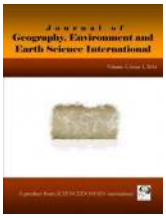

Journal of Geography, Environment and Earth Science International

11(3): 1-8, 2017; Article no.JGEESI.35657
ISSN: 2454-7352

Assessment on Physical and Anthropogenic Activities and Its Impact on Coastal Sand Dunes, West Bengal

Subhankar Patra[1*] and Jitendra Shukla[1]

[1]Department of Geography, Ranchi University, Ranchi, Jharkhand, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author SP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SP managed the analyzed of the study. Author JS managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2017/35657
Editor(s):
(1) Pere Serra Ruiz, Department of Geography, Universitat Autònoma de Barcelona, Spain.
Reviewers:
(1) Suheyla Yerel Kandemir, Bilecik Seyh Edebali University, Turkey.
(2) Kadiri Umar Afegbua, Centre for Geodesy and Geodynamics, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/20521

Original Research Article

Received 24th July 2017
Accepted 9th August 2017
Published 16th August 2017

ABSTRACT

Sand dunes are topographical height in the low-lying coastal plain of west Bengal. They protect wave attack in the low-lying areas, shelter land ward communities and assist in the retention of fresh water tables against salt water intrusion. Sand dunes are developed along the coast belt with three basic processes: Supply of sand to the beach plain, aeolian sand transport from the beach to the backshore region, and interaction between sand transport by the wind and vegetative growth or distribution. It is useful to regard a dune like a savings account of a bank. At present, of the entire coastal ecosystem, sand dunes have suffered greatest degree of human processes. Many dune systems have been irreversible altered through the activities of man, both by accident and design. Ecosystem components of the sand dunes are affected by the intensive use of dunes in the coast. Artificial structures like houses; hotels, fishery etc are disturbing the normal growth of the dunes. Removal of sands by road cutting, grazing the dune in Shankarpur, Mandarmoni areas. The level of grazing pressure is instrumental in determining species composition. Dune plants are destroyed by growth of urbanisation, agriculture and costal defence programme. We observed and measuring the rate of coastal erosion, it has been remarkable increasing in last decade. The dunes are totally

**Corresponding author: E-mail: subhankar.sbm123@gmail.com;*

destroyed by increasing wave action at many places. Accelerated dune erosion by the cyclonic storm, tidal bore and wave action. It has been observed that the front dunes are eroded and also shifted landward at the rate of 6 m to 12 m/year of this area. Certain conservation measures have been recommended including mechanism of dune maintenance by artificial simulation, dune creation and control of coastal water pollution from hotel sewage and fisheries waste water.

Keywords: Coastal dunes; coastal erosion; shifting of sand dunes; conservation measures.

1. INTRODUCTION

Coastal zone is the area of interaction between land and sea. It includes both terrestrial as well as marine resources, which may be renewable as well as non-renewable. In addition, interactions between various natural processes and human activities are important factors in the coastal area. Digha-Junput coastal tract over which this study has concentrated is a part of Kanthi coastal plain of Purba Medinipur, West Bengal (Fig. 1). The extents of the study area is between Latitude-21°36′50 ″ N to 21°43′00″N and Longitude-87°29 ′40″ E to 87°49′ 30″ E. The length from Digha to Junput coastal tract is 45 km and it has 4 blocks are Ramnagar-I, Ramnagar-II, Contai-I, Contai-II. The elevation of the coast in the southernmost region is <3m above the sea level [1]. The beach material is generally siliciclastic, quartzo-feldspathic in composition with well sorted, medium to fine sand [2]. The estuarine mud in many places, mixing with the beach sand creates mixed flats. A major portion of the mud is carried to the offshore that constantly keeps the coastal water turbid. The Digha beach, about 8 km long on the west of this coastal stretch, is dominated by sedimentation from the Subarnarekha river, whereas, the eastern-most 6 km long Junput beach gets its major silt contribution from the Hugli estuary [3]. It is ubiquitous that the modern estuary-related beaches have a range of textural gradients and morphologies controlled by fluvial, tidal and wave regime [4,5]. High discharge from the rivers, particularly during the monsoon months in this tropical coast results in deposition near the mouth of the rivers with significant subaqueous growth compared to that of its subaerial counterpart [6,7]. Depending on the present state of erosion-accretion, the entire Digha-Junput stretch is divisible into two parts having contrasting characteristics: (i) Digha to western portion of the Dadanpatrabar sector chiefly under erosional regime and (ii) eastern portion of Dadanpatrabar to Junput sector belonging chiefly to accretional regime [8].

The geological history of the coast is relatively short and the coast is still in its formative state. Its present day manifestation is the result of fluvio-tidal and coastal processes resulting from the on lapping sequence of Flandrian transgression, > 5900 yrs B.P. and off lapping sequence of delta progradation till the stabilization of the sea level at around 3000 yrs B.P. [9,10,8]. In the present research, we have tried to observe the changes of sand dunes in the physical and anthropogenic activities dimensions of this coastal ecosystem over a period of 4-6 years. For this purpose we have selected some physical components such as i) temperature regime, ii) occurrence of high intensity climatic events like cyclones, iii) shoreline change and iv) sea level change. Simultaneously, anthropogenic aspects like construction of sea wall and embankments, pollution of coastal waters, mining and transportation of beach sand, braking, flattening of coastal dunes have been studied to understand the vulnerability of the dunes ecosystem with respect to possible climate change and growth of anthropogenic activities.

This present paper focuses on the magnitude of dune erosion in the western 30 km stretch of the beach from Digha to west of Dadanpatrabar under the influence of both natural and manmade activities and has suggested some measures for its restoration and protection.

2. MATERIALS AND METHODOLOGY

2.1 Data Use

Data used for this study are –

1. Satellite imageries (LANDSET – MSS, LANDSET – TM, LANDSET-ETM+, IRS – LISS III).
2. Local sea gauge data and cyclonic data.
3. Last 10 years coastal erosion data of the study area.
4. Field observation and socio economic data

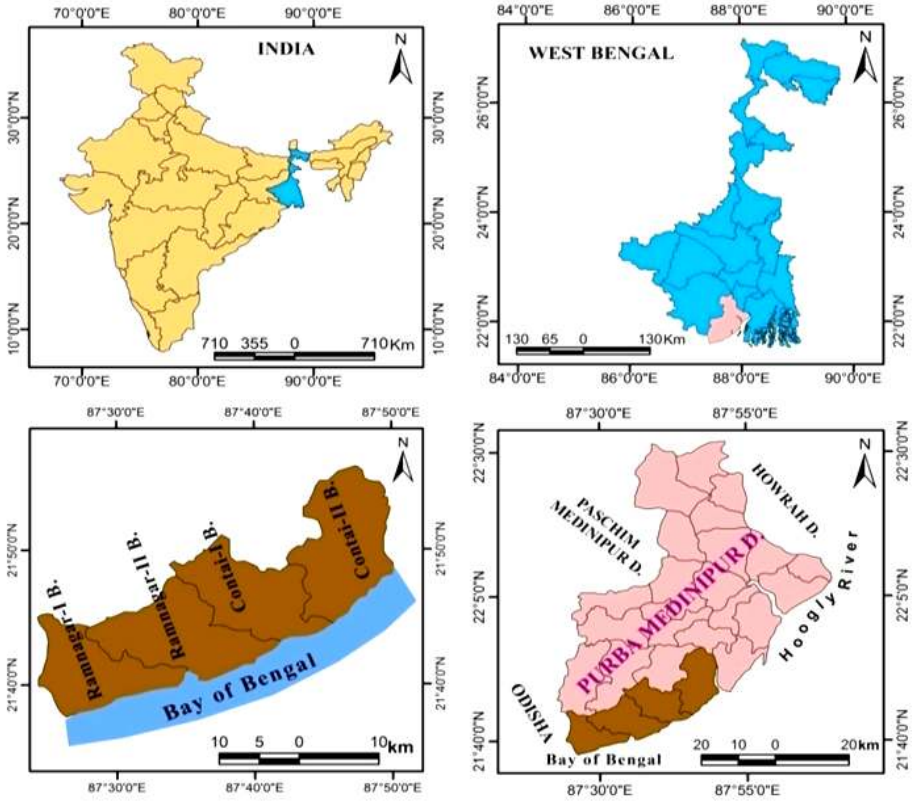

Fig. 1. Location map of the study area

2.2 Methodology

Intensive visits to the study area, extensive literature survey and experimental documentary analysis are three key measures to prepare this paper and for conducting this study. Reports of Geological Survey of India, Survey of India, Department of Tourism-Govt. of West Bengal, Department of Environment-Govt. of West Bengal, Digha Development Authority, Institute of Wetland Management and Ecological Design, Ministry of Forestry and Environment, etc. and recent research papers published in different regional, national and international journals and presented in different seminars, programmes, etc. are very essential and helping tools to complete this study. Basic cartographic materials like Geological and Geomorphological Maps (1:50000) of GSOI (1995), Toposheet-73 O/6, 73 O/10, 73 O/14(1931- '32 & 1968-'69) of SOI and IRS IC LISS-III, 2000 (23.5m), IRS P6 LISS-III, 2005(23.5M), IRS-IC, WSS-3, Geocoded FCC 73O6, 73O10 and 73O14 (1:50000) of NRSA (1997), have been used. Besides these, different cartographic and GIS techniques have been applied as necessary as.

Through field data generation and literature survey the author has attributed that this coastal tract is eroded due to many natural and anthropogenic causes – mainly high wind speed, high wave action, cyclone and unplanned construction etc.

3. RESULTS AND DISCUSSION

3.1 Dune Morphology

This area of the Bay of Bengal coast exhibits a natural museum of various dune morphology [11]. Coastal sand dunes are sedimentary deposits formed by the transport of sediment inland from the beach by wind action. Generally most of the sediment transported landward from the backshore is trapped initially by vegetation colonising the area just landward from the limit of storm wave action, leading to the development of a foredune ridge complex parallel to the shoreline. On some beaches like Junput, Dadanpatrabar their limited sediment availability or low frequency of strong onshore winds, only a single foredune complex will develop. However, in other areas like Dgha, Shankarpur,

Mandarmoni where there is an abundant supply of sediment and sufficiently strong onshore winds, extensive dune fields may develop, either through inland migration of parabolic or long-walled transverse dunes, or through shoreline pro-gradation and the formation of a succession of foredune ridges (Table 1).

3.2 Natural Forcings: Their Effects on Dune Devastation

3.2.1 Tides, waves, rip currents and longshore currents

The coastal stretch belongs to a mesotidal (tidal amplitude 2-4 m) regime with semidiurnal tides with slight diurnal inequality. The impact of macrotidal (tidal amplitude >4 m). Hugli estuary is more pronounced towards the eastern part of the study area. The moderate to high tidal amplitude creates tidal currents which act as an effective means for reworking the tidal and estuarine sediments. The wave energy is a function of the wave heights and the wave periods. It is observed that, the wave breaker type is collapsing in this area. High waves created by high velocity of wind force, due to numerous cyclones. During the storm events the raised water level and high energy wave environment or extreme events affected the upper shore. Wave climate is moderate excepting periods of cyclonic storms when the wave height may reach up to 9 m. These waves when attack the base of the dunes cause over steepening of the seaward dune face [3]. This leads to avalanching of sand from dune tops. Dune erosion leads to landward retreat of the beach, lowering of beach profile and loss of dune vegetation. Many of the planted large casurina 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 6-16cm thick (Fig. 2) for significant distances indicating episodes of inundation of the dunes at times of catastrophic floods.

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 [12].

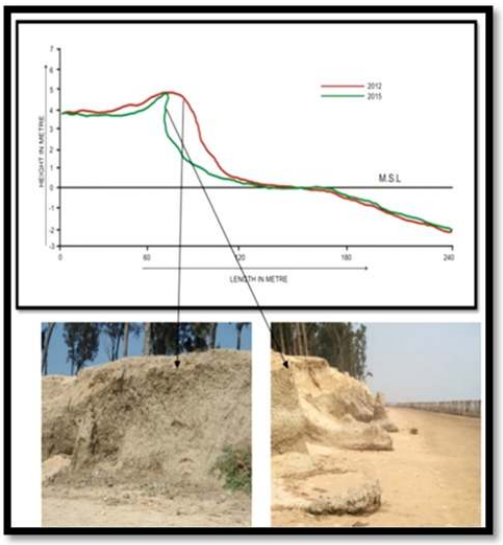

Fig. 2. Reduced dune height and exposed mud layer

3.2.2 Cyclonic storms

Frequency of storms and depressions having direct bearing upon the distribution of rainfall in Digha and the adjoining coastal areas have been studied for the period of 80 years (1891-1970). The severe cyclonic storms over Bay of Bengal registered 26% increase over the last 120 years, intensifying in post monsoon [13]. During the last part of decade (2006-2009) the northern part of Bay of Bengal registered more cyclones *viz. Sidr, Nargis, Bijli, Aila, Filin and Hud-Hud*. From the analysis of cyclone and surge data of the Bay of Bengal, a rise in the high intensity events like severe cyclonic storms has been observed and consequent damage and flooding can be inferred**.** This phenomenon has to be analyzed and explained further to see whether an increase in sea surface temperature is linked to the increase in cyclone intensity over the Bay of Bengal. Coastal sand dunes are highly influenced by wave attack at the storm tide level in the region. Physiographic changes of foredune include: dune flattening, washover dune beaches, dune crest recession, dune erosion on the sea faces, cliff formation and complete removal or elimination of dune bodies (Fig. 3). Totally unstable dunes may engulf inland areas and encourage coastal recession [14]. The height of the cliff is about 5 m in this area (Table 2).

Table 1. Morphological dune parameters of the Kanthi coastal belt

Parametres	Station of observation			
	Gangadharpur	Shankarpur	Dadanpatrabar	Junput
Height(m)	10.0	13.0	2-6	3-5
Slope	42°	45°-60°	13°	18°-24°
Landforms	Aeolian ripple, Vegetated land	Undulating Topography, Vegetated land, Tidal inlet	Undulating Topography	Dune field with vegetations
Vegetation	Casuarina, Pandanus	Casuarina, Pandanus, Lantena camera	Ipomoea, Lantena camera	Ipomoea, Lantena camera, Casuarina,
Sediment type	Fine Sand	Fine to coarse Sand	Fine to medium Sand	Fine to medium Sand
Dune face	Stable on sea side but shifting on leeward side	Erosional on sea side	Stable on both side	Stable on both side

Source: Dey, S and field investigation (2012 - 2016)

Table 2. Devastation of Dune barrier of Kanthi coastal plain

Location of Dune belt	Initial height	Alternation types after storm damage
Gangadharpur	5-10m	Rapid erosion, Severe scarping, Reduction height, Dune retreat
Samybasan	3-5m	Dune retreat, Elimination segmentation, Rapid erosion
Shankarpur	3-8m	Rapid erosion, Severe scarping
Chandpur	2-3m	Rapid erosion, Severe scarping
Dadanpatrabar	6-10m	Dune retreat, Elimination of dune bodies.

Source: Field investigation (2012 - 2016)

3.2.3 Wind velocity and direction

The Landward and Seaward movements of dunes are due to high wind speed of pre-monsoon season. It has been observed that the front dune of this area also shifted Landward at the rate of 6 m to 12m/year (Fig. 4). Erosion by overwash might have been dominant between Shankarpur to Chandpur coastal tract, because deposition was made by the landward movement of eroded sand from the dunes.

Fig. 3. Accelerated elimination of dune bodies

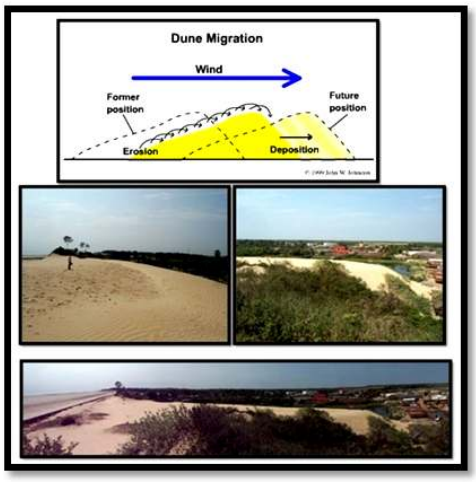

Fig. 4. Shifting of sand dunes due to high wind speed

3.2.4 Relative sea level

The relative mean sea level computed from the tide data of Digha- Shankarpur, supplied by the Department of Irrigation, Government of West Bengal while formulating the Integrated Coastal

Zone Management Plan (unpublished) for the area, shows a definitely rising trend over the last 20 years. The rate of relative sea level rise is found to be over 3 mm/year and this makes some contribution to the coastal erosion over a longer time span [15]. Considering the present rate of temperature rise, thermal expansion of sea water and higher rainfall there is a strong probability that the sea level rise will be 50 cm by 2050. This implies toe scour and associated crestal slumps of frontal dunes, removal of dune barrier by shoreline recession, reduction of dune height (Fig. 5) by wind and high wave action, cliffing at the seaward side of dune barrier and flattening of dune field by northward marching are important morphological changes of beach and dune topography of Kanthi coastal plain at present.

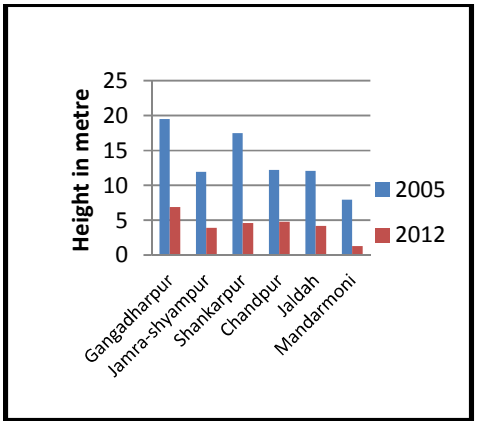

Fig. 5. Reduced dune heights from 2005 & 2012

3.3 Anthropogenic Activities and Their Impact on Dune Bodies

3.3.1 Construction of sea wall and embankments

A 4 km long boulder embankment and concrete seawall had been constructed by the State Government to protect the sea resort of Digha at a total cost of Rs. 50.5 million rupees (1US $ = Rs. 47.00 approx.) during the last one-decade. But this measure did not prove to be yielding any effective benefit against erosion of the coast.

Partial construction of seawall in the Digha sea resort area imparts a negative impact on the adjoining coastal areas (Fig. 6). It is observed for the last few years that dunes of the Digha sea beach are fast retreating landward where the seawall has terminated against the unprotected dunes. Measurements show that after the construction of seawall, the rate of retreat of the dunes is as high as 16 m to 18 m per year that was only 11 m per year in 1980s before the construction.

Fig. 6. Construction of sea dyke and eroded the dune bodies

The bulk of embankment boulders are laterites together with a smaller proportion of charnockites and amphibolites. Although the porous lateritic boulders have high power of wave energy dissipation, their sizes are small compared to the impacted wave energy. As a result, the boulders are easily displaced and broken down to small fragments and finally affect the beach sand budget. These boulders also act as hard substrates for profuse settlement of barnacles and oysters and endanger recreational activities on the beach.

3.3.2 Pollution of coastal waters

The tourist resort with respect to major pollution source is the Digha region and to a minor degree the Mandarmoni area. There are about 400 hotels, holiday homes, some eating joints and sweetmeat shops in Digha. Other tourist areas within the Shankarpur, Tajpur, Junput area etc. Though there is no inventory available, the wastes generated from these resources are also directly discharged into the coastal sand dunes waters. Water sample analysis from coastal sea of Digha, Shankarpur area clearly shows considerable amount of biological pollution especially near New Digha and Digha beach. The coliform counts are also significantly high especially in the New Digha and Digha.

3.3.3 Mining and transportation of beach sand

Mining and transportation of beach sand particularly, from the sea beaches, dune barrier

areas is a common practice in Digha, Mandarmoni and Dadanpatrabar areas of the coast. This is done mainly for construction purposes as well as for making dykes in the inland areas. This operation of beach sand transportation endangers the intertidal to supratidal sediment budget of the beach and often provokes erosion in and around the mining places that had been in stable equilibrium for a long time in the past.

3.3.4 Braking, flattening of coastal dunes

The State Government to conserve the neodune fields by plantation and with bamboo and wire fencing, human interference in these areas often destroy the whole arrangement. Sand dunes are ideal places for building hotels simply because they offer an open sea view in addition to their better basement stability in the high land areas. So the tops of dunes are generally flattened for building hotels at old Digha and new Digha even the State Government had built a hotel at Digha barely 250 m from the beach front in utter violation of the Act [3]. All these constructions are against the principle of dune-sea dynamics. In other cases, dunes are often breached for easy access to the beach for bathing and recreation. There are cases of such breaching of dunes at Digha, Digha Mohana, Sankarpur and Dadanpatrabar beaches. So the Manmade infrastructure in the coastal region like harbour, road, sand mining, waste disposal site, tourism centre, industrialization, beach resort, fish landing station, demand of fire wood etc. and allied pollution are destroying the sand dune.

3.3.5 Impact tourism type

Though West Bengal has a wide coastline overlooking the Bay of Bengal, The fragmented topographical characteristics followed by inadequate primary infrastructure have been among the deterrents of tourism development in the area. Digha and Shankarpur is the famous picnic spot of West Bengal. Picnicking under the shades of casuarinas trees on the dune surface, walking and bird watching on the sand dunes, bathing in the beaches covered by sea water, car driving and horse riding on the beaches are the major features of recreational exploitation of the coast along this seaside tourist place [16]. Many multi storied hotels have come up within a short distance at the sea wall especially old Digha. Now few hotels are developed on Digha to Mandarmoni coastline (Fig. 7). In result the exploitation of coastal sand dunes, coastal ecosystem and vegetation by many human interventions. The indiscriminate installation of heavy tube wells in to the dune bank has led to the collapse of sub-soil layers and the resultant seepage of saline water into the drinking water.

Fig. 7. Accelerated growths of tourist hotels of Mandarmoni after 2003

4. CONCLUSION

From this analytical study, it has been observed that the entire terrain extending between Shankarpur-Mandarmoni and Dadanpatrabar is under the threat of rapid dunes erosion. Storm, tidal waves, flood, sea level rise conditions etc. play jointly as natural causes of the removal of dune barrier, reduction of dune height and flattening of dune field etc. In addition to the natural factors, the anthropogenic factors have contributed much to the situation. Human intervention like harbour, road, sand mining, tourism centre, industrialization, beach resort and fish landing station particularly over the last four decades has also been very significant for the change in coastal environment.

The authors have certain recommendations in favour of protection and conservation strategies:

1. In dune building or reconstruction, sand fences and mesh matting in combination with vegetation planting have successfully regenerated dunes via sediment entrapment and vegetation colonization.

2. Beach and dune grasses baffle winds thus causing sand deposition and creating higher, wider and laterally continuous dunes.
3. Artificial dunes may be created where there is no natural dune or where long stretches of dunes are breached. But the imported dune materials must corroborate to the texture and composition of the adjoining beach material.
4. Construction of semi-permeable fences along the seaward face of dunes will encourage the deposition of windblown sand, reduce trampling and protect existing or transplanted vegetation.
5. A mass awareness programme with a slogan to save the coast is advocated as a measure of conservation strategy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Umitsu M. Late Quaternary sedimentary environments and landforms in the Ganges Delta. Sedimentary Geology, 83, Elsevier science publ. B.V. Amsterdam. 1993;177-186.
2. Friedman GM, Sanders JE. Principles of sedimentology. John Wiley, New York. 1978;792.
3. Bhattacharya AK, Sarkar SK, Bhattacharya A. An assessment of costal modification in the low-lying coast of North East India and Role of Natural and artificial forcings. International Conference on Estuaries and Coasts; 2003.
4. Wright LD, Coleman JM. Variations in morphology of major deltas as function of ocean waves and River discharge regions. Bull. AAPG57. 1973;370-398.
5. Kuehl SA, Moore WS, Levy M, Allison MA. Subaqueous delta of the Ganges-Brahmaputra river system. Marine Geology, Elsevier. 1997;144:81-96.
6. King CAM. Beaches and coasts. Edward Arnold Ltd., London. 1961;403.
7. Wright LD, Nittrouer CA. Dispersal of river sediments in coastal seas. Six contrasting cases. Estuaries. 1995;18:498-508.
8. Chakraborty P. Process-response system analysis in the macrotidal estuarine and mesotidal coastal plain of eastern India. Mem. Geol. Surv. India. 1990;22:165-187.
9. Leeder MR. Sedimentary process and product. George Allen and Unwin, London. 1982;344.
10. Bearman G. Waves, tides and shallow-water processes. Pergamon Press (in association with the Open University), Watton Hall, England. 1989;187.
11. Paul A. Morphoecological dynamics of the coastal tract of West Bengal. Ph.D. Thesis in Geography. Univ. of Calcutta. 1988; 218.
12. Bhattacharya A, Sarkar SK. (Study on salt-marsh and associated meso-tidal beach facies variation from the coastal zone of eastern India. Proc. of the International Conference on Ocean Engineering COE '96 IIT Madras, India. Dec.1996, Allied Pub. Ltd., Chennai. 1996;475-479.
13. Singh OP. Long-term trends in the frequency of severe cyclones of Bay of Bengal: Observations and simulations. Mausam. 2007;58(1):59-66.
14. Carter RW. Coastal conservation. In coastal zone planning and management. Thomas Telford, London. 1992;21 – 36.
15. Hazra S, Ghosh T, Dasgupta R, Sen G. Sea level and associated changes in the Sundarban. J. Science and Culture. (Special Issue on Climate Change in India, Ed. Dr. A.P. Mitra.). 2002;68(9-12):309-321.
16. Chakraborty SK. Coastal environment of Midnapore (East), West Bengal – Potential, threats and management. Journal of Coastal Environment. 2010; 1(1):27-40.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20521