – Murshidabad and Nadia districts of West Bengal.

(b) Mature Delta- where rivers still have well defined channels and provide some impetus for irrigation and induce drainage disposal under normal conditions. E.g.- mostly the northern part of the 24 Pgs. (S), Calcutta, roughly to the north of a line joining Kakdwip with Canning.

(c) Active Delta- dynamic functions of the hydrological system are more manifest. The channels, creeks are wide, deep and well defined; land building is still in its current phase in which upland flow changes regime with marine incursions. E.g.- southern Basanti, Gosaba etc.

Analysis: The data obtained from the Port Trust of Kolkata (Calcutta) shows the seasonal behavior of the tidal range (Fig. 1-4) is changing year after year. This is not only a matter of concern to the coastal as well as to the tidal riverside (R. Bartala, R, Saptamukhi, R. Thakuran, R. Matla, R. Bidyadhari and other minor interlinking channels like- Hogol Nadi, Karatal Gang, Pathankhali Nadi etc. and creeks) dwellers in Indian Sundarbans but also a disastrous signal to the mangroves also. This uprise tendency of the bore tide range is supposed to impact on traditional land use pattern and practices particularly in Namkhana, Pathar Pratima, Canning, Basanti and Gosaba blocks of South 24 Pargana which lie in the vicinity of the frequent cyclones originating over north Bay of Bengal. It is a well-known fact that the rate of flow of a tide increases smoothly to a maximum halfway between high and low tide before smoothly decreasing to zero again and that the interval between low and high tides is approximately six hours as per the Rule of 12th (Getchell, 1994). So, even in dry winters, the active parts due to being exposed to the annual uprise in tidal range may face intangible and critical drainage systems if the uprising of the tidal range continues in future (Fig. 1).

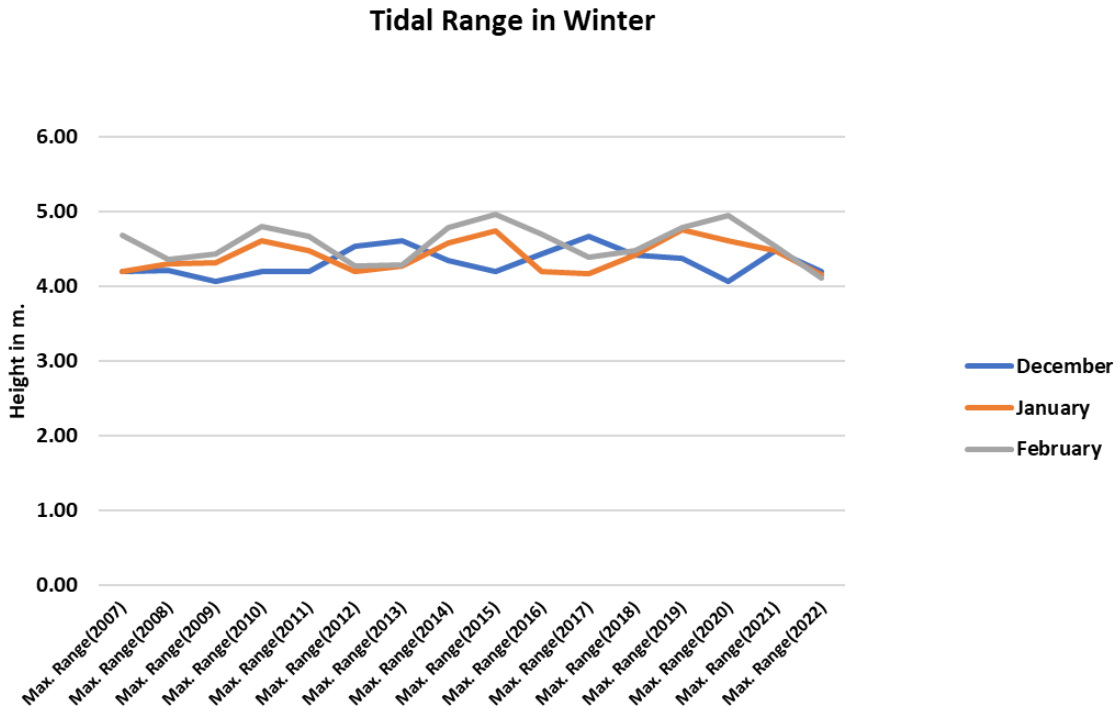

Fig. 1: Changing behavior of Tidal Range during Winter season from 2007-2022 (Source: Port Trust of Kolkata, India)

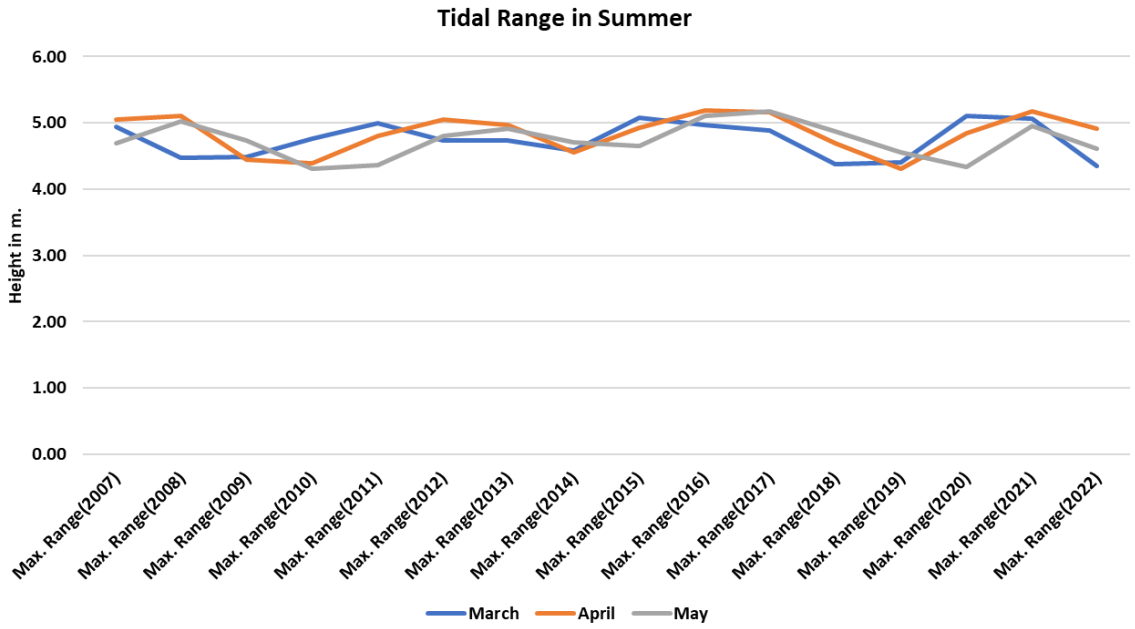

Fig. 2: Changing behavior of Tidal Range during Pre-Monsoon period from 2007-2022 (Source: Port Trust of Kolkata, India)

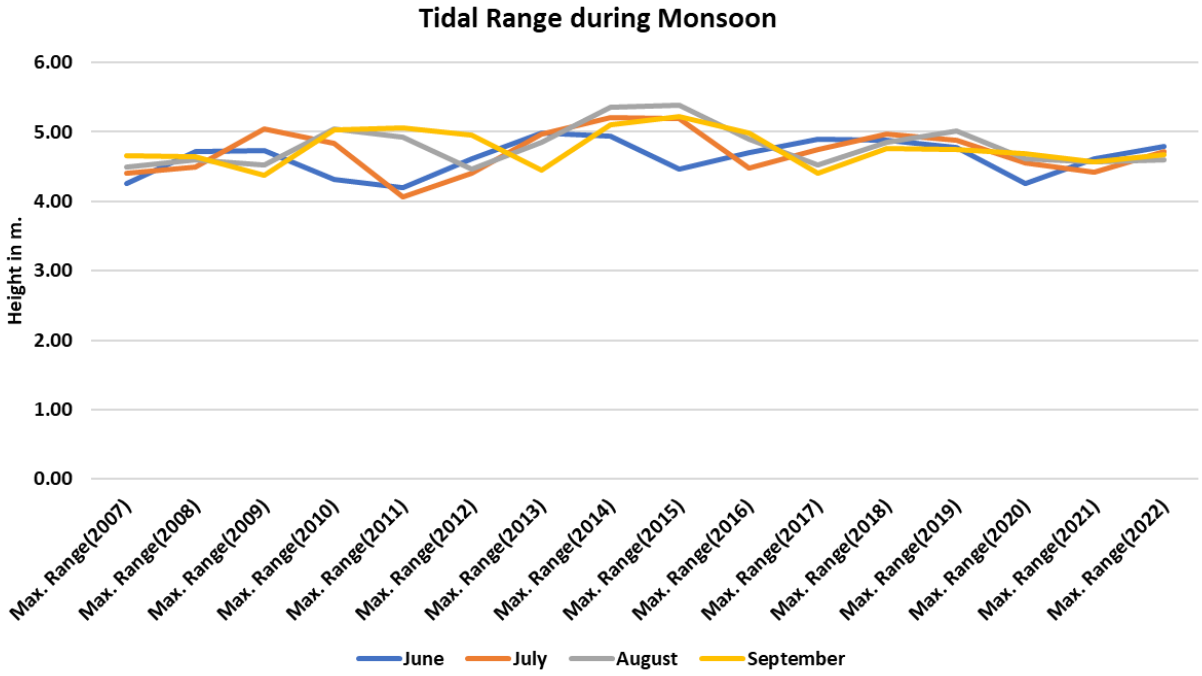

Fig. 3: Changing behavior of Tidal Range during Monsoon period from 2007-2022 (Source: Port Trust of Kolkata, India)

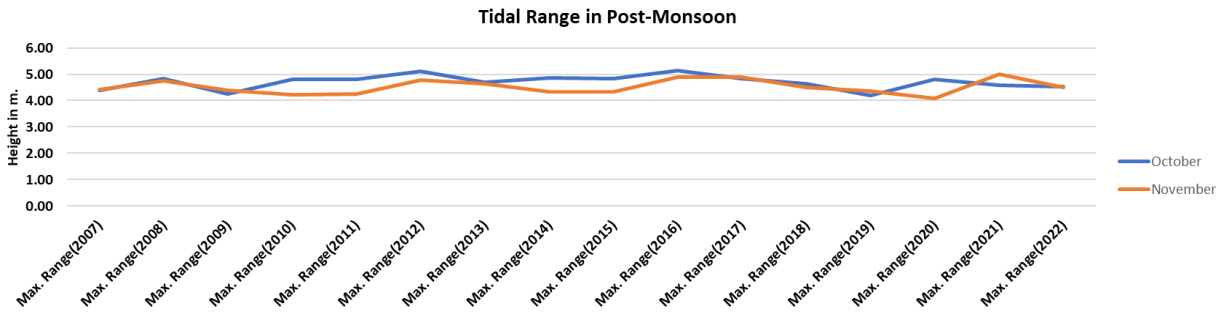

Fig. 4: Changing behavior of Tidal Range in Post-Monsoon period from 2007-2022 (Source: Port Trust of Kolkata, India)

Results: Analyzing the data obtained from NIOT, India at BUOY: BD08 ((17.82°N, 89.24°E), it has been observed that the correlation between Max. Air Temperature (at 1m) and Tidal Range is slightly negative (-0.185). Besides, the correlation between Max. Air Pressure (inhPa) and Tidal Range indicated a moderately strong relationship (+0.634). Slightly positive (+0.228) relationship has been noticed between Min. Air Pressure (in hPa) and Tidal Range. The correlation between Max. Angle of Wind Direction and Tidal Range was moderately negative (-0.405). Slightly positive relation (+0.180) has been noticed between Max. Wind Speed and Tidal Range.

The correlation between Max. Wind Gust and Tidal Range is slightly positive i.e., +0.194. The average tidal range data from the year 2007 to 2022 reveals the fact that the minimum level of tide water range uplifted from 3.83m (pre-Aila in 2009) to 4.27m (post-Aila in 2010). Thus, it has been found that the ENSO cycle controls the cyclonic phenomena over Bay of Bengal and the meteorological parameters play key roles over the bay water surface and have sufficient influence over the tidal range along the coast of Bay of Bengal since 2007-2022.

Conclusion: This study based on the data retrieved from NOAA (2011-2022) and data obtained from Port Trust of Kolkata (2007-2022) along with field verification, clearly finds that the tidal behavior has been changing along the north Bay of Bengal which directly influences the coastal morphology of Indian Sundarbans. Side by side, the insurgence of the cyclonic storms accelerates the tidal flood and breaching of embankments particularly in the active deltaic part. Global warming and changing pattern of ENSO cycle can also be considered as the key factors in increasing the tidal water range in north Bay of Bengal. It is expected that areas having height of 0m-2m above mean sea level like Sagar and onshore parts of Namkhana, Pathar Pratima, Kultali, Basanti and Gosaba blocks are susceptible to severe river bank erosion and will become very much vulnerable to livelihood in Indian Sundarbans.

The existing intricate tidal drainage system have already been silted up enough towards the upstream area, hence, rising of sea level since last few decades and increasing frequency of severe low-pressure systems along the northern margin of Bay of Bengal are widening the downstream parts of the major tidal channels of Indian Sundarbans to accommodate the tidal water influx naturally through bank widening. So, instead of mitigating the issues of bunding the tidal channels and creeks along the shoreline areas, it is suggested to dredge the upstream and interlinking channels and creeks as early as possible to strengthen the river valley capacity to hold the surplus tidal water. More and more mangroves should be planted on both sides of the riverbanks or embankments to increase the accretion of sediment load along the banks. Only increasing the density of mangroves can reduce the magnitude of saline water flooding due to the increasing tidal range. Air Pressure above the north Bay of Bengal also regulates behavior of tidal range as noticed in the study and this type of meteorological research works must be carried on to manage and mitigate tide related issues in Sundarbans and other deltas in Asia as well.

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