THE INFLUENCES OF NATURAL ENVIRONMENT UPON THE EVOLUTION OF SAND DUNES IN TROPICAL ENVIRONMENT ALONG MEDINIPUR COASTAL AREA, INDIA

by

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ABSTRACT

This paper assesses development of coastal sand dunes particularly along tropical coast. In-depth study along on coastal dune morphology along Medinipur coastal tract shows that sea levels remained very dynamic during the Holocene period. Evidence of Holocene sea level changes are found which were responsible for the origin almost parallel distinct dune colonies through the geological past along this coastal tract. The existence of tropical-monsoon climate with its seasonal phenomena plays an important role for long-term geomorphic development along the coast. The vegetation enhances the barrier property of dunes as well. In this paper possible biological interactions between sand mass of dunes and vegetation in different stages of development has also been dealt.

Key words: Coastal dunes, sea level change, vegetation, seasonal change, Medinipur coastal tract.

INTRODUCTION

Medinipur coastal tract is a part of West Bengal coastal area of India, having a length of about 20 km from Orissa border in the west to the eastern end of Farquhar sector in the east within 21°30’ N latitude to 21°44’N latitude and 87°25’E to 87°45’E longitude (Fig-1). Geologically this is the coastal stretch of Indo-Gangetic plain. The present geomorphic divisions like the beach, active dunes, modifilts etc of the present study area has developed within last 6000 years (Paul, 2002, p-78) with the last sea level fall after Holocene climatic optimum through sand deposit by Subarnarekha river (Bandyopadhyay “2000, P-17). Several scientific studies show that the sea levels along the Bay of Bengal coast remained very dynamic in nature throughout geological times. Early works by Umittsu (1987, P-164-178), Chatterjee (1972, Pp-1-15), Merh (1987, Pp-225-221) etc. show that the Holocene period was
marked by several phase of sea transgressions each followed by regressions. According to the recents, a sharp rise of sea level along the Bay of Bengal Coast occurred around 6000 years BP (Islam and Tookey 1998, Pp-1-15) after that a regression of sea level along this coastal tract took place (Banerjee and Sen, 1987, P-307-326) which caused southward shifting of shoreline (Roy and Chattopadhyay, 1997, Pp-177-206). Over the last 500 years the whole Bengal basin have been sinking southward due to heavy sediment deposition on Ganges-Brahmaputra valley (Banerjee, 1968). This causes a relative rise of sea level to the eastern part of this coastal tract while a shifting of the western part of the coast is occurred, which results a relative fall of sea level in the present study area (Pethick, 1984).

The present study area falls within subtropical humid climate with three distinct seasons viz. Pre-Monsoon (March-June), Monsoon (July-Oct), and Post-Monsoon (Nov-Feb). The maximum daily temperature ranges between 26.7°C and 36.8°C while the maximum temperature lies in between 5.7°C and 24.7°C (G.S.I., 1991,P-2). The range of average annual rainfall as recorded in 1992-93 is 1192mm-1956mm with relative humidity varying between 60% and 90%. Wind direction varies from season to season. In summer to rainy season wind blows generally from S-SE direction while in winter season wind blows from NNE direction. The seasonal characteristics of tropical monsoon climate influence wave dynamics and causes significant morphological changes over the Madinipur coastal tract. The southwest monsoon brings moist wind with sailing depression that generates strong wave action during the months of July-Oct (Pethick 1984). In the winter the dry northeast wind plays an important role in aeolian action upon the coastal geomorphology.

Madinipur coastal tract is characteristically almost flat with wave dominated sandy beach along with chains of sand dunes and mud flats. This area is a central museum of several types of coastal dunes, which preserve the geological history and reflect the physical environmental influence upon present landforms as well. Almost parallel formation of 4 distinct dune colonies during 6000 years indicates seaward shifting of shoreline with early sea regression or ostaciation of sea level (Steers, 1937,P-205-260) along this coastal tract. A recent research by Banerjee et al (1997, Pp-492-501) shows that the dune chains of this area are entirely of aeolian origin formed during the late sea regression. Paul (2001,P-165) assessed that these dune chains are formed by aeolian sand transport over the beach ridges and vegetation interaction and related with shoreline shifting by sea level changes. Considering the geomorphic significance of the coastal dunes we decided to perform an analysis on the geomorphology of coastal dunes of this area. The primary objective of this study is to provide a better understanding about the geomorphic evolution of coastal dunes under tropical monsoon environmental conditions. The technical discussion starts with the general geomorphic classification of the dunes and their characteristics. The role of natural vegetation in different stages of development of the coastal dunes of this area has discussed. This part extends with a study of morphological changes of dunes through various seasons and their impact upon long-term development. The conclusive section discussed the present environmental hazards of this coastal area.
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seasons b: The pressure influence as S. West monsoon easterly significant it brings months portant
1 sandy sum of typical set of 4 ne with coastal settings of 3001. P: beach surfaces term an of this situation chnical d their of the logical project d area.

Figure 1. Location of the selected study area.
METHODOLOGY

Prior to visiting the field area, an extensive study of literature was done such as reports of Geological Survey of India, Disaster Development Authority, Department of Environment of Government of West Bengal etc and recent research papers published in different journals and presented in different seminars, congresses etc to prepare a complete fieldwork programme. The field programmes included:

1) Study of the geo-historical background of the coastal area.
2) shoreline changes during the last 6000 years
3) an examination of the climatological controls on morphologic modification of the study area.

The basic cartographic materials used to obtain better knowledge on the study area and they were used as tools of analysis (Table 1).

| Table 1. Basic cartographic materials used to assess recent shoreline change |
|---|---|---|---|
| Basic materials | Year of publication | Scale | Publisher |
| Geologic and geomorphologic map of Digha area | 1995 | 1:50,000 | Geological Survey of India |
| Current shoreline parameters and disaster management plan of Digha coast | 1995 | 1:50,000 | Geological Survey of India |
| Present shoreline map for Digha planning area | 1995 | 1:10,000 | Geological Survey of India |
| Coastline plan for 205 using Digha planning area | 1995 | 1:50,000 | Digha Development Authority |
| Topo-ladl/3 OS/6 | 1948-49 | 1:50,000 | Survey of India |
| Topo-ladl/7 OS/10 | 1931-32 | 1:50,000 | Survey of India |
| Topo-ladl/7 OS/10 | 1948-49 | 1:50,000 | Survey of India |
| Topo-ladl/7 OS/14 | 1931-32 | 1:50,000 | Survey of India |
| Topo-ladl/7 OS/14 | 1948-49 | 1:50,000 | Survey of India |

Different techniques have been applied and instrumental survey works have been done during fieldwork from 2000 to 2003 to find out the geomorphologic evolution of this area. Data collected through field investigation by simple leveling survey method (using Dumpy Level), Rangeing Rods, Staff and measuring tape; during various sessions have used for preparing various maps. Effects of wave action and resistant features around the beach were identified during the fieldwork. The field study was directed towards understanding the following:
The Influences of Natural Environment Upon the Erosion of Sand Dunes (Netha Dey, et al.)

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a. development of the coastal dunes through geological past.
b. present morphological character of coastal dunes.
c. types of vegetation and their role in dune development.
d. influence of climatic conditions in dune development.

SHORELINE SHIFTING

Evidence of marine coastal sediment, mangrove roots and, marine shells are found below 26-6m depth under the surface in Kholaghat-Tamirisk region (21°55 N to 21°53 N 87°39 E to 87°38 E 1膝angul), which indicates the previous position of shoreline during the Pleistocene epoch (Chakrabarti and Had, 1996, pp. 117-124). The Geological Survey of India (1995, P-3) has detected that shoreline positioned 5-15 km inland from the present shoreline around 6000 years BP. Around 3000 years BP the shoreline position was 2-5 km inland from the present shoreline.

Landsward shifting of shoreline due to rise of sea level and subsequent land erosion is a major environmental issue of Medinipur coastal tract in the present day. In the well-known work of O'Malley (1911), Bengal District Gazetteer, Mithapur, the possible history of recent shoreline shifting of this area has been described. Evidence of a village is found in the map of Vijatpur (1664 A.D.), van De Broek (1668), James Reuel (1777) and plot chart of Thomas Bowrey (1689), which was named "Naricoil" or "Biricoil". O'Malley described that in the early settlement records of British government, Biricoal was known as sal parghawa. According to report in the 16th century Biskul (Biricoal) become a seaside resort for the European officers. They constructed a bungalow, which was used by Lord Warren Hastings. This bungalow was later washed away by the transgression of the sea. However today a very common myth exists among the fishermen of this area that the bungalow of Hastings often emerges from the water at the time of low tide at a distance about 5 km away from the shore. Further the Public Works Department constructed an inspection bungalow, about half of kilometre inland from that place, within nozua Bhag, but with transgression of the sea this entire area has gone under sea. In 1852 Boroji described the natural beauty and fresh environment of this area (O'Malley 1911, P-5-6). But the existing name of the area was also found in his description as he writes "...of the three bungalows upon them, two are gone and one all but gone." These evidences suggest that erosion is not a contemporary phenomenon along this area. Evidence also suggest that over the last three centuries the problem of erosion has aggravation along parts of Medinipur coastal tract Growani (1997, P-61-63) assessed that about 6000 m land eroded from 1775 to 1986 and around Digha at an annual rate of 28-4m year (Fig-2). Both Digha and Shankarpur sectors are suffering by rapid beach narrowing and lowering. From west to east Digha beach is now narrowing progressively and at the eastern end of Old Digha Township, the actual beach width remains only 5-10m.
From the recorded data and comparative study with Survey of India topographs, satellite images and field data it is found that during 1951-52 to 1968-69 the westward part of Midnapur coastal tract (from Subarnamela river estuary to Jatranala inlet, length: 13 Km) was under prominent accretion. Rest of the area, from Jatranala to Pichhabadi inlet (length: 28.5 Km) was under erosion. Though from Jaldia inlet to Pichhabadi inlet there was a little accretion during this period, net positive change of shoreline was landward during that time.

During 1968-69 to 1997 a remarkable change is found along the coast. During this period a new zone of accretion has emerged towards the east, from Jaldia inlet to Pichhabadi inlet (length 13.5 Km). But from Jatranala inlet to Jalchhikudia (length 15 Km) rapid erosion took place. This creates a big problem of land loss with registration of many environmental refugees in this area (Department of Environment, 1999, Pp:17-19). This study shows that erosion and accretion of occur side by side along this coastal area. But it is also observed that during 1931 to 1967 the general tendency of shoreline change was to shift landward. It indicates a sharp rise of sea level during 1951 to 1967. By contrast in recent years accretion occurs in western and eastern parts of this coastal tract. But Digana and Shankarpur sectors are still under serious wave erosion (Mukherjee & Chatterjee, 1997 Pp:2-4, Bandyopadhyay, 2001, Pp:58-59).

RESULTS AND DISCUSSIONS

1. Origin and morphology of dunes along Midnapur coastal tract

Coastal dunes morphology consists of distinct parallel dune chains and depressions (Patrick, 1984) which have a significance of geomorphic evolution throughout geological time (Dey and Haquin, 2003). In the light of the recent hypothesis the following two models of coastal dune formation have been suggested (Viles and Spencer, 1995, P:68-69):

1) Dune formation associated with rising sea level condition (transgression) - as sediments are pushed onshore from continental shelves.

2) Dune formation in association with falling sea level as exposed offshore sandy accumulation become prone to wind deflation.

For practical understanding of the above-mentioned hypothesis, we conducted a study along the selected field area. On the basis of the field study, two main geomorphic classes of the dunes of this area are observed, they are Paleo-dunes and Neo-dunes. Between these two date columns, intra-dune depression exists.

Paleo-dunes

These are older dune chain with 2 to 16 m heights which indicates the early shoreline positions during 2900±60 Years B.P. (Ramesh and Sen, 1987, P:307-320) corroborated that regression of sea along this coastal tract around 5000 years BP resulted seaward drifting of shoreline and formation of paleo-dunes. These dunes got maturity by the growth of natural vegetation under stabilized environmental condition during last 3000 years B.P. Axial line action is responsible for the slowly decrease of dune heights.
The older sand ridges are actually situated almost parallel to the active dune chain beyond 3 km from the beach and complex in form. These are nearly 0.5–1 m in elevation. This area is characterised by thin soil profile. The sandy terrain of beach and dunes is found without any soil cover. At some places very thin clayey soil profile is found which is eroded to impermeable in character and composed of very thin clayey loam with a maximum 1.00 mm in size (GSI, 1995). In this part some agricultural activities are found.

Inter-dunal depression mud flat

Long-dunal mud flats are found beyond 200 m nearly parallel to the sea from Chuna border to Old Digha in between neo-dunes and paleo-dunes. These occur between the front dunes and the older dune tracts, which are marked by high tide level and swash-trace level. This layer of mud with remobilised sands from the dunes are found covered by grasses and bushes.

Neo-dunes

This type is found on the upper face of the beach. Some seasonal small dunes normally form during the drier seasons by sand drifts (1.5–4.5 m high). It is accepted that further regression of sea and sea-ward shifting occurs after 3000 Years B.P. (GSI, 95) which resulted in a new platform for the development of another dune chain in front of the paleo-dunes. The fore dunes of present day started to form with initial sand deposition. Growth of vegetation plays an important role for stabilisation of dunes. Recent rise of sea level along this coastal tract causes landward shifting of dune belt. In Udaypur sector as the shoreline is shifting southward due to accretion the some front dunes of this part are being gradually stabilising by free growth of vegetation. In the other sectors the neo-dune belts have a tendency to shift landward and realigning their position with recent rise of sea level, which result a negative condition of nature.

These dunes collapse and get decayed during the monsoon season. Vegetation cover in these dunes is rare or little. Foredunes are found on the margins of beach. These dune shaped sand dunes are 12 to 19 m high with steep slopes >45°. Front dunes are very common along the study area. The erosion-marks on the front dunes indicate the present high tide level as the dunes are situated on the upper front of the beach. No soil formation is observed on these dunes.

2. Influence of vegetation in dune formation in different stages

Vegetation in sand dunes alters the performance of a dune by leaving a contribution in the form of checking dune erosion, causing accretion of sand mass and enhancing the dune stability. The sand mass with vegetation dispersed in it forms a complex system with high degree of heterogeneity. The fibers physically prevents close to the surface of a composite behave different from the one present in the bulk Dawing similar concept, vegetation of sand dunes can also be classified into two main types, one close to or exposed to the dune surface and the other inside the mass. The surface vegetation gives
rise to pseudo-coating effect and the interspersed or the vegetation in the bulk mainly causes reinforcement effect. The main functions of these two types are:

**Surface Vegetation**
1. checks the velocity of wind and causes drop in wind load (as natural sand fence).
2. absorbs wave impact.
3. prevents sand mass beyond a certain part from undergoing abrupt change in properties (like gaining water content etc.).

**Bulk Vegetation**
1. shares different external stresses incumbent on the dune.
2. checks crack propagation.
3. enhances the barrier property of the sand mass.
4. controls the erosion susceptibility of swelling clays and sands by some adhesion mainly rising out of biological interactions.

Biotic influence in dune formation has observed during the first work (Figure 3, Plate-1).

![Diagram of vegetation roots and sand accumulation stages](image)

**Figure 3.** Penetration of vegetation roots and their influence on sand accumulation in different stages of dune development.
Plate-1: Stages of dune development a) Initial growth of salt tolerance grasses with extension of beach by accretion at Baguranajoli, b) Stabilization of dunes by growth of Ipomoea Sp at Baguranajoli, c) Growth of trees on extensive dune belts Shankarpur, d) Rear end of mature paleo-dunes near Digha

Numbers of important features of the morphological development of coastal dunes of Medinipur coastal tract falling within the tropical environment have emerged through the field study, which can be stated as follows:

1) At the initial stage of the dune development, formation and extinction of long-shore spits along the coastal margin are the main platforms. Catastrophic cyclones break the spits into disconnected barrier islands. Marshlands trap silt and prograde the mud flat towards the barrier margin at high tide. Beach ridge feature occurs along the upper slope of the beach face by the naked sea wave energy. The dune formation begins above the beach ridge feature by wind-blown sands from the open and dry foreshore at low tide. Vegetation cover makes the nucleus of dune development. Grasses like Alorachot lagopusoides, Leersia hexandra, Paspalum distichum can only tolerate the over wash process and sand accumulation in this area.

2) In the next stage accumulation of sands and transformation of vegetation occurs which continues dune developing process. Through strong wind velocity fine sand particles being lifted and thrown-up from the seaward slope of dune ridge before being deposited at the back-bar in pre-monsoon time. This process causes inland movement of the dune ridges.
3) The dune ridge become detached from active shoreface and separated from the coastal inland and this inland sand ridge will stabilize the surface with complete vegetative cover in the form of distinct topography known as a dune sand ridge (Paul, 1996). In this stage the colonisation process is going on with the vegetative growth. As the coast is very exposed, the unconsolidated substratum of the shoreface is in constant movement. To stabilise the unconsolidated conditions only low growing "Spinifex humifusa" deeply penetrating root system survives (Shukla, 2001). This confirms the vegetative accretion installation. The turf spay leaves of "Spinifex" helps in deposition of fine sands transported by aeolian process.

4) The unstable sands with very low fertility status discourage plant's colonisation. In this developing dune sparse vegetation going in a scattered way. The pre-dominating species of this developing dune are: Littorella uniflora, Eryngium latifolium, Euphorbia humifusa, Bursera articulans, Ipomoea purpurea. The hard and deep penetrating roots of the herbaceous species can survive in this less fertile sandy soils and gradually cover 30-75% of the new-dunes.

5) In this semi-fixed dunes the herbaceous species invade some shrubby plants which can also survive in this semi-arid and semi-fertile sandy soils. The next species to colonise are: Glycosmis pentaphylla, Cyperus esculentus, Pandanaceae tree (Oryzae dillenia), Calotropis gigantea. Among these species, Pandanaceae stabilise the shoreface and act as a buffer against the erosion of loose sands. With Pandanaceae, Acacia tridentata also dominate the dune slopes in this stage. Gradually dunes becomes lower with age by the process of erosion.

So, in the stabilised dunes all types of plants (herbs, shrubs and trees) proceed which complete the succession and finally stabilised the dunes (Figure 4) as well to makes the soil impregnate with nutrients gradually, thus facilitates the full vegetative growth.
3. Influences of vegetation cover on dune movements along the study area

Dune movements have been found to depend not only upon the sand and wind speed, pattern and thickness of vegetation cover play a very important role (Dey, 1999; Bhakat, 2001). Here the authors have made a scheme of dune classification according to their pattern vegetation cover and rate of migration on the basis of field study along the Subarnarekha delta plain. This is presented in the table below:

<table>
<thead>
<tr>
<th>Types of dunes</th>
<th>Estimated percentage of vegetation cover</th>
<th>Characteristics</th>
<th>Vegetation **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile sand dunes</td>
<td>0 to &lt;30%</td>
<td>Geologically known as “beach front dune complex”, mostly affected by wind in dry season and by wave in rainy season.</td>
<td>Cyperus distichus, Borassus australis, Elaeocarpus indica, Euphorbia thorogfo, Eryngium pus- capnos, Lumnare normontana, Salix carocarpa, etc.</td>
</tr>
<tr>
<td>Semi-stable sand dunes</td>
<td>30% to 70%</td>
<td>Geologically known as “Older dune complex” found beyond 3km from the sea to 15km inward.</td>
<td>Cuscuta sp., Capiros sp., Gymnonema pennagynella, Lantana camara, Oplochlo sp., Pandana sf, etc.</td>
</tr>
<tr>
<td>Stable sand dunes</td>
<td>More than 75%</td>
<td>Beyond 10-15km from sea, lower height (2m or less)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Field Investigation Report and **Bhakat (2001)

4. Seasonal influences upon long-term geomorphic changes

It is accepted that seasonal changes of sea level is one of the remarkable features of tropical-monsoon areas which influences geomorphology of coastal areas (Dey, 2000: Dey, 2003) such as break (width and angle) dune (height and angle) and mud flats. Seasonal changes in wind direction and wave action also influence the variations supply of sand along the study area. The nature of sand supply through the seasons are as follows (here WE indicates the west to east direction of littoral drift and EW indicates east to west littoral sand drift).
Table 3. Seasonal nature of sand supply along Subarnarekha delta plain

<table>
<thead>
<tr>
<th>Area</th>
<th>Length (in m)</th>
<th>Generation-Deposition</th>
<th>Season</th>
<th>Sand supplied (in 10^6 tons/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Udupi sector</td>
<td>5.0</td>
<td>Pre-depositional</td>
<td>Pre-monsoon</td>
<td>240.2 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Monsoon</td>
<td>141.8 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-depositional</td>
<td>Post-monsoon</td>
<td>92.7 (OE)</td>
</tr>
<tr>
<td>Napha sector</td>
<td>5.5</td>
<td>Pre-depositional</td>
<td>Pre-monsoon</td>
<td>233.9 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Monsoon</td>
<td>278.9 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-depositional</td>
<td>Post-monsoon</td>
<td>137.8 (OE)</td>
</tr>
<tr>
<td>Shankpur sector</td>
<td>9.5</td>
<td>Pre-depositional</td>
<td>Pre-monsoon</td>
<td>122.5 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Monsoon</td>
<td>190.1 (OE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post-depositional</td>
<td>Post-monsoon</td>
<td>98.7 (OE)</td>
</tr>
</tbody>
</table>

Table based on Bhindari (2002).

Seasonal changes of the sand dunes are also very important for the geomorphology of the study area. Local sea level rise during the monsoon season wave erodes the upper front dunes (Plate-26 & 27a). In this period the dune belt shifts slightly landward, storm wave activity often destroys part of the dunes, breaking the continuity of the dune belt. Moreover, in the pre-monsoon season the strong south-westerly wind triggers the landward dune movement, which causes a loss of fertility of the agricultural lands.

In the post-monsoon season the reconstruction of sand dunes starts under the impact of north-easterly wind (Plate-26 and 27b). The angles of the dune slopes, which were steep and relatively high-angled in monsoon seasons, get reduced in height and slope-gradient. The angles of front dunes are maximum in late post-monsoon (January-February) and minimum in the last part of monsoon (August-September).

Height of the dunes also varies with the changes of seasons. Seasonal change of front dunes ultimately results a landward shifting at a yearly rate of 2m to 5 m along this coastal tract which is a strong evidence of gradual increase wave action along Medinipur coastal tract.
Plate-2: a) Eroded foredune during monsoon season at Shankarpur sector b) Marks of wave erosion on foredunes at Udaspur sector, c) Developing neo-dunes in post monsoon season at Jamalpur-Daspatrabar sector, d) Social forestry during post-monsoon season at Shankarpur

Table 4. The seasonal change of dune morphlogy:

<table>
<thead>
<tr>
<th>Situation of dunes (in between)</th>
<th>Pre-monsoon</th>
<th>Monsoon</th>
<th>Post-monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Udaspur sector</td>
<td>Angle 35°</td>
<td>Height 18m</td>
<td>Angle 31°</td>
</tr>
<tr>
<td>Digha sector</td>
<td>Angle 33°</td>
<td>Height 12m</td>
<td>Angle 35°</td>
</tr>
<tr>
<td>Shankarpur sector</td>
<td>Angle 37°</td>
<td>Height 7m</td>
<td>Angle 32°</td>
</tr>
</tbody>
</table>

Source: Field investigation 2001-2002

CONCLUSIONS

Formations distinct dune belts of in this area clearly indicate the dynamic nature of natural environments during the Holocene epoch. Seasonal character of this tropical coastal area plays very vital role in developing the sand dunes along with the natural vegetation. Vegetation cover control movement of dunes and morphological modification along the coasts. The vegetation dispersed in sand mass increases the stability of a dune to resist wind and wave action by many folds. The contribution of vegetation results from both structural and biological interaction of itself with sand mass.
Besides this, it is observed that there is a tendency of sea level rise at a remarkable rate during the last 300-500 years along Medinipur coastal tract (Nigori, 1970, Pp. 1-36). There is ample evidence (Haque et al. 2001, Pp. 25-37) of sea level rise at a considerable rate (0.5 mm per year) in this part during recent years. Prominent landward encroachment of dunes alongwith the shoreline changes strongly support that sea level rise is now at an alarming stage in this area. Human intervention, particularly over the last three decades has also been very significant for the change in coastal environment. Construction of fishing harbours, covering a large area at Shankarpur sector, development of tourism and associated industries (mainly ice and fishing ship/boat-building industries) along the coast have aggravated environmental hazards. Recently social forestry has been introduced by the Department of Forestry, Government of West Bengal to protect the beaches and dunes from wave erosion (Plate-2d). Under these circumstances study of both long-term and short-term environmental influences on the geomorphology of the coast would be very important for sustainable development scheme for the future.

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