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Behavioral Pattern of Coastal Morpho-Dynamics of Talasari Coastal Zone, Odisha

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ABSTRACT:

The coastal zone is the complex of marine and fluvial and aeolian processes and always vulnerable to climate change and unscientific human interferences. The result is that the shape and size of the coastal zone is changed in the form of shifting of shoreline, erosion of dune field and beach area although there are potential opportunities of coastal landscape development. The present work is in the aim of exploring behavioral pattern of morpho-dynamics of the coast and its impact on the coastal zone of Talasari coast, Odisha. The study is also carried out to quantification of morphological changes and detection of responsible factors affecting the morpho-dynamics of the study area. The typical coastal hydrodynamics and frequent landfall of cyclonic storms and anthropogenic activities in and around the study area are the major responsible factors for the changes in the morpho-dynamics. The study was also carried out to predict the pattern of coastal erosion. Both erosion and accretion are noticed along the coastal tract. Temporal study of beach profiles, shorelines, ripple marks and sand dunes shows the morphological changes in the area. Intensive literature review as well as field survey data are used to find out the extent and trend of morphological changes in this fragile coastal ecosystem. Modern techniques and methods like remote sensing and geographical information system are also incorporated to study the changes and to develop a management plan for the coastal landscape.

KEY WORDS: Morpho-dynamics, Morphological changes, ripple mark, beach erosion.

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INTRODUCTION:

Presently the coastal area of Talasari is under a mesotidal range (2-4m) and controlled by estuarine environment. The tidal behavior of the Bay of Bengal, sediment dynamics of Subarnarekha River and geomorphological as well as geological attributes of this region signify the typical morphodynamics of the coastal area. Banerjee M, Sen P. K[2] and Banerjee.P[1]remarked that the coastal landscape of this area is developed within last 6000 years with the fluctuation of sea level rise, which is derived from the existence of older sand dunes. Formation of several parallel sand dunes ridges, Chenier plain, straindplains, mudflat, barrier spit, salt marshes, tidal flats are the result of morpho-dynamics of the area. Human activities, such as agricultural practice, tourism development, construction of ports, and destruction of dunes and mangroves are modified the coastal morpho dynamics of the area. So the coastal zone is under increasing stress due to changing behavior of morphodynamics and human interference. Episodic events, such as cyclones, floods pose serious impact of the behavioral pattern of coastal processes and create threat to coastal erosion in this area. This research work was designed to develop and apply a methodology to characterize the temporal dynamics of coastal landscapes by identifying the driving forces and using indices of change. As the coast has wide beach surface and enrich geodiversity like mangroves, sand dunes, fishes, mohana, deltas, casuarinas etc provide opportunities for the local people and the investor to develop tourism in the area. So the challenges of the coastal landscape of Talasari must be sustainably managed for the future of the society.

REVIEW OF LITERATURE:

Physiographically and culturally coastal areas are very significant for the geographers. Many research works have been done on the coastal landscape and its driving forces. Talasari coastal zone is also very significant area for researcher. The first physiographical account of this area was done by D.Niyogi[21, 22] in 1970s which emphasized on the morphology and evolution of the Balasore shoreline, Orissa. D. Niyogi[21, 22] also explained the geological background of beach erosion at Digha and its surroundings. A. Gupta[18] worked on the nature and evolution of West Bengal Coast. Many works were carried out by Geological Survey of India during 1975 and 2001, but they mainly emphasized the geological formation. Bhatnagar NC[5], Sundara Rajan GV, Raghav Rao KV, Krupanidhi KVJR, Krishna Rao IVR, Ahmad M, Radhakrishna TS, Siddiquie HN, Jha BN, Kripakaran V, Kameswaran N[5] worked on the geology and ground water development potential of Balasore district, Odisha. A.K Mishra[20] et.al interpreted the geological and geomorphological characteristics of Quaternary formations in Subarnarekha basin. Dr. Ashis Kr. Paul[24] worked on the coastal geomorphology and environment since the year 1985. He emphasized on the physiography and environmental events of

the Subarnarekha Delta plain. Prof. G.K. Panda and A.K. Kanungo[23] also studied the spatial variation in the nature of landforms of the northern part of Orissa Coastal Zone, in the year 2007. They emphasized the macro, meso and micro tidal zones and the tidal processes. But they did not emphasize on the morpho-dynamics and its impact on the coast. Before that, Sambasiva Rao, M, Nageshwara Rao, K and Vaidyanathan, R.[28] worked on the Morphology and evolution of Mahanadi and Brahmini-Baitarni deltas. P.K Banerjee, S. Goswami, and S. Chatterjee[4] have worked on genetic re-interpretation of the shore parallel sand ridges of the Balasore-Contai floodplain. R. Varadarjulu and Hari Krishna[27] worked on the wave characteristics of Praradip Port of Orissa which was also helpful for my research work. D. Niyogi[21] also worked on the Quaternary geology of the Coastal Plain in West Bengal and Orissa in the year 1975. S.N. Chatterjee[11] discussed on some aspects of beach erosion and littoral drift at Digha. Dr. A.K. Paul[24] worked on the Chenier beach ridge and Chenier sand ridge formations around Subarnarekha estuary during his research work. L.K. Banerjee and T.A. Rao[3] studied the mangroves of Orissa coast and their ecology. S.C Mishra, R. K. Nayak, B.P. Chowdhury, N.K. Dhal, C.S. Reddy[11,12,13,15,29], et.al also worked on the mangroves of Orissa coastal region but not in the Subarnarekha estuary. A.B. Goswami[13] have studied the salt water encroachment in the coastal aquief at Digha, Midnapore district , West Bengal. A.B. Goswami and P. Ckakraborty[8,16,17] prepared the final report on Quaternary Geology and Geomorphology of the coastal plains of Medinipur district, W.B. and Balasore district, Orissa. But the study was done based on the remote sensing and GIS platform. S. Dey, P. Ghosh, and A. Nayak[14] worked the influence of natural environment upon the evolution of sand dunes in tropical environment along Medinipur coastal area. There are some limitations in these researches such as micro level study like beach profiling, ripple marks their formation, comparison between the behavioral pattern of tidal and wave activities, landscape change of Talasari coastal area are not studied so far. The author is tried to establish the relation between morphodynamics of the coastal area and changing morphology of the area to delineate the future trend of shoreline change. The research work is also emphasized on the man-environment relation in the fluvio-marine landscape of Talasari coast.

OBJECTIVES:

The primary objective of the study is to explain the behavioral pattern of morphodynamics of the coastal environment and its impact on the modifications on the morphology of the area. To justify the primary objective of the study some related works also done on the following heads.

a) To explain the beach morphology of the area measurements of sand dune, beach surface topography are done by field survey.

b) To emphasize the morphodynamics of the area the wave pattern, tidal behavior, sediment dynamics are also studied.

c) To correlate between shoreline position and coastal morphodynamics.

d) Finally the delineation of factors of beach erosion and deposition and point out some suggestions for management.

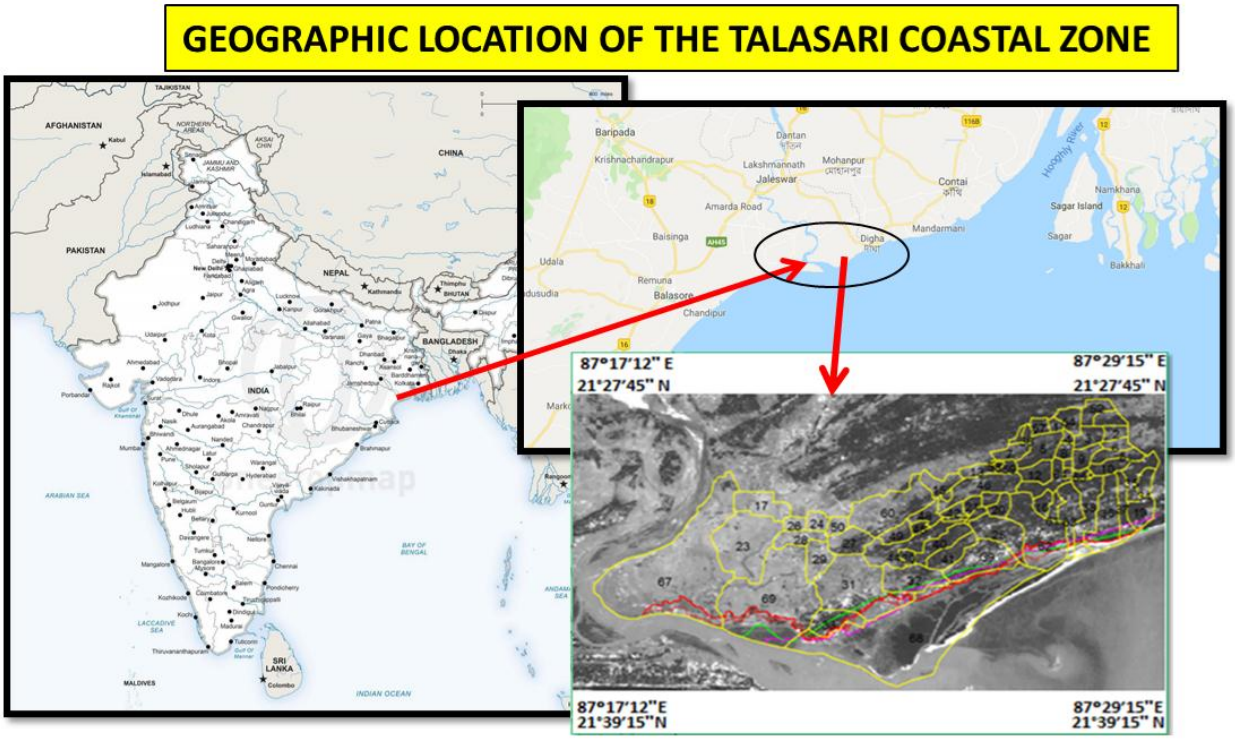

Figure no.1: Location map of the study area

MATHODS AND MATERIALS:

The whole study is divided into three components. The first component is on the study of beach characteristics i.e. beach morphology, beach sediments and beach energetics are the basics of morphodynamics of the area. The second component is on the study of beach dynamics in respect of changes in different scales and response to relative sea level rise. The final component is emphasized on the impact of beach dynamics i.e. beach erosion diagnosis and forecasting. The theoretical aspects encompassing the present and previous conditions of the landscape system were collected from archival materials, different books, journals, and papers, reports prepared by different organization like GSI, CWC, DRDA, SRC, WTCER, National Library, and AUOT. Topographical sheets of SOI, Satellite imageries (IRS 1C, P6 LISS-III of 1998 and 2006) were acquired from NRSA, Hyderabad, and downloaded information from Websites and Google satellite image 2014. Intensive field survey was done and collection of primary data like landforms and land use characteristics, geomorphological evidences, morphology of sand dune, coastal vegetation and socio-economic

aspect related to coastal landscape are observed and studied with the help of instruments. The methods used are both qualititative and quantitative in nature. The study has been based on the method of multi date mapping from toposheets and the temporal satellite imageries with the use of GIS software ERDAS imagine 8.5, and Arc. View – 3.2(a). The toposheets and Satellite imageries are visually and digitally interpreted with the help of Remote sensing and GIS technology.

RESULTS AND DISCUSSION:

Morphological characteristics of the coastal tract:

The Talasari coastal area encompasses a series of parallel sand dunes, developed along the coastal belt due to different processes like supply of sand to the beach plain, aeolian sand transport from beach to the back shore region , interaction between sand transport by the wind and vegetative growth, the low wind velocity, meso to macro tidal ranges and damp sand conditions of the maximum growth of sand dunes. Inland of Talasari lie a series of fossil sand dunes, culminating in modern sand dunes at the existing shoreline. It is clear from this simple morphological evidence that excess sand was available over the past and up to the present and this excess has been stored in the dunes. However the Talasari shoreline is now eroding. The erosion appears to have set in motion in the 1970s since, before that time, local people report a wide accreting beach existed. The dunes are tended towards the ENE & W.S.W direction. Beaches modified their shape regularly with the changes of wave energy at different events in the meso tidal zone along with annual storms occurrences. The beach profiles extend from the landward of wave action at high tide level to the water depths of 12 to 14 m at low tide. Sediment mobility within this dynamic zone and the shallow water transformation of wave energy modifies the beach profiles. Beach features are recorded through the series of survey profiles along the significant sand beaches in the area. There are several beach features across the profiles of dissipating beaches. Beach profiles of Talasari include features like prominent backwash ripple, bars, barriers, rip channels, beach cusps, beach face, berm crest, low tide terrace, rill marks, swash marks, low tide mudflat and salt marsh. The slope of the beach face results from a dynamic equilibrium between the run up or swash of water up the beach face and the return flow or backwash of water down the face, depending upon the beach permeability and grain size distribution of beach sediments. Progradation of beaches and growth of spits with sediment eroded from nearby cliff cut dunes by wave attack and transported alongshore are well observed at Talasari.

On the basis of surveyed data of sand dune the coast can be classified into two , old and new sand dunes, distinguishable by their distinctive physical features grain size and heavy mineral assemblages. They are shaped mainly by the south west and to a lesser extent by the North

West winds. In both the cases sand dunes have a medium diameter of 0.094 to 0.44 mm. South of Nangaleswar (21°36′:87°12′) there are six sets of dunes running in a W.S.W – E.N.E direction continue towards further east (Paul,1985). The cross sectional shape with steeper slope (>30^0) wind ward side and gentler slope (12^0 - 18^0) leeward side signifies a special character of dune ridge which also ranges between 8 -12m in height around the coastal zone (table-1). The profiles of beach dunes reveal that most of the area is covered by unconsolidated sand with little grass covered. Lower reaches of the beach dune is mainly consisted of fine grained mud.

The major bed forms observed in tidal flats are ripples of diverse and complex forms and are mainly governed by the combined influence of variable flow directions controlled by waves and tides during falling tide level (when shear velocities decline), wind stress and recession of water level on various sloping surfaces (Chakraborty). According to Chakraborty there are several forms of sand ripple formation on the beach surface of the area. 'Sinuous' to 'straight-crested' oscillation ripples with 'tuning fork' type of bifurcation are common in the wave dominated coastal tidal flats. Interference ripples having secondary ripples of different patterns characterize all tidal flats. In the near-coast areas there are many forms of interference ripples. The most common form is the 'ladder-back' ripples with the development of secondary current ripples on the stoss side or in the trough regions of early formed ripples which may be current or wind-induced wave ripples. These secondary ripples, in places, override the earlier forms (figure no.2). In tidal channels of wave-dominated coasts a new form of interference patterns, the 'pyramidal ripple' has been noted. Such ripples can also register interference of a third set of ripples from minor flow or rill marks depicting pseudo-ripple. During the monsoon period, particularly when cyclonic storms prevail, the pattern of interference ripples changes. Coastal tidal flats show large crescent-shaped dunes with secondary ripples developed in the lee-sides of earlier bed forms. Cyclonic storms also generate large scour pools in coastal tidal flats in which 'brick pattern ripples' (Matsunaga and Honji 1980[19]) or ripples showing 'crocodile skin' structure can be found.

Burrows of ghost shrimp disturbed the laminae (figure no.4). An average of 8-12cm large size crab burrows are noticed per square meter area and average 70-140 small crab burrows per square meter are also identified. A large number of mud crabs and gastropod species create surface unevenness by producing mounds and trail marks. An overall decrease in burrow density with increase in burrow diameter is detectable towards HT line. Larger crab populations appear to be highly constrained with inundation while smaller burrow makers are not. This conclusion is consistent with a shoreward increase in the dispersion of burrow orientations in larger burrows. The high density of crab burrow affects the stability of beach surface and help to erosion.

Table no. 1: Field observation records of sand dunes.

Sample location	Leeward inclination	Leeward length	Windward inclination	Height
21^0 36.384′N,87^0 27.894′E	15^0	60m	82^0	7m
21^0 36.484′N,87^0 27.534′E	18^0	5m	65^0	1.2m
21^0 36.403′N,87^0 27.952′E	12^0	7m	30^0	0.5m
21^0 36.392′N,87^0 27.925′E	18^0	31m	75^0	2m
21^0 36.435′N,87^0 27.955′E	8^0	3m	46^0	1.8m
21^0 36.403′N,87^0 28.009′E	15^0	29m	80^0	5m
21^0 34.390′N,87^0 22.859′E	17^0	11m	58^0	8m

Source: Field survey, 2012

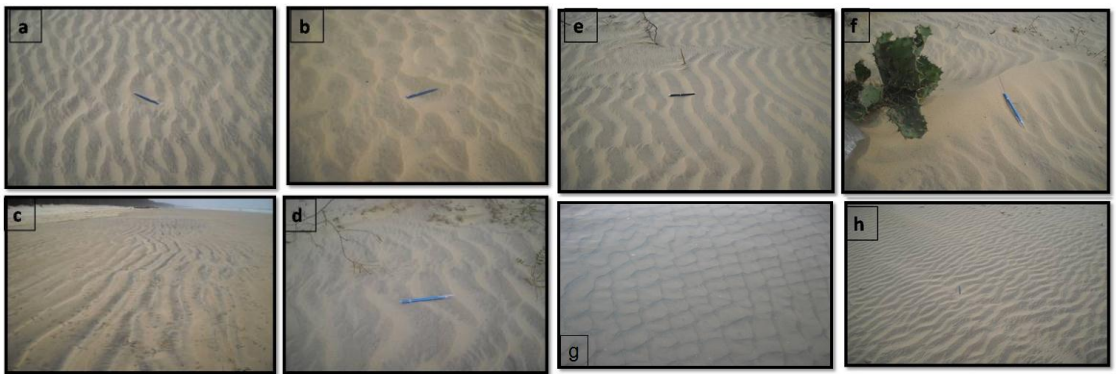

Figure no. 2: Different ripple bed formation on the present day beach surface

a) Asymmetrical ripples with flat topped crest, b) Interference pattern in symmetrical wave ripples, c) Swash marks with straight ripples, d) Symmetrical wave ripples with rounded crest line, e) Symmetrical wave ripples with peaked and continuous crest, f) Small dune with ripple pyramidal formation, g) crocodile skin structure, h) Asymmetrical ripples with sinuous to linguous crest.

Correlation between shoreline position and morpho-dynamics:

In response to coastal morphodynamics of the area, shoreline is in dynamic in nature. The temporal shorelines of the area reveal that the entire coastal tract is under erosion and deposition paradigms. The present scenario indicates that the extent of coastal erosion has increased manifold in the recent past, along with acceleration of the rate of erosion. Present analysis shows that along the Talasari Coast there are 3 segments with different coastal dynamics (Figure no.3). These are:

1. Accretional regime of Northern part of Talasari Coast. However, the rate of accretion has been reduced from maximum 50meters/year (up to 1998) to 12.5meters/year during 1998-2014.

2. Erosional regime of Udaypur and Talasari area where the rate of erosion has marginally increased. Near the mouth of Subarnarekha river there is also erosional regime.
3. Stable protected region of Talasari to northern part of Subarnapur.

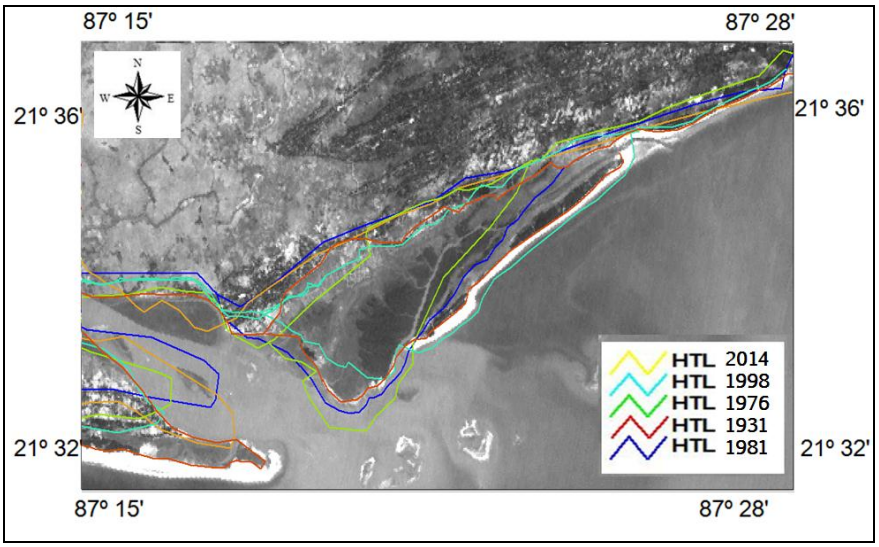

Figure no. 3: Status of shoreline position

Factors of beach erosion:

Tidal behaviour of the area is the main responsible factor for beach erosion. Average tide height varied from 2mts to 4.5mts, with an upward rising trend conspicuous in the months of June to September which coincides with the S.W monsoon season. In some years fluctuations from the normal height is though noticeable due to occurrence of cyclones. The moderate to high tidal amplitude creates tidal currents which act as an effective means for reworking the tidal and estuarine sediments. Wave climate is moderate excepting periods of cyclonic storms when the wave height may reach up to 7m. These waves when strike on the base of the dunes causes over steepening of the seaward dune faces and leads to avalanching of sand from dunes top. Sometimes erosion in the base of the dune field leads to rotational downfall of sands from upper segment of large dunes accelerates the rate of beach erosion (figure no.4). Dune erosion leads to landward retreat of the beach, lowering of beach profile and loss of dune vegetation. Many of the planted large caesarian trees are uprooted by gradual progress of erosion. Internal structures of the dunes, along with various cross-bedded units, exhibit on exposed face intercalated mud layers (5-15cm thick) for significant distances indicating episodes of inundation of the dunes at times of catastrophic floods. Oblique wave approach (angle less than 5^{o}) and long shore drift also responsible for erosion in the area. Rip currents and alongshore currents transport sand at mutually right angle directions. There are seasonal reversals of NE winter to SW summer winds which play a significant role for transporting the dry

sand of the sub aerial beach causing mobilization and remobilizing of dunes and in spilling sand from the dunes to the intertidal zone (Bhattacharya and Sarkar, 1996).

Figure no.4: A) Rotational downfall of dune slope. B) Sediment deposited in the mangrove swamp. C & F) Bioturbation structure eroded the dunes D) Red crab doing burrows on the beach surface. E) Dune erosion due to wave action.

According to Coastal Sediment Cells report that during the 20th century extensive reclamation of intertidal areas took place in the area to provide new agriculture areas which also reduce the dune areas. Building embankments to exclude tidal water reduce the volume of the tide that flows into and out of the Subarnarekha estuary and this means that the current speeds have been reduced so that sand can no longer be flushed out of the mouth of the estuary in to the coast zone instead, the sand has built up around the mouth of the Subarnarekha forming a on chain of barrier islands. The result has been that northern part has been paucity of sand. But the waves arriving at this shore have not changed. They continue to transport over a million tonnes per year towards the east. Since this amount of sand is not available from the Subarnarekha the waves erode it from the shore causing the rapid erosion now experienced in this area. Constructions of several barrages over the river Subarnararekha have considerably reduced the water discharge and availability of sand and silt supply at the estuary. Low amount of sediment load increases its entrainment capacity and erosion potentiality. So erosion takes place.

Tourism development also poses threat to the coastal landscape of Talasari. Though tourist flow in this coastal part is relatively lower than Digha but is responsible for reducing resistance of dunes and beaches by cutting trees and sand mining in the area which leads to beach erosion.

Lack of mangrove forest on the Talasari beach also help to erode the beaches and dunes by tidal and wave action. During storm surge erosion is in increasing trend due to free hitting.

The relative mean sea level, computed from the tide data of Digha area, supplied by the Department of Irrigation, Govt. of West Bengal shows a definitely rising trend over the last 20 years The rate of relative sea level rise is found to be over 3milimeters/year and this may have some contribution on the coastal erosion over a longer time span. As the relative sea level is rising in trend it leads to accelerate erosion in the area.

Factors responsible for accretion:

The onshore drift in winter is causing seasonal accretion. The ratio of long shore drift and cross-shore drift is in the order of 10^3, which indicates that the coast is dominated by long shore drift. Waves approaching a beach obliquely and the long-shore drift of beach sand in the Wave swash zone.

The Subarnarekha River is also carried sediment to the area. When seawater completely loaded with sediments, it starts to accumulate the coarser fractions on the shore face, resulting in accretion. Sand dunes which are eroded by wave action are also the source of sediments in the accretional zones.

SUGGESTIONS AND CONCLUSION:

From the above discussions it is revealed that the coastal morphodynamics of Talasari area is the complex work of marine, fluvial and aeolian processes. Mainly the beach morphology is comprised of new and older sand dunes. The beach surface topography was controlled by tidal and wave action and developed typical ripple marks which are further developed in to dunes. The main source of sediments in the area is supplied by Subarnarekha River. Beach erosion is also the other source of sediments in the middle part of the beach. It is revealed that till 1970s the beach was mainly in accretional mode but sediment input has decreased so drastically as to cause erosion in the northern portion. A number of suggestions may be drawn from the study that will influence the shoreline management planning.

a) Dunes fields should be covered by afforesting ipomoea biloba species to restrict sheet erosion of the dunes by wind and waves. Fencing with Jhau ballas and sand bags may be initiated in the seaward side of the toe of the dune field to arrest offshore sand movement and facilitate sand accumulation during winter.
b) No further reclamation should be taken place in the Subarnarekha basin. Any further reclamation within the Subarnarekha this will exervate the erosion.

c) No more development of the agriculture or aquaculture in the Subarnarekha estuary should take place.

d) No other barrages would be constructed in the upper catchment of Subarnarekha. If made it would reduce the sediment supply in the area which will increase the erosion rate in the area.

e) Protection against high tide and coupled storm surges should be done. Groins can be made across the shore at the mouth ward region of Subarnarekha in order to arrest the sediment and restrict further erosion.

f) Avoidance of areas to be eroded by long shore drift and relative sea level rise.

g) Beach should be nourished in order to sustain its current level of sand volume and elevation, and in order to keep attracting visitors.

So it can be concluded that the study of behavioral pattern of morphodynamics of the coastal zone is necessary for the assessment of geodiversity and sustainable management of coastal landscape as natural processes as well as human interferences are root causes of modifications in the coastal area.

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