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CONTENTS

QUATERNARY GEOMORPHIC EVOLUTION OF THE ST. MARTIN'S ISLAND IN BANGLADESH

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Abstract

The St. Martin's island is the only coral bearing offshore island of Bangladesh with an area of about 8 km2. In this paper the Quaternary geomorphic evolution of the island has been reconstructed. The island is structurally controlled and its present landform has been shaped by four major factors, such as sea-level change; tectonic activities; geomorphic process and anthropogenic activities. During the Pleistocene period, the exposed outcrop at Dakshinpara was deposited, which has been identified as the Pleistocene shoreline at about 6 m above the present sea level. The mid-Holocene slow rise of sea level with some sequence of regressions was suitable to accumulate coral reef within the tidal range of the island. Boulders and conglomerates of cemented calcium carbonates and fossiliferous materials were also deposited along with rocky corals. Late-Holocene sand accumulation accelerated the process of dune formation. During this period due to rapid siltation by tide, wind and wave Uttarpara and Dakshinpara became well connected, the area near Galachipa became much wider than today and the island got nearly its present shape. In recent years due to increasing number of population, human activities and unplanned tourist influx, the landform and physical environmental setting of the island have become fragile. Moreover, human activities in the mainland, particularly changing land use pattern and erosion from hill surface have lead sediment to disperse in to this part of the shelf, which eventually affect the physical shape of the island

Introduction

The St. Martin's island is the only coral bearing offshore island of Bangladesh. This tiny island in the Bay of Bengal is located at about 10 km south from the south-eastern most tip of the mainland and lies between 20°34´ & 20°39´ N latitude, and 92°18´ & 92°21´ E longitude. The main island is dumbbell in shape and is divided in four parts: Uttarpara, Galachipa, Dakshinpara and Siradia (Fig. 1). It is approximately 8 km long in north-south direction, with the maximum width of about 1.6 km in the north and minimum of 100 m at the middle near Galachipa. The area of the island is about 8 sq.km and the average height is 2.5

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m from MSL with the maximum of 6 m high cliff. This small island is very rich in biodiversity and biologist termed it as Living Museum. (Sarkar *et. al.*, 1998; Aziz, 2002).

Aerial photographs (1:50,000) of November, 1998, Toposheets (1;50,000) of 1967 and other published thematic maps and documents have also been used.

There are about 6000 inhabitants in this island and nearly 60% of them are directly depending on fishing or fish drying, 20% as boatmen, 15% business and only remaining 5% on agriculture. Literacy rate is very poor (less than 7%) and the health facility is nearly absent. The people of this remote island are very vulnerable to cyclones and storm surges. Their only communication with the mainland is by traditional engine boats or trawlers. The St. Martin's Island is the most attractive tourist spot in Bangladesh. During the winter season the island becomes crowded with tourist from different parts of the country. The indigenous culture of this remote island, its rich biodiversity and ecosystem are now under threat by influx of people from outside.

Objectives, Methods and Materials

The paper aims to explore the Quaternary geomorphic evolution of the St. Martin's island in the context of relative sea level moments and local tectonic activities. However, with the view to understand the evolutionary history of the island, the major attempts undertaken are (i) to identify the major geomorphic units of the island; (ii) to explore its lithological sequences; (iii) to study the dune morphology and their development process; and (iv) to study the bathymetry around the island. Detailed fieldworks were conducted during the winter of 1999, 2000 and 2001, and necessary samples were collected for laboratory analysis. Landsat imageries of FCC bands 2, 3 and 4 (1:100,000) of 1995 and SPOT imageries (B&W) of 1990 (1:50,000) have been studied to isolate major geomorphic units and to delineate important landform patterns black and white.

Geomorphic Classification

In this study the geomorphic classification of the island is initially been made from 3D views of Aerial photographs, which has later been confirmed by plot to plot field checking. A total of 13 types of landform units have been identified which are: alluvial plain, lowland, lagoon, coastal dunes (high and low), hillock, sandy beach, shale beach, tidal plain, saltmarsh, rocky corals, spitbar and sandy isles (Fig.1)

The general topography of the island is almost flat and is occupied by fine to medium grained alluvial deposits. Overlaying the bedrock, these alluvial deposits of less than two meters thick, have developed good soil horizons and an extended alluvial plain has been formed. This plain landform occupies 33% of total area of the island (Table 1) and mostly been used for crop cultivation. At the southern part of Dakshinpara, the plain land is sub-basin in shape and become shallow inundation at Spring High Tide. This lowland area is mostly been covered by planted mangrove *Sonneratia spp.* and other dense vegetation. There are three lagoons in the island of which lagoons at Uttarpara and Dakshinpara have now become muddy swamps with shallow water and are only connected to the sea at high tide through shallow creeks (Plate 1). But the lagoon on the west of Siradia is under shallow water deposition and is protected by wide spread boulders and stone corals. It is of course that the lagoons in the north are older in origin and shows longer sequences of evolution process, and the lagoon in the south is much younger and is under active marine influence.

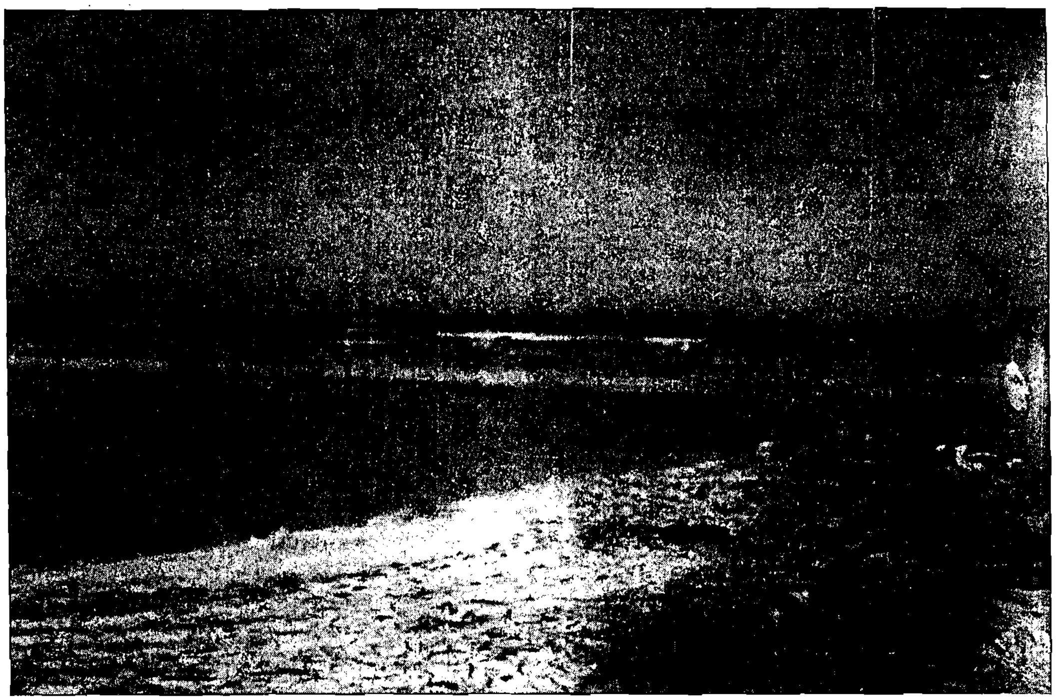


Plate 1: Lagoon at Uttarpara showing shallow water

Coastal dunes are developed in widespread immediately above the beach and along the shoreline (Plate 2). Such dune system has well developed surrounding the middle parts of the island. Dunes of the St. Martin's are of two types: high and low dunes. High dunes are up to 6 m in height and are mostly found on the western side of Galachipa. Dunes along northwest and southwest corners of the island are lower in height, undulating and are broadly extended. Dune system of the St. Martin's island acts as a natural defense against storm and tidal surges, and save lives and properties. In the east coast of Dakshinpara a hillock of 6 m in height, more than 150 m length and covering an area of about 500 sq.m is the highest exposed outcrop of the island. Haque *et. al.* (1979) identified this outcrop as 'coquina bed' of the St.Martin's comprising well bedded to loose sand to pebble clasts composed of corals, gastropod, bivalves and foraminifera. Chowdhury et. *al.* (1992) on the other hand identified this unit as Pleistocene beach rock.

Table 1: Geomorphic Classification of St. Martin's Island

67Geomorphic Unit	Area (in sq.m)	% of total area
Alluvial Plain	2.65	33.17
Lowland	0.27	3.40
Lagoon	0.47	5.82
Coastal Dunes (high)	0.08	1.05
Coastal Dunes (low)	0.31	3.86
Hillock	0.06	0.71
Sandy Beach	0.83	10.34
Shale Beach	0.16	2.01
Tidal Plain	0.52	6.53
Saltmarsh	0.04	0.50
Rocky Corals	2.61	32.62
Spit	0.08	0.98
Sandy Islets	0.02	0.30

Source: Field survey

Encircling the island, particularly in northeast, the zone between the Spring High and Low Tides can be characterised by an accumulation of marine sands and has developed an extensive sandy beach. This beach system has also been well developed surrounding the centre of the island. Differential beach sloping clearly indicates micro-scale spatial variation of sand accumulation along the beach. At the northeast corner, the gentle gradient results a wide emergence of land at low tide; whereas, on west side, particularly at the middle, the beach slope is steeper. The absence of mud in beach sand has led the island to a wonderful swimming place in transparent water and a tourist attraction. Along the west and east sides of Dakshinpara, beach materials have overwhelmingly been composed

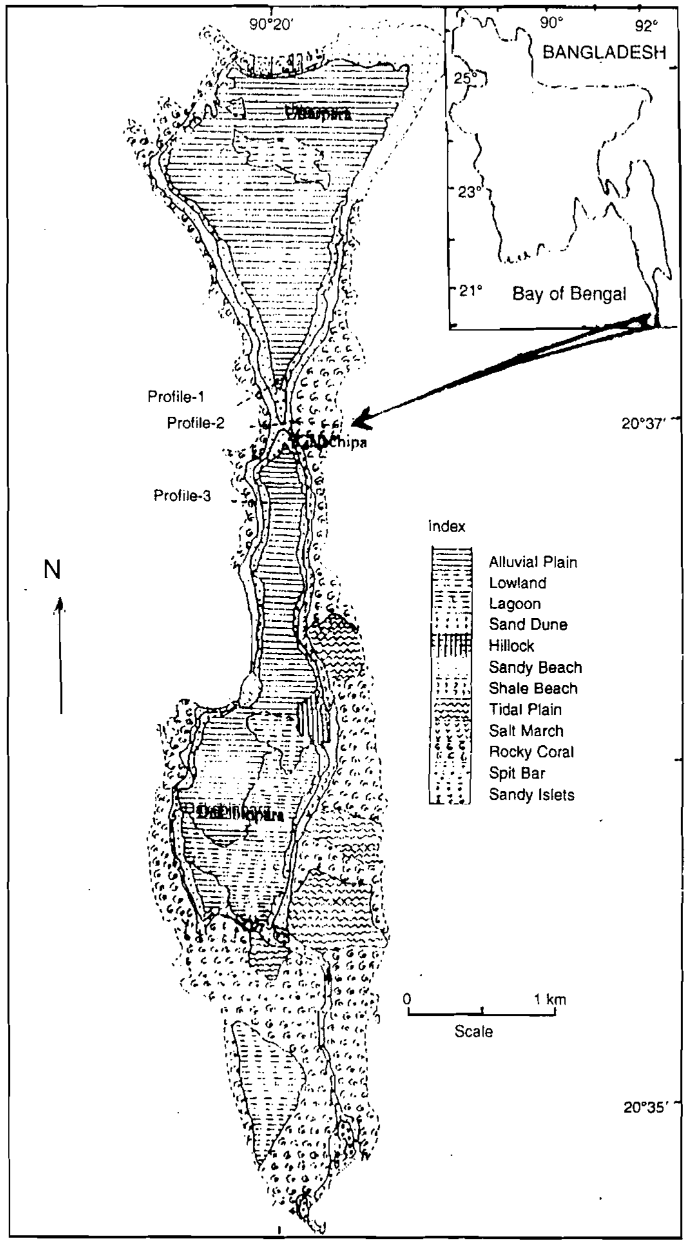


Figure 1: Geomorphic Classification of the St. Martin's Island

of medium to coarse shale fragments and broken coral debris. This unique shale beach landform is light gery to light purple in colour, rarely includes any minerogenic composition and is extended up to the lower tidal limit of the island. Tidal plains are well extended along the eastern beach of Dakshinpara. This landform unit is almost flat to semi-saucer in shape. The bedrock consists of mostly fine to medium grained semi circular to circular shaped sand with minor amount of shale fragments and foraminifera. The tidal plain unit at the southeast end of Dakshinpara is incised into a channel due to surface erosion by tidal current. This channel gets up to a meter inundation during the high tide and all southern islets become disconnected by tidal water from the mainland. The bed materials of this plain land show the evidence of firmly cemented materials by calcification. The process of cementation in between high and low tide range is due to the result of direct precipitation of Mg-calcite and aragonite from solution within the rocks (Chowdhury *et. al.*, 1997). A small stripe of saltmarsh landform has been identified along the bay like coastline of the western coast of Dakshinpara. Remnants of mangroves and well-developed salmarsh grasses have been recorded; the Lithostratigraphy at this unit shows two sequences of mangrove peat layers separated by minerogenic sediments.

Plate 2: Coastal Dune parallel to the shoreline

Rocky corals in their growth position have formed a very unique geomorphic feature of the island, particularly in the east and south (Plate 3)). The formation of such stones involves an *in situ* accumulation of hermatypic coral growing on top of another. It also includes the breakdown of coral blocks into fragments and is exposed in many places along the beach. Stone corals are also found in association with rocky boulders, which are also exposed along the shoreline and together occupies 32% of the island. These boulders are cemented beach materials deposited within the inter-tidal zone in areas of small tidal range. Beach materials may range from fine sands to large boulders and are cemented by calcium carbonates. Chowdhury *et. al.* (1992) identified these as beach rocks composing of white calcareous cemented sand materials occurring in coastal recession. The thickness of these rocky boulders is the result of high and low tidal range along the coast.

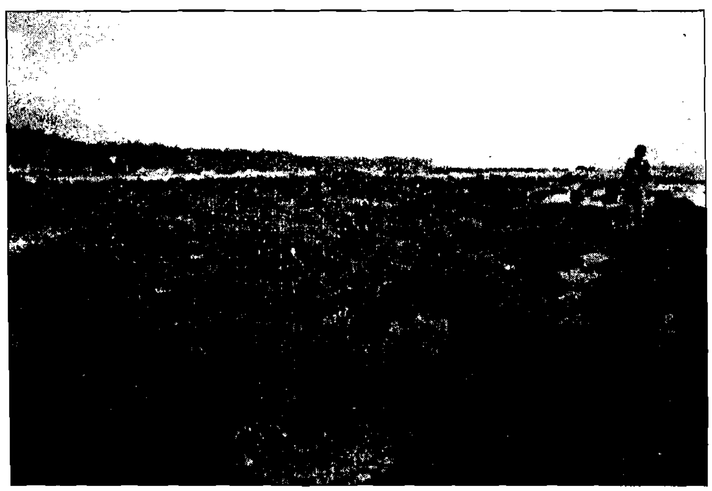


Plate 3: Rocky corals in their growth position

A unique geomorphic feature of St. Martin's island is the development of a spit bar in its south. This typical spit bar landform of about 2 kms long and less than 100 m wide connects the mainland with Siradia (islets). This bar has been formed due to deposition and movement of fine to medium grained sand materials by wave and tidal currents. Siradia in the south consists of three small islets of which the middle one is the largest and the southernmost one is possibly the oldest. The peaks of these islets are less than 3 m in height from the MSL and become disconnected from the main land by nearly 1 m deep water at high tide. These are composed of relatively coarser sand particles with frequent shale fragments, broken coral debris and foraminifera, and are overlaid nearly all sides by stony corals and boulders. The middle islet has an undulating surface feature, has a sub-basin on its top and is under shallow water depth at extreme high tide. From its southeast corner, a horn like landform is exposed seaward. All these islets are covered by keya (*Pandanas*) plants and some bushes, although some mangroves are also grown in the middle islet.

Lithostratigraphy of the Island

Khan (1964) identified the oldest exposed rock unit of Dakshinpara formation of Late Miocene in age, which Chowdhury *et. al.* (1992) suggested to be much younger. None of those works were based on any lithostratigraphic records. However, in this study a total of eight boreholes were made at different geomorphic units with the view to illustrate the time-altitude succession history of the island (Fig. 2). Based on stratigraphic records, their laboratory analysis (particle size, minerological and microfossils), and field observations the inferred lithostratigraphic succession of the island is shown in Table 2.

Table 2: Lithostratigraphic Succession of the St. Martin's Island

Geological Age	Landform types and their Evolution	Thickness	Lithological Description
Late-Holocene	Coastal Dunes	up to 6m	Fine to medium sand coated with broken shale
	Spit bar	up to 2.5m	Medium to coarse sand rich in mica
	Sandy and Shale beach	exposed	Fine to medium sand with frequent broken shale
	Tidal Plain and Marsh	up to 1.5m	Fine sand under cementation, marshy peat
Mid-Holocene	Alluvial Plain and Lowland	up to 2m	Grey silty clay with clay clasts and broken shale
	Sandy Islets	up to 3m	Coarse sand rich in foraminifera
	Lagoon	up to 1.5m	Dark gray silt with frequent broken shale
	Stony Corals and Fossiliferous Rocks	exposed	Pebbles of shale, coral fragments and foraminifera
Early-Holocene	Patches of Stony Corals and Boulders	submerged to exposed	Boulder conglomerate of dead corals, shale, and calcareous sandstone
Pleistocene	Pleistocene Outcrop	up to 6m	Medium to coarse grained hard and compact fossiliferous sandstone, rich in foraminifera
Late Miocene to Pliocene	Basement of the Island of Dakshinpara formation	Base not seen	Fossiliferous sandstone, calcareous sandstone and Fossiliferous conglomerate interbedded with non-calcareous silty shale

The Dakshinpara formation is the basement of the island and has attained a thickness of 324 m consisting of fossiliferous sandstone, calcareous sandstone and fossiliferous conglomerate interbedded with non-calcareous silty shale (Mohiuddin, 1992). A major part of the formation is in the sea and a little of which is traceable. The rocks of Dakshinpara formation is rich in foraminifera and the most common species are *Cibicides. sp., Triloculina sp., Globorotalia sp.*, which indicate the formation of Late Miocene to Pliocene in age (Plate 4).

The Dakshinpara formation is overlaid by completely cemented hard outcrop of the so called 'coquina bed' of Pleistocene age. A long bands of this rock is well exposed along east coast of Dakshinpara (Plate 5), which Chowdhury *et. al.* (1992) have identified as Pleistocene beach rock as signature to high strand line during the Pleistocene. This rock has been formed by the deposition of calcite cement from ground water between sand grains at water table in beaches with subsequent cementation on exposure.

Plate 4: Foraminiferal sp. (*Cibicides sp)* identified

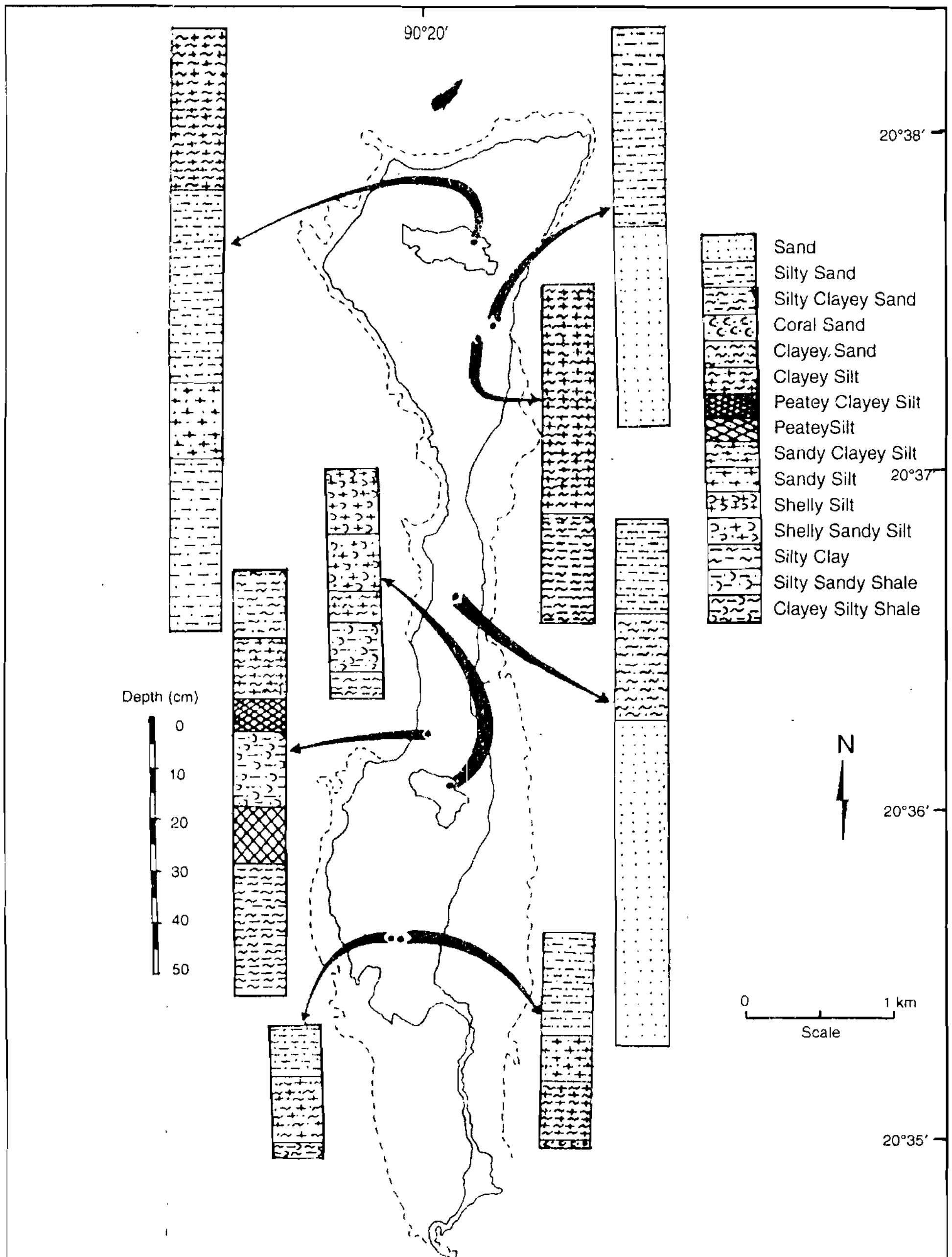


Figure 2: Lithostratigraphy of the St. Martin's Island

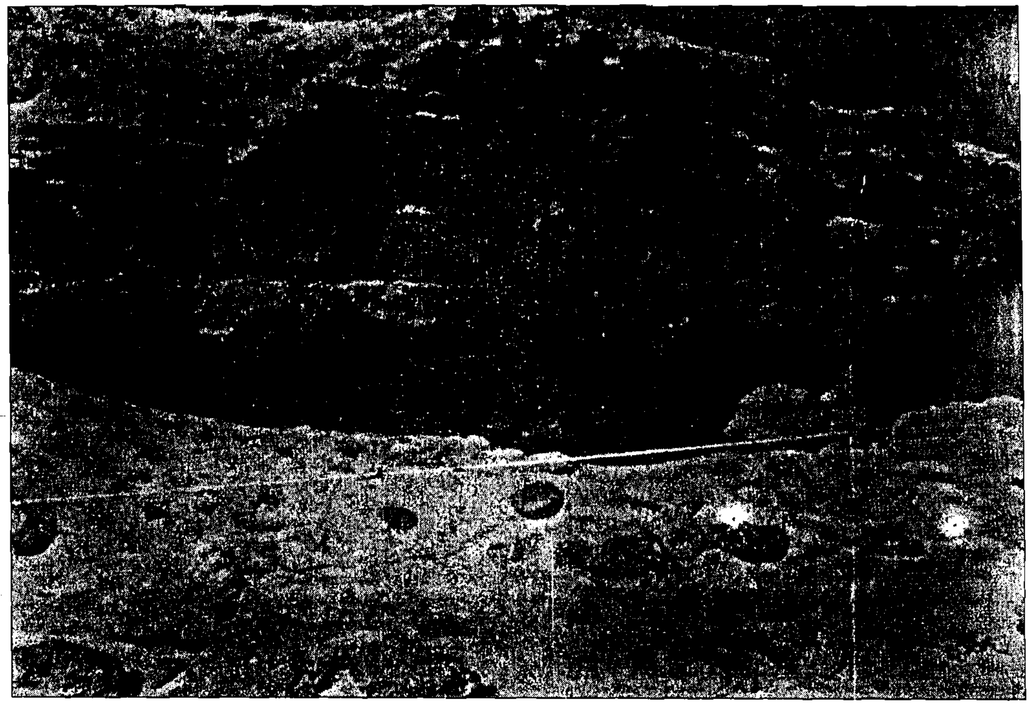


Plate 5: Pleistocene beach rock showing higher standline

Corals are grown and fossiliferous boulders conglomerate are cemented between high and low water marks. Postglacial eustatic sea level change played a significant role to coastal and shelf morphology. During the early-Holocene, the sea level was rising so fast that only a patches of such rock forms were possible to be accumulated. However, during the mid-Holocene, when the eustatic sea level was stabilised, and local-regional processess were significantly operational, large accumulation of such rocky formation took place along the shoreline of the island. In some places of the island, the rocks directly face the open sea and normally cropout approximately at sea level. These occurred in bands; the oldest band lies farthest seaward and the youngest continues inland under the beach.

Lagoons are most remarkable geomorphic features of the St. Martin's island. Records from two of these lagoons (Borehole No.1&6; see Fig. 2) show well the post-glacial geomorphic evolution history of the island. Lagoon sediment reveals at least fours sequences of depositional environment. Dark gery clayey silt fine sands were deposited by offshore current during the mid-Holocene, which has been overlaid by silty sand with drifted broken shales and corals fragments.

However, a sequence of dark silty sands of late-Holocene regressive phase with frequent coral fragments dominate the major litho-sequence of these lagoons. The southern most lagoons is well sheltered by outcrop of rocky corals and boulders, and is currently being deposited under a regressive phase indicating the land uplift due to local tectonic activities.

The island's physiography is almost flat and consists of about one meter thick bulf grey to dark grey alluvium silty clay with frequent sands overlaying the thio-facies of coarse to medium grey-sands with mica of marine origin. Formation of this alluvial sequence took place during the mid-Holocene when the sea level stabilised followed by a regressive phase. During this period the formation of small islets (Siradia) in the south also began and continued. Spit bar sands began to deposit since the later part of the Holocene to connect the islets.

Dunes are the most remarkable geomorphic features of the island of recent origin. Dunes sands (Borehole 2 & 4) are fine to medium in texture and coated with fine broken shales, rare organic particles and living rootlets of herbaceous plants. The sediment shows some signature of initial stage of soil formation. The dune sands are underlain by light grey alluvium clayey-silt. (also see below).

Records collected from the salt-marsh landform (borehole 5) bears special interest to explain the geomorphic history of St. Martin's island. The site shows two clear sequences of mangrove peat, separated by a 15 cm thick layer of silty to fine sand with frequent broken shale. The peats are light blackish to dark grey in colour, show rootlets in their growth position, *in situ* in origin and include fine silt and clay of mangrove ecosystem. Islam (2001) identified the coastal mangrove peat of Bangladesh as signature of the sequences of marine regressions, which can be correlated well with the peat sediment identified in this study area (Borehole 5). The marsh sediments of the St.Martin's, thus records at least two sequences of marine regressions, each followed by a transgression since mid-Holocene. However, palynological studies and 14C dating of marsh sediments can collectively be applied to make further conclusion.

Dune formation and stability

Coastal dunes are formed by the accumulation of sands due to interaction of wind, current and waves along the shore. Dunes are well developed at some places along Bangladesh coast, particularly along the Chittagong coast and more specifically at the St. Martin's island. A very few attention is given to illustrate the morphology and evolution history of these dunes in the past. However, in this study attempts are made to understand the morphological characteristics of coastal dune system of the island based on field survey and laboratory analysis of dune sediment and vegetation samples.

It has already been mentioned earlier that dunes of the St. Martin's island are classified in to high and low type (see Fig. 1). High dunes are ridge like topography, up to 5 m in height, very steep windward but gentle leeward slope and are parallel to the shoreline. Low dunes are less than 2 m in height, undulating surface topography, gentle sloping both land and sea sides, extended over a broad area and widely distributed along the coastline of the island. Table 3 shows some of the characteristic features of these dunes.

Table 3: Characteristic Features of Dune System at the St. Martin's Island

Characteristic features	High Dune	Low Dune
Height	Up to 5 meters in height	Less than 2 meters in height
Windward slope	Slope very steep, up to 45o angle	Gentle slope, less than 15o angle
Leeward slope	Gentle slope	Gentle slope
Surface topography	Ridge form with sharp peak	Undulating with two or more domes
Dune face	Erosional on seaside and pogradational on landside	Stable on both seaside and land side.
Beach	Narrow	Wide
Structure	No bedding formed	Aeolian cross bedding
Soil formation	Poorly formed	Good soil formation
Sediment types	Medium to coarse sand, poor in organic material, some broken shale	Very fine to medium sand, good organic materials
Foraminifera identifies	*Streblus sp. Quinqueloculina sp Elphidium sp. Ammonia sp*	*Cebicides sp. Orbidorsalis sp. Elphidium sp Ammonia sp.*
Vegetation	Poorly vegetated: common vegetation *Pandanas, Teporosia.sp, Cynodon sp. Sida.sp. Eupatrium.sp Vitex negunda*, and *Mesoneuron sp*	Well vegetated: common vegetation *Cocos mucifera, Areca catechu, and Bumbosa arundinacea,*
Major uses	As natural defense against storm surge and wave.	Settlements, fish-drying fields and small scale vegetation production

Three cross-sections were made to examine the dune topography, dominant plant communities and their relationship with the sea level position (Fig. 3). Three major land successions of these dune topographies, from the high tide mark, are sandy beach, dune system and plain land. Dune systems are mostly developed within 40-60 m basement parallel to the shoreline. The bottom sediment on windward side is very rich in foraminifera assemblage and less in organic materials.

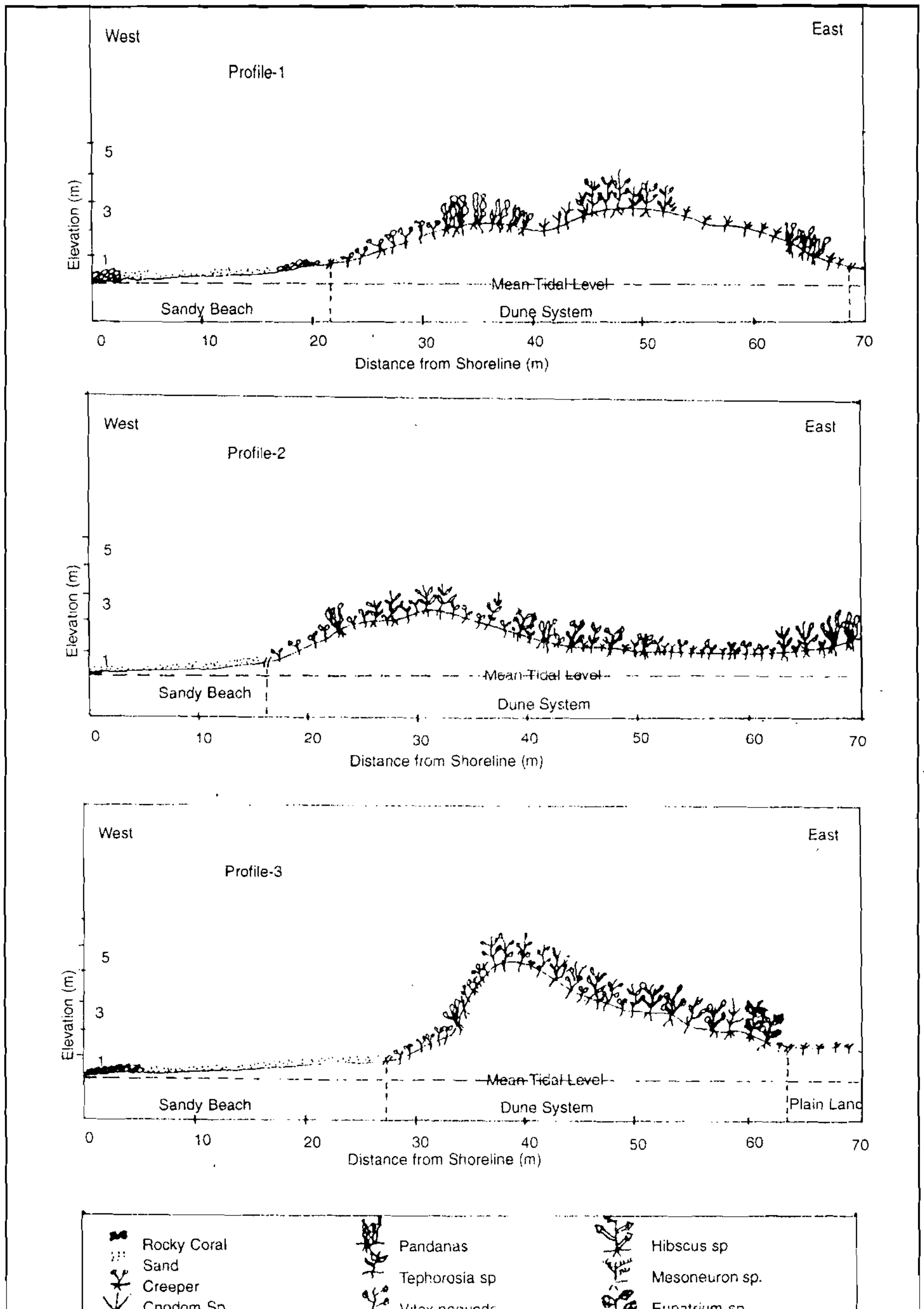


Figure 3: Dune profiles in the St. Martin's Island

This side is very dynamic, very poorly vegetated and under continuous process of reworking of sediment due to both erosion and accumulation of drifted sands. The most common vegetation types on this part of dune are *Pandanas, Teporosia.sp* and *Cynodon sp.* However, leeward side of dune system is nearly stable and well covered by vegetation. Some common vegetation types at this side are *Sida.sp., Eupatrium.sp, Vitex negunda,* and *Mesoneuron sp.*

Interpretation of geomorphic evolution of this dune system is very complicated and need detail systematic investigation. The early analysis of some of the records collected as part of continuous observation by the first author with his team shows that at least there are two major phases of dune formation in the St. Martin's island. The oldest sequence was during the late-Holocene marine regression and the other sequence is in recent regressive stage of the sea. However, in recent years the dunes at Galachipa are under continuous stress of erosion due to wave and wind actions.

Wind plays the most significant role in dune formation. Aeolian activity is usually accelarated by abundant transport of sands towards the coast or by destruction of plant cover on older stable dunes (Hellemaa, 1998). Sand accumulation to dune formation is related to the relative falling stage to the sea level, when ground water level also falls at the coast and exposed more sand to drift under Aeolian force. Rutin (1983) suggested the mathematical model to determine the ability of wind to transport sand at different height level and found that ability increase with 3.2 power of the wind velocity. An attempt was made in this research to arrest sediment at different height levels using sediment traps. Ten such traps were placed along the coastline facing the sea. These traps were designed and installed (see plate 6) following the description of Rutin (1983). However, no sands were trapped in any of the trays, except a single tray at 60 cm height near the west coast of Galachipa. Rutin (1983) demonstrated that in most cases the maximum amount of transportation of sands for the development of coastal dunes took place at a height of less than 60 cm. However, the process of such transportation is the results of differences in source of sand drift, the topographic relief, the general wind flow, velocity and direction, and air humidity at that area. In winter the winds are mostly north and northeast, and along Chittagong coast the speed ranges from 3 to 7 km/hour (Ahmed, 1957). This aeolian force is not enough to drift sands from the shore to initiate and develop coastal dune morphology at the St.Martin's island. Dune dynamics are very much seasonal and sands are mostly drifted during the dry period from March to May when the humidity is less, sands are dry and wind speed is strong enough to carry sand particles.

Bathymetry

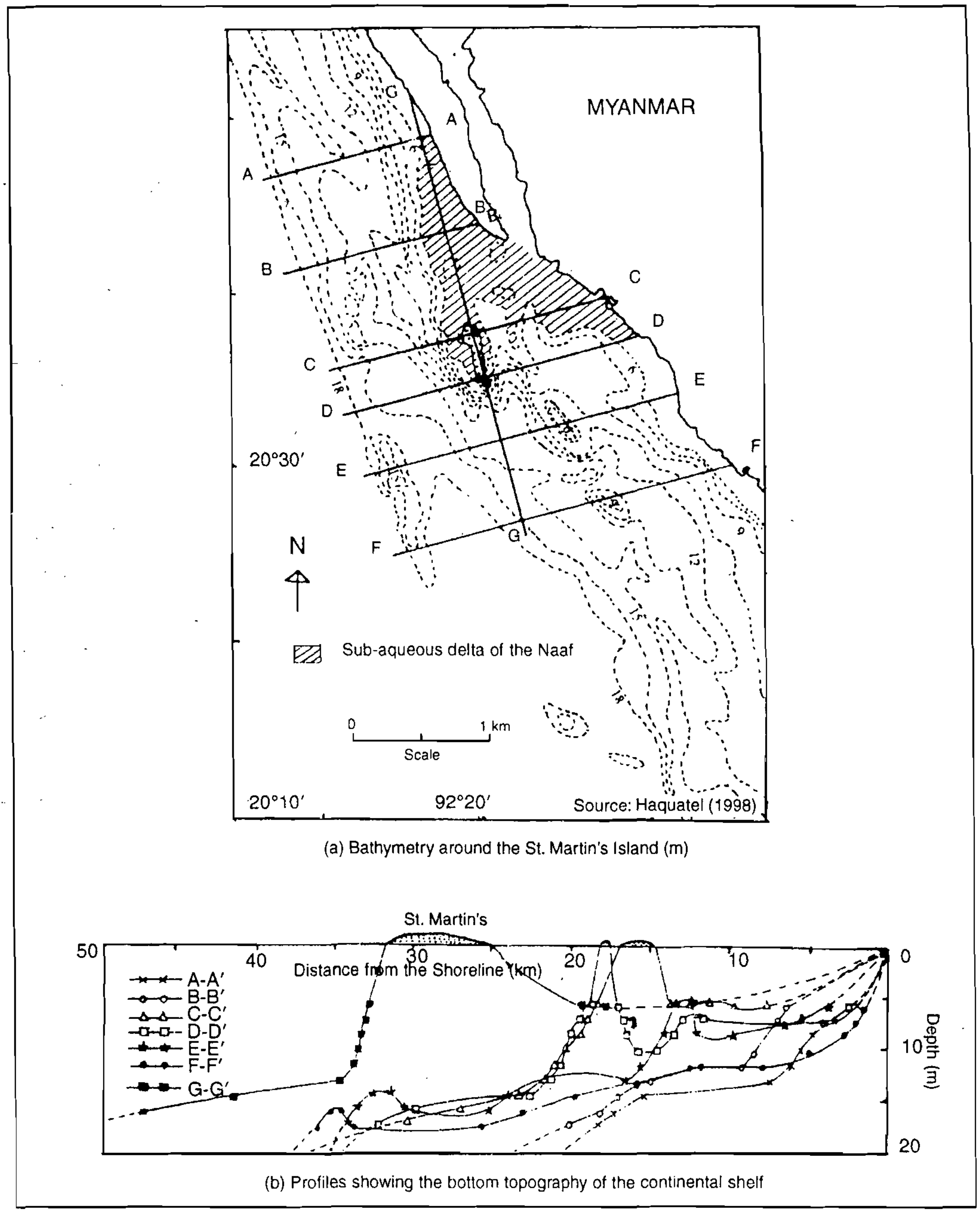
No attempt has yet been made to establish the relationship of evolution history of the island with the surrounding bottom topography and physical oceanographic processess. In this study the bathymetric map of the area around the St.Martin's island, showing the delineated outline of topographic features of the shelf, has been examined. One longitudinal and six cross-sectional profiles are drawn to show the distance-depth relationship (Fig. 4). Haq *et. al.* (1998) argued that the origin of the island is structurally controlled and the structure can be evaluated from seismic profiles, attitudes of beds and also from topographic expression of the sea floor of surrounding areas. Structurally the St.Martin's island is a part of the at least 84 km long and 22 km wide St. Martin's anticline of the Chittagong fold belt; the contour pattern of sea floor and attitude of bedrock is only exposed in this island. Topographic expression shows the converging contours on both north and south of the structure and has developed a wide sub-aqueous delta platform of the Naaf river (hatched area in Fig. 4). The water depth at this platform is less than 6 m and this sub-aqueous Naaf delta system is extended from Teknaf coast to southern most tip of the St.Martin's island, covering an area of about 200 sq.km. The shelf topography around this area has a sharp slope break between 6 and 12 meter water depth, and extended in north-south alignment from Teknaf coast to further south of the St.Martin's island. Near the southern end of the island the slope is very steep which indicates large scale erosion during most part of the Holocene. The 12 m and 6 m contour lines are two important topographic features which delineate the shoreline positions during the early and mid-Holocene period, respectively. The 18 m contour line, placed at about 10 km from the island is the seaward base of the St.Martin's anticline. Since the structure was deeply eroded by wave action on the south and southeastern sides, as shown from steeper slope of the sea bottom, obviously the contours bent towards the axis intersecting the bedding planes over this side (Haq *et.al.*,1998).

Geomorphic evolution: a discussion

A wide range of records from filed level investigations, their laboratory analysis and available imageries, maps and chars have collectively been used in this study to infer the geomorphic history of the St.Martin's island which are discussed below.

i) Process operating

The island is structurally controlled and it's present landform has been shaped by four major processes, such as sea-level change; tectonic activities; geomorphic process and anthropogenic activities.



(a) Bathymetry around the St. Martin's Island (m)

(b) Profiles showing the bottom topography of the continental shelf

Figure 4: Bathymetry around the St. Martins Island

a) Sea level change:

The causes of sea level movements are complex interactions of a number of factors operating globally, regionally and locally. These causes are mostly naturally induced and derived from climatically and geologically controlled components. The adding of post-glacial melting water from land to sea has increased the volume of the global ocean and has been considered as the single major cause to post glacial rapid rise of sea level. This climatically controlled movement of melts water under the condition of glaciation and deglaciation has been defined as glacio-eustasy by Fairbridge (1961). Based on coral evidence from Barbados Fairbank (1989) suggested that during the last glacial maximum, about 18,000 years BP, the sea level was 120m below the present. During this time most part of the Bengal continental shelf was the exposed continental landmass. For the Bengal basin the sea level curve presented by Umitsu (1987) shows a high rate of 7.27mm/yr. sea level rise since the late Pleistocene. The early-Holocene rapid eustatic rise of sea level from deglaciation played the significant role to shape up the shelf and coastal geomorphic configuration of Bangladesh including the area surrounding the St.Martin's island.

b) Tectonic activities:

Tectonic components comprise all crustal deformations of endogenetic in origin, which may result in subsidence and uplift of wide areas. Jelgersma (1961) recognized tectonic movement as an important variant to land/sea movement particularly in mobile belts and in areas recovering from isostatic down- warping. Since mid-Holocene there are evidences of both rise and fall of sea levels, even in a small geographical context. Such spatial variation of rates and directions of relative sea level movements are dominated by local and regional tectonic activities (Jelgersma and Tooley, 1995). The Bengal Basin is a part of the Himalayan orogeny and parts of the Basin have been uplifted as the result of neotectonic activities (Morgan and McIntire, 1959) . Bakhtine (1966) also argued that the geological structure of the eastern folded flank of Bengal basin comprising the hill ranges of Chittagong and Chittagong Hill Tracts, and is tectonically active and uplifting. Haq *et.al.* (1998) suggested that the converging topographic expression of the St.Martin's anticline can only be explained as the result of tectonic uplift of the anticline. Due to absence of seismic profiles and geophysical records, the rate of uplift has not yet been possible to quantify. However, Islam (1991) recorded the temporal variation of tectonic uplift of the Madhupur Pleistocene Terrace ranging from 0.15 mm/yr, during the early Holocene to 0.25 mm/yr, during the recent time. Such an accelerating rate of uplift in recent time could be due to tectonic readjustment of regional geological structures, including the St.Martin's anticline.

c) Geomorphic process:

The coast, including the offshore islands and continental shelf is a zone of intense energy input of ocean current, river discharge, wave, tide and wind, and shows a complex interaction of these sources. The shelf topography and the geomorphic characteristics of innumerable offshore islands of Bangladesh are predominantly delineated by the sediment influx from the upstream and also reworking of sediments from tide, tidal surge, wave and ocean current. Physical geography of the hinterland and climate conditions determines the amount and composition of the fluvial discharge. The Ganges-Brahmaputra-Meghna (GBM) system annually deliver an estimated 1.8 to2.4 million tons of sediment in to the Bay of Bengal most of which is bypassed in to the deep sea through the Swatch of No Ground (Jabber, 1979). Kuehl *et. al.* (1989) calculated that if there was no such bypassing of these sediments, the outer continental shelf would rise up to the present sea level in less than one thousand years. They also calculated that 20% of total riverine sediment load is deposited by flows generated during the surge of tropical cyclones. Although the sediment influx from the GBM system is primarily being deposited at the Meghna estuary to develop the sub-aqueous delta front and innumerable offshore islands, the dispersal of such influx is very poor along the eastern part of the shelf and nearly absent at water deeper than 50 m. However, sediment discharge from the Naaf river, sediment washes from the mainland (Teknaf hills) due to erosion and reworking of marine deposits have developed a complex depositional environment in this part of the shelf. Such geomorphic processes affect the sedimentation to develop the sub-aqueous delta of the Naaf river and also play the significant role to geomorphic shaping of the St.Martin's island.

d) Anthropogenic activities:

The history of human occupancy in the St.Martin's island goes back to about a thousand years old with the migration of 13 families from the mainland (Gain, 1998). Now the population has increased to about 6 thousands. Due to increasing population, human activities and changing land use practice, the landform and physical environmental setting of the island have now become fragile. The St.Martin's island is the only off-shore island having magnificent sandy beach, beautiful accumulation of corals and unique dune features. In recent years, particularly during the winter season, unplanned tourist activities in this tiny landmass have increased significantly and the physical environmental setting of this only natural park of the country is now under tremendous ecological stress. Mining of corals and the destruction of this natural ecosystem have now become a great concern to academics, policy makers and local people. Oil spill from mechanized boats has increased in recent years. Rotten fishes and garbage are also thrown straight to the seawater. All these activities by local people and tourists have lead the morphology and surrounding physical setting of the island changing and environmentally vulnerable. Moreover, human activities in the mainland, particularly changing land use pattern and erosion from hill surface have lead sediment to disperse in to this part of the shelf, which eventually affect the physical shape of the island.

ii) Stages of evolution

Papers published earlier on geological evolution of the St. Martin's island differ in their respective scientific arguments (Khan, 1964; Chowdhury *et. al.*, 1992; Chowdhury *et. al.*, 1997; Alam and Hassan, 1998; Haq *et. al.*, 1998). However, in all these papers sea level change has commonly been identified as the key factor to the formation of the island, and the occurrence of corals and their stony boulders have been acknowledged as the most remarkable geomorphic feature. In this study the Quaternary evolution history of the island has been reconstructed at different geological stages, which are as follows:

a) Pleistocene

Pleistocene is an important geological period of Quaternary, the base of which is placed at about 1.6 million years ago. This period is characterised by an extensive but highly variable ice cover throughout greater part of the northern hemisphere and delineated by their associated climatically controlled sea level fluctuations. At least four glacial-interglacial cycles have been identified during this period and the last interglacial stared at about 0.13 million years, which lasted for around 11,000 years (Roberts, 1989). During this period the global temperature was 2-5oC higher than today and an eustatic sea level rise of 5-6 m above the present has been recorded (Lowe and Walker, 1997). The exposed outcrop at Dakshinpara was deposited during this period, which Chowdhury *et. al.* (1997) has identified as the Pleistocene shoreline about 6 m above the present sea level. Carbonate sands within the inter-tidal zone are cemented by fine fibrous aragonite to form these rocks. These rocks are typical geomorphic features of the inter-tidal zone and indicate a higher strand line of the Pleistocene, although due to lack of records on quantitative measurement of tectonic uplift, the vertical relationship of their accumulation in relation to present sea level position is difficult to identify. However, at present this Pleistocene rocky landform is the oldest exposed part of the island.

The last glaciations is an important geological event in the history of the earth which started at about 0.11 million years ago and attained its maximum extents around 18,000 yrs BP with the global sea level drop of up to 120 meters (Fairbank, 1989). During this period the shoreline of Bangladesh was far south from the present and most part of the continental shelf was then exposed. The St.Martin's anticline remained as part of the mainland of Chittagong fold belt during the greater part of late Pleistocene.

b) Early Holocene

Since the last glacial maximum, two distinct periods of sea-level changes can be recognised. Between 18,000 and 6,000 yrs BP, due to the melting of mid- and high-latitude ice sheets, there had been a rapid eustatic rise of sea-level, a processes operating globally. Tooley (1978) calculated an extraordinarily rapid rise of sea-level, at a rate of 34-44 mm yr-1 at about 7800 yrs BP for North-west England. Such rapid rises of the early Holocene sea-level have also been demonstrated by a number of researchers (Jian *et al.*,1991; Loveson, 1993; and Hashimi *et. al.,* 1995). The empirical evidence of relative sea level movements of Bangladesh during the geological past is very scanty. Impression of the country's sea level scenario is primarily derived from the so called eustatic curve, without attaining any consideration to the local records. However, based on litho-facies in the Holocene coastal sedimentary sequences Umitsu (1987) identified early Holocene rapid sea level rise, with a drop at about 12,000 BP along Bangladesh coast. During this period of rapid sea level rise the shoreline began to shift landward with some pauses as recorded from sharp slope break. Early Holocene shoreline erosion is well documented along the southern edge of the St.Martin's anticline. The island became disconnected from mainland at about 6000 yrs BP (Haq, *et. al.*, 1998). Only the Pleistocene rocky landmass remained as the main island at that time. At least two sandy islets emerged north of the Pleistocene rock, which were encircled by stony corals and rocks, and were connected by a narrow spit bar, as presently seen their analog at the south of the island.

c) Mid-Holocene

Since the last 5000 years, due to less significance of glacial components, the global sea level is stabilised and there has been very little change of eustatic sea-level, perhaps less than 0.50 m derived from deglaciation (Clark *et al.*, 1978). The sea-level movement during this period was dominated by regional and local tectonic activities, long term subsidence, release of water and sediment from the catchment, and anthropogenic activities (Jelgersma and Tooley, 1995). The mid-Holocene slow rise of sea level with some sequence of regressions was suitable to accumulate coral reef within the tidal ranges of the island. Boulders and conglomerates of cemented calcium carbonates and fossiliferous materials were also deposited along with rocky corals. Shallow lagoons were well protected during the mid-Holocene with very slow rate of siltation. An about one meter thick lagoon sediment has been deposited under the regressive stages of the sea. However, the accumulation of alluvial deposits on top of the reef formation is of recent geological origin. Medium to fine grained calcareous sand materials, derived from the fragmented coral debris are air borne and have developed extensive alluvial plain and lowlands morphology of Uttarpara and Dakshinpara. Two sandy islets (now Siradia) begun to emerge on the south of Dakshinpara, which remained disconnected from mainland by deep water, even at low tide.

d) Late-Holocene

Late-Holocene sand accumulation accelerated and the first stage of dune formation at the St.Martin's island initiated. During this period due to rapid siltation by tide, wind and wave Uttarpara and Dakshinpara became well connected, the area near Galachipa became much wider than today and the island got nearly its present shape. An extensive tidal plain and salt marsh developed along the shoreline. Peat composition indicates the presence of mid to late-Holocene mangrove vegetation in this island. Sand begun to accumulate to develop spit bar to connect the islets with the mainland of the island. During the recent period coastal dunes developed earlier become broader, stabilized and covered with dense vegetation; but the secondary cycle of dune formation is currently in operation under the relative recession stage of the sea. Most of these dunes are unstable, facing aeolian erosion on their windward side and very sparsely vegetated. Due to wave cut erosion the landform at the middle of the island on its west is rapidly reducing the width and if it continues in near future the Uttarpara and Dakshinpara might get again disconnected from each other.

Conclusion

The St.Martin's island is not a typical coral island, rather it is a submarine hill, similar to Teknaf range, on top of which it bears some corals records of Holocene origin. The theory of coral formation is not enough to explain the geomorphic evolution of the island. However, it's can better be explained after the Daly's

(1920) glacial controlled theory of sea level movement and neotectonic activities. A drop of sea level during the glacial period would form an eroded platform, on which the coral accumulation started with the rising of sea level. The tectonically controlled anticlinal basement of the island indicates a thick accumulation of sediment at the synclinal troughs. The shallow bottom topography of the shelves does not necessarily mean only the emergence of landmass under fluvial conditions due to southward migration of the coastline, rather it indicates rapid siltation and high sediment accumulation. In the present study only some of the salient features of the geomorphic evolution history of the island have been inferred, yet remaining many scientific questions unexplored. However, through systematic investigations, particularly based on seismic profiles and continuous field recording many of such queries can be answered and thus suggested.

Acknowledgement:

Some field data collected by the students of Geography Departments of Chittagong University (session 1999-2000) during their fieldwork at the St.Martin's island in winter 2001 under the leadership of the first author have also been used in this study and is acknowledged. Thanks are also due to Prof. K. Maudood Elahi, Department of Geography and Environment, Jahangirnajar University for his comments to improve the text.

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SEA LEVEL CHANGE: ITS IMPACT ON WEST BENGAL COAST

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Abstract

This paper reviews the record of the Quaternary sea level changes as a 'natural' phenomena and correlates the evidences of such changes from the east coast of India and West Bengal. Within a time scale of 100 years, however, the 'relative' change of sea level with respect to land becomes more important than the 'absolute' eustatic level. A global rise in the sea level definitely affects the relative position of the land sea interface which is otherwise affected by local subsidence or uplift. In this work, we have considered the acceleration of the rate of sea level rise as a consequence of anthropogenic contribution, and used a methodology for estimating the relative sea level change from tide gauge data. A link between the sea level rise and coastal erosion has also been established using a case study of Sagar island of Sundarban delta as an example. Finally the impact and implication of such accelerated change of sea level have been discussed and policy options suggested.

The sea level along the East coast of India has ever kept changing since the Geological past. After the formation of the broad outline of the present day east coast by 150 million years BP, the shoreline positions changed for several times over the past 100 million years due to complex land-sea interactions.

Major transgressive events in response to global change in sea level can be recognised (Mukherjee & Hazra, 1997) in the Cretaceous, Eocene, Miocene, Plio-Pleistocene (Fig.1) from the subsurface seismic and drilling data. However, macro-level response of the 2,735 km long coastline over a larger time window of 100 million years differ considerably when we consider a lower order space-time scale, like the response of 273.5 km long coast line over the past 1 million years or that of a 2.7 km long coastal stretch over the past 100 years.

Unlike the Geologic past, sea level changes during the last and the present century, have had considerable impact on human existence and activities along the coast. While planning development of coastal regions, we often fail to consider the possible impact of the sea level change on the plan area. For environmentalists concerned about coastal pollution and degradation, sea level change appears as a manifestation of human induced global warming which can be altered by

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managing the developmental activities, CO_2 and methane emission. Coastal planners often tend to overlook the link between coastal erosion and sea level rise while attempting to resist submergence of coastal stretches or degradation of mangrove forests.

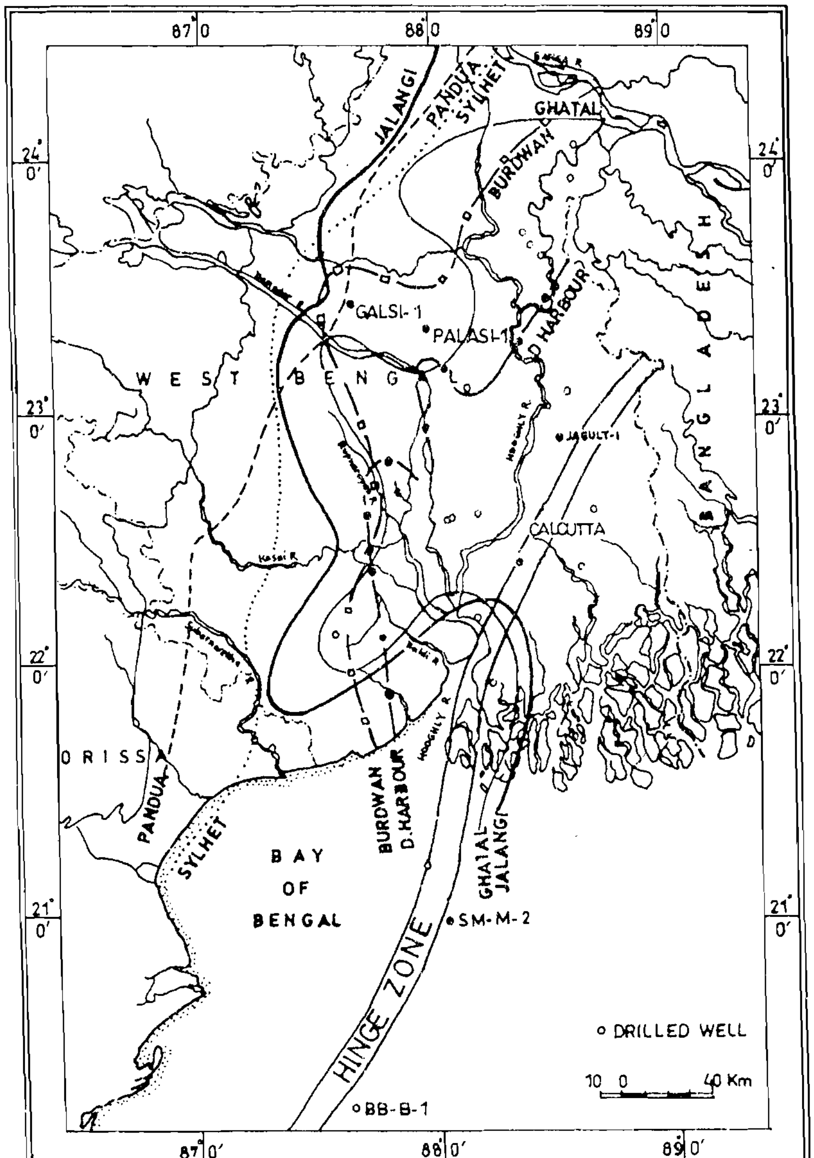

Figure 1: Change of shoreline position through time in West Bengal (Mukherjee & Hazra 1997)

Quaternary sea level change

The Quaternary period, comprising last two million years of earth's history, is characterised by strong climatic variation. The beginning is marked first, by a major glacial stage succeeded by alternating glacial and interglacial stages. Alternating cold and arid, warm and humid conditions represents the glacial and interglacial stages in the tropic. The most important phenomenon related to such variation, observable all over the globe, was that of glacio-eustatic sea level changes. The glacial stage marked by fall of sea level, inter glacial by high sea level.

The Quaternary climatic history has been subdivided on the basis of drift deposits in the river Danube and it's various tributaries in Alps, and five major glaciation events separated by transgressive deposits of warmer inter glacial periods have been recognised. Further studies (Shackleton & Opdyke, 1973; Moore 1982, Chapel & Shackleton 1986) have established that sea level fluctuated many more times than envisaged by earlier workers. Kukla (1977) correlated original Alpine units with oxygen isotope results and recognised 17 glacial and inter glacial period in Europe over the last 1.7 million years.

There is little agreement among the researches about the actual values of high and low sea level. It is observed by some workers (Fairsbridge 1961) that sea level attained a highest strand line position at +220 m during the Calabrian transgression. Though correlation between regression and low sea level has been generally agreed upon, doubts have been expressed about very high transgressional seastrand (Curry 1961, Shepard 1963, Moore 1982). Erosional terraces and coastal deposits occurring at higher levels do not necessarily indicate the high sea level position. Tricart (1974) has contradicted the older concept of very high sea level strand. He suggested that Quaternary sea level never rose beyond +40 m of the present level and inferred only +1.5 mm rise during the last Flandrian transgression. Cumulative evidences from different coastal areas (Curray 1969, Gulicher 1969) indicate a Holocene transgression of +1 m to +6 m between 6,000 to 2,000 BP at least in the Indian Ocean (Merh, 1987). The sea level fluctuation diagram prepared by Cooper (1991) appears representative in this regard (Fig. 2).

On the east coast, evidences of recent to sub-recent sea level change can be observed from the submerged marine terraces or calcareous oolites at 60–120 m of water depth. It has been estimated from the dating of coral Acropore, 125 km. off Karaikal coast, that sea level during the last Glacial maxima 18,000 years before present was 100 m below the present level (Narasayya *et.al*, 2002). According to this estimate sea level has risen at the rate of 4.61 m per 1,000 years during the last 11,000 years. The youngest of the event represent the Flandrian transgression 6,000 years before when the sea level reached 6 m above the present sea level. Till 3,500 years BP, the East coast registered an event of regression resulting in many geomorphic features like parallel beach ridges or marine terraces.

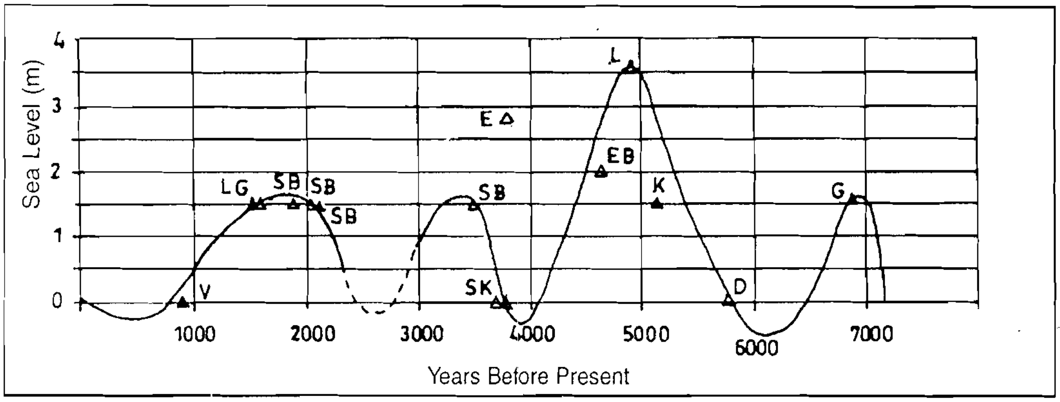

Figure 2: 7,000 years of sea level fluctuation (*after Cooper, 1991*)

Evidences along West Bengal Coast

Surface mapping in 1:50,000 scale by GSI has been able to establish several Quaternary deposits in the coastal tract of West Bengal. In the Rupnarayan–Damodar – Bhagirathi basin, five major formations (Lalgarh, Sijua, Bethuadahari, Panskura and Diara) ranging in age from late Pleistocene to recent (75,000 years BP upper Lalgarh, recent coastal delta fan and flood plain deposit of Diara formation younger than 560±100 BP (Roy and Chattopadhyay, 1997). Subsurface continuation of the formations has been confirmed with water well drilling data on this part of the Bengal Basin. Five-fold divisions of slightly different lithology have been proposed for the coastal tract from Subarnarekha to Hooghly confluence (Lalgarh formation, Sijua formation, Kanthi formation Ramnagar formation, and Recent coastal deposits). A similar chronological span has been assigned to them with limited C14 data. Some of these formations have marine-brackish-nonmarine intercalations and stand as evidence for short lived marine incursions during late Quaternary times. While the relative antiquity of these Quaternary deposits has been established, there is no fine resolution chrono-stratigraphic studies (Wagner, 1990) to date the transgressive events. Micro-depositional environment and climatic studies are also needed in the two depositional domains.

Banerjee and Sen (1987) used ditch sample of average 13 m depth from four locations (Kolaghat, Calcutta, Barrackpur and Dumdum) for a critical paleo-ecological analysis. They also conducted radiocarbon dating of some samples containing biological remains to decipher chrono-stratigraphy from an assemblage recovered from - 7 m to - 2 m depth (from present MSL). From areas situated 80 to 120 m inland of present day coast, they established a transgressive phase (the Ammonia transgression) during early-to-mid Holocene (7,000 to 6,400 years BP). From recognition and dating of tidal mangrove species they recognised another phase of rapid inundation of inland areas by sea during 6,400 to 6,175 years BP. Depth distribution and radiometric age data of mangrove peat, wood logs and brackish water sediments have been used to infer sea level changes during Holocene. It is seen from their analysis that sea level rose from - 7 m at 7,000 years BP to 0m at 5,000 years, and remained stable there after.

However, for depth calculation, effect of neo-tectonic activities causing vertical shift of datable datum horizon (Dhondial, 1987 p.231, Roy and Chattopadhyay, 1997 p.195, Sanyal, 1999, Banerjee, 1993) needed to be considered further. It is also quite unlikely that sea level remained constant after 5000 years B.P. There are strong evidences from Bethuadahari formation of an event, which can be correlated to transgressive sea level changes between 6,000-7,000 years BP. Similarly, the overlying Panskura formation gives evidences of sea level changes between 3,000 to 100 years BP. Studies by the School of Oceanography, Jadavpur University, indicate a major transgressive event (2920±100 years) in the recently exposed palaeomud containing Glauconom Sculpta shell in Bakkhali to Chandipore coasts. Another minor transgressive event can also be found around 500-600 years BP.

Sea level did not remain stationary even during the recent past. Over the past century oceans have risen between 10 and 25 cm (Milliman *et al.*1989). From the analysis of geologic and archeological data it is found that over the previous 2,000 years rate of sea level rise was 0.4 mm/year (Masatomo,1993), which increased to 1-2.5 mm/year over the last century. Thus there has been a significant acceleration in the rate of sea level rise during the past 100 years, which may be attributed to the global warming and related physical processes. It is also alarming that the rate of land loss due to sea level rise will be significantly higher than that of the past.

Sea level rise and erosion

Relative sea level rise, a product of combined eustatic and isostatic changes, contributes to the process of submergence and erosion in the time scale of centuries to millennia. Local sea level change can accelerate erosion over a time scale of months to years. Storm surge is very critical to the magnitude of erosion over a time scale of hours to days. Seasonal effects or generation of waves of large height due to individual storm also contribute to erosion over a time scale of hours to months. Generation of waves of short period due to presence of storm or seasonal effects over a time scale of hours to months also have strong influence on erosion. Accretion process, on the other hand, is facilitated by the presence of waves of small steepness, and waning of long shore currents. Erosion rate at a given point along the shoreline depends on (i) direction of littoral drift (ii) inlet dynamics (iii) gradient of submerged sea (iv) relative mean sea level.

Global sea level rise is likely to increase submergence of low-lying coastal areas. High and low tides will advance landward and will lead to increased erosion as near shore waves, would break further inland. Erosion amplifies inundation and is responsible for greater land loss. The extent of inundation is determined by slope of the supra tidal coast. But the total shoreline retreat is determined by the average slope of the entire beach profile. Thus vulnerability of any coastal stretch will depend on (i) average beach slope, (ii) gradient of the supra tidal coast (iii) nature of sediment supply iv) relative rise in sea level.

For rapid appraisal, sea level fluctuations were estimated from the tide gauge data of Sagar island observatory (21°31'N 88°03'E) only. From similar analysis of tide gauge data, Warrick and Oerlemans (1990) estimated a global sea level rise in the order of 0.5-3 mm per year. In the present study, possible contributions of ocean-atmospheric effect, vertical land movement and anthropogenic activity have been carefully assessed and filtered out. A time series analysis of the undisturbed mean sea level, free from any perturbation has alone been considered.

Data for five years, *viz.*, 1985, 1990, 1996, 1997 & 1998 has been examined. Measurements have been taken daily on at 6 hour interval. Monthly mean sea level has been calculated using continuous data of high and low tides for every month. Annual mean sea level of the respective years has been calculated taking the mean of the monthly data. From the least square fitting of regression line on the data of annual mean sea level, an estimation of yearly rise of annual mean sea level has been made. The 'zero' elevation has been taken for undisturbed sea surface, free from any perturbation.

Comparing the annual sea level variation (Fig. 3) it is observed that the annual mean sea level has risen steadily between 1985 and 1998. This indicates a minimum 4 cm rise in relative sea level during the study period (1985-1998) of total 14 years. Some corrections have been incorporated to exclude the effect of sediment loading. Finally from a least square fitting of regression line on the data of annual mean sea level, a yearly rise of annual mean sea level has been estimated to be 3.24 mm per year. In the Ganga-Bramhaputra delta the suspended sediment load is high. If we consider sea level rise due to sedimentation to be 0.1mm per year, the net rate of sea level rise would be 3.14 mm per year (Hazra *et al*, 2002). This is significantly more than the present trend of average global sea level rise of 2 mm per year.

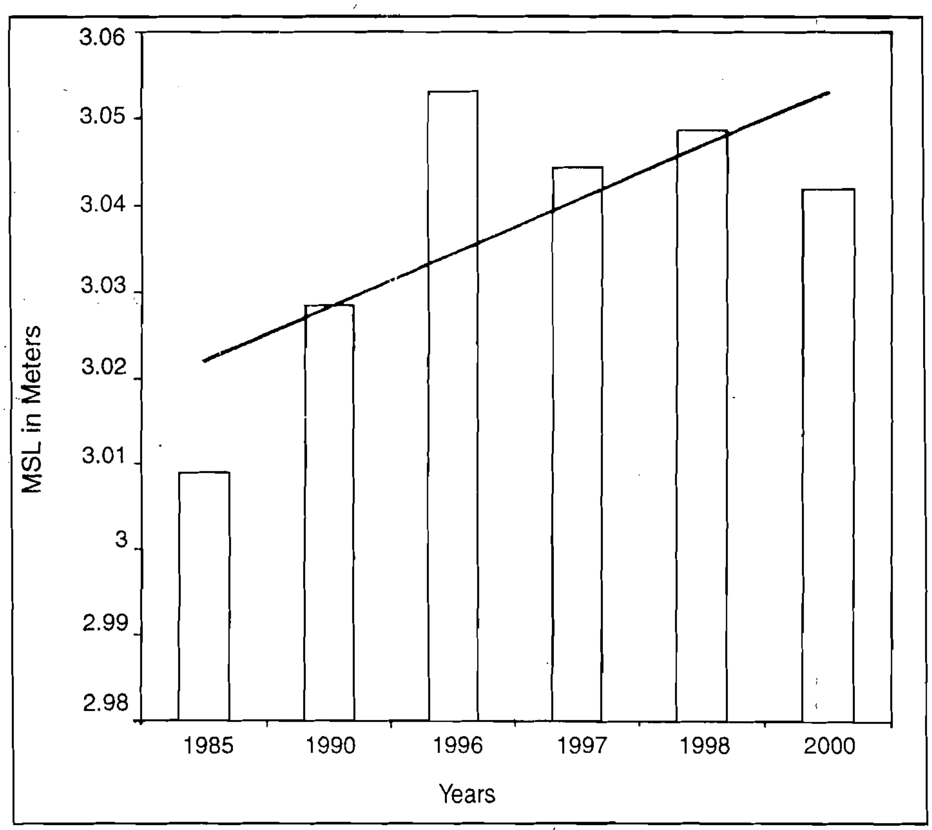

Figure 3: Yearly sea level variation near Sagar Island

Similar calculations for Paradwip, however, reveals a rate of relative rise in sea level to be 1.69 mm/year only, due to the emergent nature of the coast. Both in Sagar and Paradwip there is an indication of rise in sea level. At Sagar island the amount of rise is significantly higher than the global average. At Paradwip the amount of sea level rise is less than the global rate of sea level rise. It is therefore imperative that any effort of determining vulnerability or assessment of risk of coastal system should concentrate on rate of relative sea level rise in a local scale rather than the absolute sea level rise in a global scale.

In order to understand the effect of relative rise in sea level on coastal erosion, correlation analysis has been carried out over the following places (i) Sagar Island(ii) Chuksardwip (iii) Jambudwip (iv) Namkhana (vi) Mausuni island.

Data for this analysis comprise of erosion rates measured comparing Survey of India Topo-sheet of 1969 with satellite imagery of 1995 and 1999 using GIS techniques, and rate of sea level rise over the time spans 1969-1995, 1995-1999, 1969-1999.The correlation coefficients between rate of sea level rise and erosion rate at various locations have been computed for each of the six islands. In most of the cases the correlation is very strong, often over 90% (Hazra *et al*, 2002).

The changing shoreline configuration of the Sagar island at the Hoogly-Thakuran estuary were studied using the Survey of India Topo-sheet of 1969 and satellite imagery (*IRS 1B*) of 1995 and 1999. It has been observed that barring a few exceptions like Nayachara etc. where artificial measures are responsible for the growth of the island, the Sagar island complex has been steadily loosing land areas at an alarming rate over the past thirty years. During this period, the maximum land loss at Sagar itself has been in the order of $34Km^2$.

Assessment of coastal erosion along the Digha–Dadanpatra stretch reveals similar trend (Table I & II). A general observation is that while the entire coastal stretch from Digha-Shankarpur to West Dadanpatra is presently under severe coastal erosion, the eastern segment of Dadanpatra coast near a small tidal estuary is under stable to accreting condition. An acceleration of erosion is also noticed from the year 1994.

Analysis of sea surface temperature anomaly data spatially averaged (latitude range 20° - 25° N, longitude range 85° - 90° E) over the Bay of Bengal for the time period 1970-1999 has been done by the school (Sen, 2001, pers comm., Hazra *et al*, 2002) to find out the trend of temperature change. It has been observed that the mean temperature is rising at the rate of 0.019016°C/yr. The important aspect is that the rate of temperature rise is fairly correlatable with the rate of rise in sea level in this part of the Bay of Bengal. It supports the feature of global warming and have serious implication on the rising trend of sea level. If this trend continues, more submergence of coastal land in these regions is inevitable. As a result, considerable amount of land loss will occur making thousands of people homeless due to destruction of their original habitats and making them some kind of 'environmental refugee (Hazra & Baksi, 2001). Appropriate adaptation strategies and mitigation measures needed to be considered to tackle the 'slow onset' type disaster due to sea level rise, particularly in coastal areas.

Table 1: Shoreline changes along Shankarpur-Alampur coast

Longitude	Year		Status	Total (mt)	Rate (mt/year)
	From	To			
87° 31" 30"	1969	2000	Erosion	298.396	9.625
87° 32" 00"	1969	2000	Erosion	398.332	12.840
87° 32" 30"	1969	2000	Erosion	454.983	14.670
87°87° 33" 30"	1969	1994	Accretion	32.27	21.291
87°87° 33" 30"	1969	2000	Erosion	4.600	
	1994	2000	Erosion	142.716	23.786
87° 34"00"	1969	1994	Accretion	127.53	85.101
	1969	2000	Erosion	11.460	
	1994	2000	Erosion	355.35	459.256
87° 34" 30"	1969	1994	Stable		
	1994	1999	Erosion	100.84	620.169
87° 35" 00"	1969	1994	Stable	-	-
	1994	1999	Erosion	326.37	854.396
	1969	2000	-	-	
	1994	2000	-	-	
87° 35" 30"	1969	1994	Stable	-	-
	1994	1999	Erosion	312.69	352.115
87° 36" 00"	1969	1994	Stable	-	-
	1994	1999	Erosion	341.74	356.960
87° 36" 30"	1969	1994	Stable	-	-
	1994	1999	Erosion	327.94	054.520
87° 37" 00"	1969	1994	Stable	-	-
	1994	1999	Erosion	298.60	049.760
87° 37" 30"	1969	2000	Erosion	482.760	15.570
87° 38" 00"	1969	2000	Erosion	511.829	16.5000
87° 39" 00"	1969	1994	Erosion	298.06	311.900
	1994	1999	Erosion	270.339	54.060
	1999	2000	Stable		

Table 2: Shoreline changes along Alampur-Dadanpatra coast

Longitude	Year		Status	Total (mt)	Rate (mt/year)
	From	To			
87° 37' 30"	1969	2000	Erosion	320.098	10.350
87° 38' 00"	1969	2000	Erosion	381.090	12.290
87° 38' 30"	1969	2000	Erosion	441.249	14.230
87° 39' 00"	1969	2000	Erosion	415.037	13.390
	1994	2000	Erosion	139.384	23.230
87° 39' 30"	1969	2000	Erosion	415.996	13.420
	1994	2000	Erosion	224.882	37.480
87° 40' 00"	1969	2000	Erosion	294.761	9.510
	1994	2000	Erosion	121.347	20.224
87° 40' 30"	1969	2000	Erosion	182.334	5.880
	1994	2000	Erosion	61.993	10.332
87° 41' 00"	1969	2000	Erosion	173.326	5.590
	1994	2000	Erosion	95.993	15.998
87° 41' 30"	1969	2000	Erosion	138.898	4.480
	1994	2000	Erosion	86.737	14.460
87° 42' 00"	1969	2000	Erosion	96.304	3.110
87° 42' 30"	1969	1999	Accretion	146.166	4.870
87° 43' 00"	1969	1999	Accretion	233.120	7.770
	1999	2000	Erosion	35.110	35.110
87° 43' 30"	1969	2000	Accretion	301.730	9.730
87° 44' 00"	1969	2000	Accretion	336.586	10.86
87° 44' 30"	1969	2000	Accretion	250.870	8.090
87° 45' 00"	1969	2000	Accretion	77.92	52.510

Impact of recent sea level change on West Bengal coast

It is apparent from the foregoing discussions that the major impact of Sea level change in West Bengal is continuing erosion and parallel retreat of coast line, barring some small patches like New Digha or Dadanpatra Bar- east, close to the estuary. However, it is apparent that the deltaic Sundarban coast and open Digha coast would respond differently to the phenomena of sea level rise. Tectonically Sundarban has been a subsiding coast since the rate of sediment supply to the Ganges-Brahmaputra system used to be more than the rate of subsidence. This resulted in the growth and out building of Sundarban Delta even during transgressive phases. However, the Digha coastal stretch remained an emergent coast through out the recent geological past (last 7,000 years). Series of sand dunes extending from Kanthi stand as evidence of palaeo-shoreline positions. The preset accentuated coastal erosion from 1990s onwards points to the possibility that the rate of sea level rise has overtaken the rate of emergence of the coastal segment, along with reduction of sediment supply in the Subarnarekha estuary – which nourishes the beaches of Digha–Junput coastal stretch. This has resulted in strong coastal erosion in Shankarpur or Dadanpatra Bar which even till 1994 were considered as accretional areas.

In the Sundarbans, twelve southern sea facing islands are witnessing severe coastal erosion. From Sagar to Bhangaduani, it has been estimated that during the last 30 years–erosion has overshadowed the accretion in this deltaic island system. During this period, the Sundarban has suffered a net area loss of over 100 km^2. Even two islands like Lohachara and Bedford have vanished due to erosion and submergence, making 6,000 odd inhabitants of these two islands homeless 'environmental migrants'. In a recent study (Hazra *et al,* 2002) using computer simulation of island area in different sea level rise scenario, it has been estimated that by 2,020, Sundarbans may lose 14% of its land area and the number of people displaced from their original habitat in Sundarbans will cross 30,000 mark.

This is an alarming situation which needs immediate attention of planners and policy makers. In India there are no laws, policies, insurance or funds to protect, compensate and rehabilitate this group of vulnerable communities like 'environmental migrants'. Not only in Sundarbans, but also along Digha coast, several mouzas, which are still shown on the landuse and land holding maps, have been engulfed by the sea during the last 30 years.

Being on a mainland coast, the inhabitants would be forced to migrate further inland without being compensated for their loss of property.

During the COP 8 of the countries involved in the climate change protocol, this issue has been raised and discussed by the school. It is learnt that an 'Adaptation Fund ' has been created to meet this challenge globally. However, for any worthwhile negotiation to proceed, the Central Govt. can help greatly by taking this case up, as the people have been displaced by the sea-level rise accentuated by global warming. The global climate change and sea level rise has yet another serious effect on the intensity of cyclones and storm surges along the West Bengal coast. Though the frequency might show a decline, high impact events like cyclones more than 64-127 knots wind speed and associated surges with 10-30 ft high water column have shown an increase, and are likely to increase in future. This creates a situation where the properties and life along the Sundarbans come under further risk. Building of cyclone shelters, cyclone warning and cyclone-drill along with a well orchestrated disaster management plan can ameliorate the adversity of impact to a certain extent.

However though West Bengal is among the first states in India to come up with a coastal zone management plan, the plan does not include these aspects. In a country like India where coastal disasters (both quick onset and slow onset type) are likely to increase in future – disaster management should be an integral part of the coastal zone management plan of any state or area.

In order to come up with an implementable and pragmatic plan for our coasts, the concept of 'coastal zone' should be revisited. The coast of West Bengal registers a highest density of population growth and economic activity in the last two decades. With the enforcement of the 'coastal zone regulation' by the Supreme Court, developmental activities within 200 m and 500 m from the 'High Tide Line' have been restricted since 1991. Such an arbitrary zonation fails to take into account the diverse nature of our coasts (like Sundarbans and Digha), differential rate of sea level rise and vulnerability of the coastal disasters on one hand, and the social, economic and cultural diversity of the coastal community on the other. It remains a major challenge of this country to ensure sustainable development to our coast in spite of sea level rise. A community which is economically, educationally and socially developed will be able to meet this challenge in a much better way than the vulnerable hapless people coping with sudden disasters.

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COASTAL DEFENCE STRATEGY AND ITS IMPACT ON COASTAL ENVIRONMENT

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Abstract

Unique solution of wide-spread coastal erosion of any coastal stretch, cannot be provided. The solution of coastal erosion would have to be site-specific and depends on the beach characteristics and coastal dynamics of a particular beach stretch. This article review the interactive process of various shore protectives structures with coastal dynamics, *viz.* wave dynamics, littoral dynamics etc. and also illustrates the impact of various shore protective structures on coastal environment. Finally an example has been considered from West Bengal coast for further illustration. The considered coast is backed by a seawall. The impact of the seawall on coastal environment of the beach stretch has been illustrated here. The impact of a proposed structure (groin) along with the existing condition has also been explained and presented in this paper. It could also be explained from the proposed structure for the considered beach that the solution of beach erosion is site and character specific.

Introduction

Coastal erosion has become a widespread problem in the world today. Sixty percent of the world population lives close to the coasts. A constructive response to this issue is therefore very important and urgent. However, a single solution to the global erosion problem is not possible. The degree and pattern of coastal erosion and accretion depends on various factors like wave, tide, bathymetry, and beach morphology that includes size of beach materials, amount of slope gradient etc. All these change from one region to another. Hence, a local analysis of causes of sea erosion is very much essential before adopting any particular type of shore protective structure.

This article reviews the major types of defences used to manage coastal erosion and evaluates their application in some parts of the West Bengal coast.

Dynamic nature of the coast

The beach has a tendency to achieve dynamic equilibrium with sediments moving cross-shore and along-shore. On the other hand, erosion and accretion is a cyclic

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process due to variations in the influencing parameters of coastal dynamics. The time period of the cycle varies widely, depending upon beach dynamics, controlled beach morphology, bathymetry and wave climate.

If bathymetry of a particular coastal area gets modified due to changes in ocean dynamics, it results in alterations in refraction pattern and energy concentration. This may eventually change the erosion-accretion pattern in that particular stretch of the coast. Therefore, time series analysis of bathymetry may provide some idea on changing patterns of coastal erosion and accretion. The time series analysis of Survey of India (SOI) topo-sheets and geocoded satellite imageries (FCC) of different years often provide reliable information on rate and pattern of coastline changes. The changes of wind direction also show a seasonal change in erosion and accretion pattern.

Another major reason of beach erosion is the deficiency of sediments in seawater. Low amount of sediment load increases its entrainment capacity and erosion potentiality. On the other hand, when seawater is completely loaded with sediments, it starts to accumulate the coarser fractions on the shore face, resulting in accretion. This process of removal and accumulation often continues in alternative stretches in a beach and may change seasonally due to alterations in wave dynamics.

To prevent coastal erosion, various types of shore protective structures are commonly used. The effect of these structures on shoreline changes varies widely and tends to be site-specific. They can be selected only after detailed analysis of erosion problem of a given area. For example, selection of a structure for an eroding sandy beach is mainly done on the basis of predominant direction of sand movement.

Shore protection: natural and artificial

The beach itself provides natural defences against wave attacks, currents and storms. The wave heights continuously increase as they come towards the coast due to shoaling. *The first line of natural defence* against them is the slope (Fig. 1) of near shore bottom, which causes waves to break, dissipating their energy over the surf zone. Dunes are the *second line of defence* for absorbing the energy of the waves that overtop the berm. On the other hand, artificial shore protective measures are provided by constructing structures and by beach nourishment. In addition to these, bioengineering techniques, involving plantations and geotextile (may be jute or synthetic), are also used. The main types of natural shore protection forms and their comparable artificial counterparts are shown in Table 1.

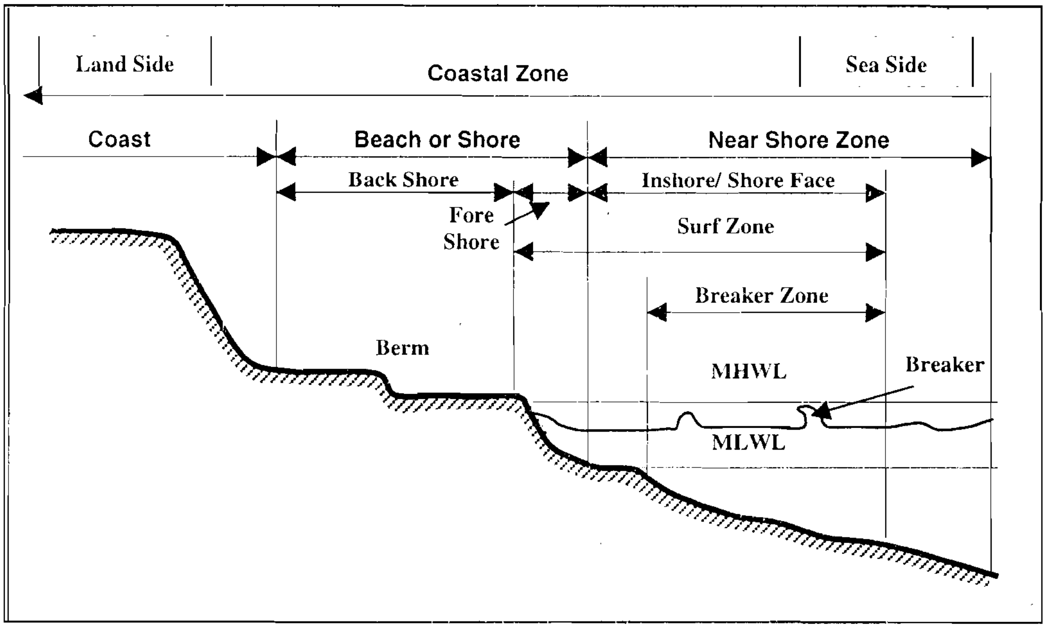

Figure 1: General profile of beach and shore face

Table 1: Natural and artificial shore protection (Bruun and Nayak, 1980)

Natural Shore Protection	Artificial Shore Protection
Shore rock	Seawall
Rock Reef	Submerged bulkhead or mound
Rock island	Offshore breakwater
Headland	Large breakwater perpendicular to or at an angle with the shoreline
Rock perpendicular to shore	Groin
Sea floor vegetation	Bottom mattress
Sand dune	Sea dyke
Material transfer to shore by: 1. Wind drift 2. Rivers	Artificial nourishment from land sources
Longshore littoral drift and on shore drift from sea bottom	Artificial nourishment from offshore sources
Natural bypassing of drift at tidal inlet	Mechanical bypassing of drift at tidal inlet

Measure of shore protection

This section describes the function and suitability of common engineering structures and techniques used for alleviation of coastal erosion problem. Selected bioengineering techniques are also discussed.

Shore-parallel structures

These are placed parallel or nearly parallel to the shoreline and are generally used where:

- the shore has to be maintained in an advanced position relative to the adjacent shore
- there is scanty supply of littoral materials
- there is little or no protective beach and
- a specific depth of water along the shoreline is to be maintained.

Bulkheads

Bulkheads are walls with vertical faces (Fig. 2). Constructed of steel, timber or concrete piling. The primary purpose of building bulkheads is to retain or prevent sliding of the land and the secondary purpose is to protect the land against damage by wave action.

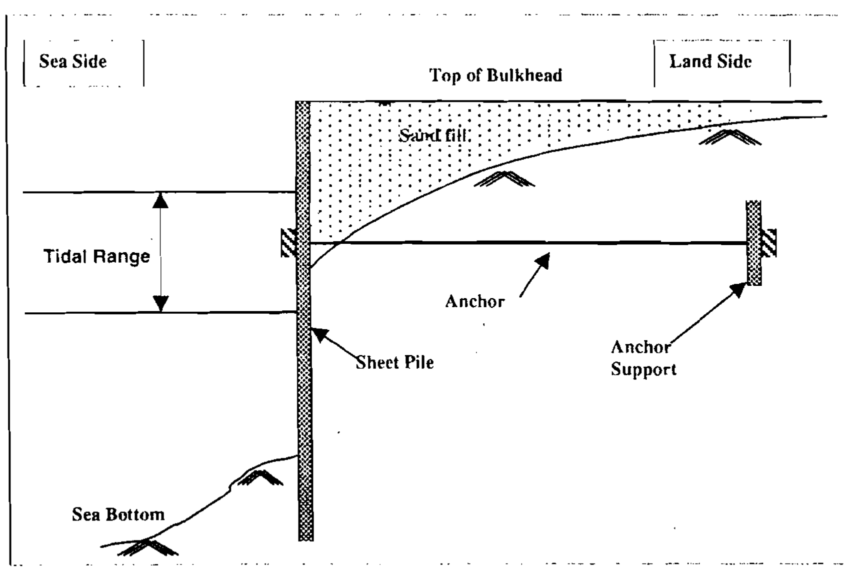

Figure 2: Schematic diagram of bulkhead

Utility and effect of bulkheads: A bulkhead provides a vertical face with considerable depth of water in its front that may be used as wharves. However, it, cannot be used to prevent erosion close to coastal resorts, due to unavailability of sandy beaches. It is also not an effective shore protective measure against toe scour caused by reflected waves.

Seawalls and revetments

The primary purpose of constructing these structures is to protect land and upland properties from damage by waves; the secondary purpose is to act as retaining walls like bulkheads.

Seawalls usually have vertical, curved, sloped or stepped faces according to energy condition of the beach requiring protection (Fig. 3). Constructed of mass concrete, concrete blocks or armour layers with suitably designed filter drainage at the bottom of the foundation, a seawall may be of impermeable or permeable in nature.

A revetment armours the slope face of a bluff or dune. It is usually composed of one or more layers of stone of required size and weight or of concrete construction (CERC, 1984). Its rough inclined face dissipates wave energy with less damaging effect than vertical walls.

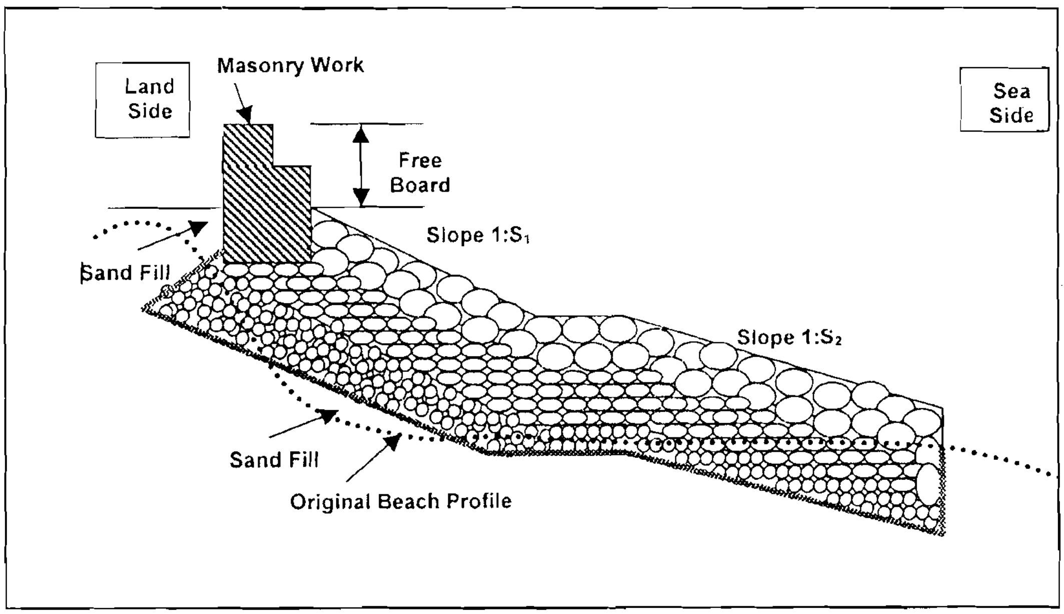

Figure 3: Schematic diagram of revetment-type sloped armour seawall

Utility and effect of seawalls and revetments: Seawalls may be structurally stable, but the construction cost is very high. They also hinder easy access to the beach. Since it is a gravity-type construction, the strength of the underlying soil at its base should be sufficient to carry the heavy load of the structure otherwise the structure, gradually, collapses. For this reason only apron type seawalls often seem most appropriate to construct. Although seawalls protect the upland from erosion, the downward force of the waves reflected from it can rapidly scour sand from its front, resulting in toe erosion and beach lowering. As a result, the slope of the beach becomes milder and consequently the breaker distance from the coast also gets reduced. A stone apron or toe wall with properly designed filter material or drainage type synthetic geotextile (presently using) of sufficient thickness beneath the armour layers is necessary to prevent this. In a region with strong longshore drift, the incident waves get diffracted at the down-drift end of the seawall and concentrate the whole energy at that point, which may cause severe erosion beyond the seawall stretch, at its down drift side.

Breakwaters

These structures are designed to protect an area from wave action (Pope and Rowen, 1983). Mostly used in connection with harbour protection, two basic types of breakwaters can be designed: shore-connected and offshore or detached breakwaters. They may also be classified into wall-type and mound-type breakwaters.

Utility and effect of breakwaters: Breakwaters have a lee area in which waves are lower than incident waves. They cause the wave either to break or to reflect depending on tidal stage and wave height. The amount of wave energy dissipated or reflected by the structures depends on their slope, porosity, depth of water at the toe, as well as wave height and wave steepness. Diffraction of waves also plays an important role in the functional design of breakwaters. Littoral drift is another important consideration in the planning and designing of breakwaters. It may become necessary to prevent erosion in the down drift side or too much accretion in the up-drift side in cases of shore-connected breakwaters. The width between two breakwaters or the distance between a single breakwater and the coast is very important with respect to harbour oscillation and surging. It is always necessary to prevent accretion at harbour entrances. Offshore breakwaters may cause less interference with littoral drift. However, because of wave diffraction, a tombolo may form at the coast (Fig. 4).

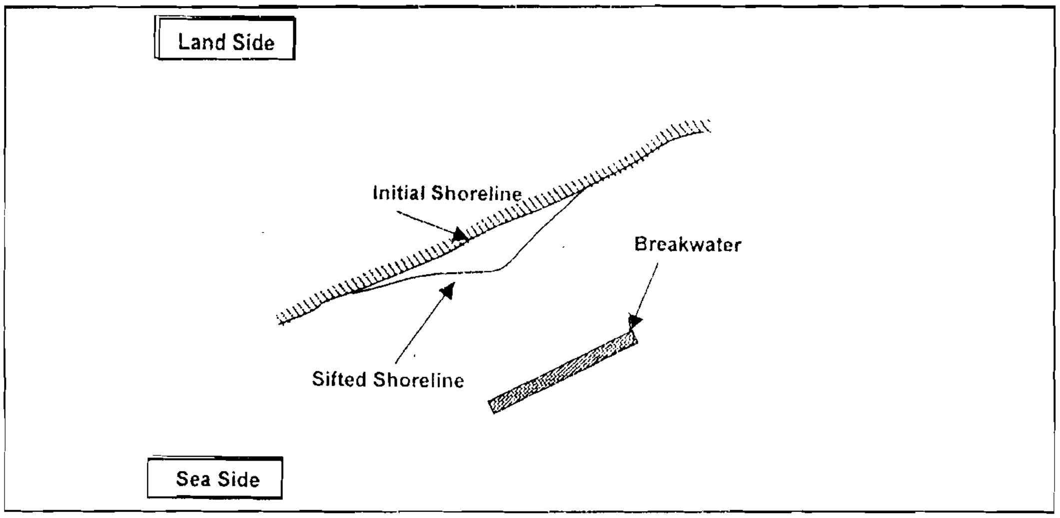

Figure 4: Schematic diagram of detached breakwater

Shore-normal structures

Groin

This is a barrier type structure placed perpendicular to or at an angle to the shoreline to intercept and trap littoral drifts. A typical groin extends from beyond top of the berm to the normal breaker zone (Wiegel, 1964; LeMehaute and Soldate, 1980). Groins are mainly used to widen or to provide protection to recreational beaches. They may also be used as a littoral barrier to prevent accretion in down drift areas. A schematic diagram of a groin showing its impact on shoreline changes is presented in Fig. 5.

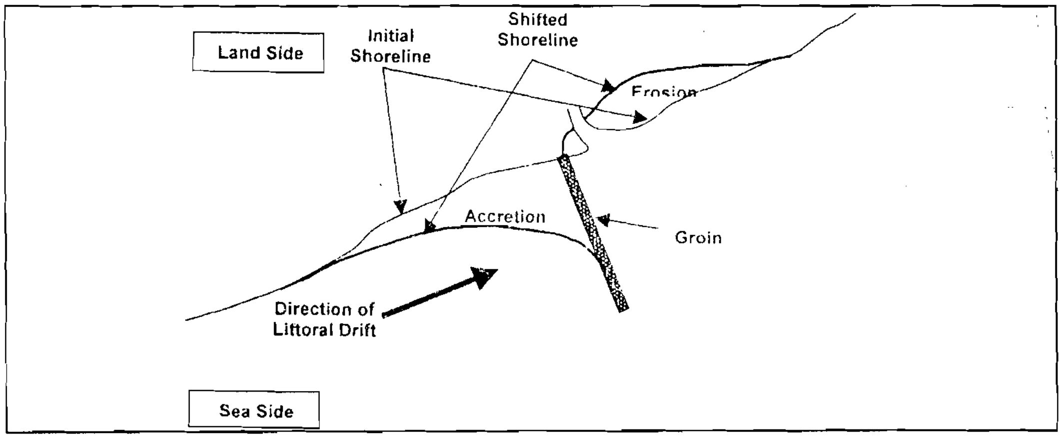

Figure 5: Function of single groin

Groins are usually constructed of materials like timber, steel, stone and concrete and are classified according to their permeability, height and length. A series of groins placed together to protect a long section of shoreline is called groin system or groin field. Too closely spaced groins, however, may divert sediment offshore rather than widening the beach.

Utility and effect of groin(s): Typical effects of a groin on the up-drift portion of the beach include accumulation of drift materials and steepening of the beach profile. On the down-drift stretch, supply of drifted materials reduces, resulting in erosion and flattening of the beach profile. When the accreted slope reaches ultimate steepness for the coarser fraction available, deposition in the up-drift stretch ceases and the entire littoral drift bypasses the groin. An accretion fillet on the up-drift side of the groin brings the shore towards a stable alignment perpendicular to the wave orthogonal. The impoundment capacity of the groin depends on slope stability and alignment of the accretion fillet. These, in turn, depend on the grain size characteristics of littoral materials and the direction of predominant waves. Where there is periodic reversal in the direction of longhsore transport, there may be a zone of accretion on both sides of the groin and zone of erosion between the groins (in case of groin system).

Beach nourishment

Sand pumping is a common method of maintaining stable slope in sandy beaches by artificial replenishment of eroded materials.

The source of the sand may be situated offshore or onshore. Offshore source is used in places where the eroded materials are deposited in the sea by the waves. Onshore source, like sand dunes, is utilised in the regions where the removed materials are subjected to longhsore drift (Kraus, 1983; Krause and Harikai, 1983). The grain size of the sands pumped in should normally be higher than the size of the beach materials of the eroded beach requiring replenishment.

Sand pumping involves high recurring expenditure and can generally be used only in beaches close to coastal resorts with rich economic returns. Constant removal of sands from the interior areas also has an adverse environmental impact.

Plantation programme

Plantation of trees or shrub can be used to prevent or reduce coastal erosion in regions with comparatively low energy level, like sheltered inlets and estuaries. The roots of the plants penetrate deep into the materials subjected to erosion and hold them together. Before going for plantation, the characteristics of the coastal materials and tidal environment need to be checked for careful selection of type of plants.

Plantation of mangroves to promote sediment trapping in the intertidal zone and saline grasses for protection of dune erosion is a common practice in tropical areas. Plantation of mangrove species needs to be done in the sectored areas (Table 2), according to inundation frequency, inundation level and slope of the coastal stretch (Paul, 1991; Banerjee, 1998). Once planted, the woody vegetation has to be protected by the forest authorities from reckless exploitation.

Table 2: Profile of mangrove plants and associates used in plantation programme

Species	Height (m)	Wood Volume	Plantation Period	Zone of Plantation
Avicennia marina	0.5 – 5.0	Medium	July-August	On the mudflats
Avicennia alba	0.5 – 5.0	High	July-August	
Avicennia officinalis	0.5 – 5.0	High	July-August	
Pandanus tectorious	1.5 – 4.0	Medium	September-October	On the coastal sandy region, where dunes are not sufficiently grown
Lantana camara	0.5 – 2.0	Medium	May-June	
Opuntia dillenii	0.5 – 2.5	Medium	May-June	
Calotropis gigantea	1.2 – 2.0	Low	May-June	On the dunes, where vegetation are not sufficiently grown
Ipomoea pes-carpae	0.1 – 0.25	Low	May-June	
Launaea sarmentosa	0.025 – 0.05	Low	May-June	
Cyperus exaltatus	0.5 – 1.5	Low	September-October	

Geotextiles, gabions and geogrids

Geotextiles are fabrics made of synthetic or natural fibres that have wide application in stabilisation of slopes and promotion of plantation. These materials are fixed onto the vulnerable surfaces with help of pegs driven into ground or boulders buried into trenches.

Due to high permeability of jute geotextiles, pore pressure cannot develop when they are subjected to tidal inundation. If plantation is made on a surface covered with jute geotextile, the fabric helps to prevent dislocation of the saplings. As the vegetation grows within 4-6 weeks, the geotextile gets decomposed and does not hinder growth of the plants.

The *gabion* is an encasement (the size may be 1.5 m×2.5 m×1 m) of small sized boulder (2-5 kg) and soil grains held together using galvanized wire mesh. Inside the mesh, geotextile may be used to protect leaching out of soil grains. The soil used in the *gabion* helps to grow surface vegetation. Instead of wire mesh, geogrid, made of high-density polyethylene, may also be used to make the gabion casing. The geogrid is more flexible and durable in saline environment.

River basin management

Sometimes it due to lack of sediment supply from major river source, the beach may face erosion problem. There the river basin management comes into the consideration to save the coastal region. Reduction in sediment input may occur when the ebb-tide current velocity becomes less than the flood-tide current velocity. This situation may develop due to human intervention like construction of dams. Dumping of power plant waste material into the river also results in reduction in depth of the river channel. Dredging or flushing of the river channel often becomes the only solution to this. In this regard, the water bioengineering technique may also be adapted at upstream, which increases the flow velocity of water in the river channels (Schiechtl and Stern, 1996, 1997) and helps to flush out the downstream deposited sediment. This flushed-out sediment may then enter the eroding beach due to littoral current and nourish the same.

Water bioengineering

The dense shrub and tree growth on banks of the estuaries not only decreases flow velocities but also influences the distribution of velocities within the estuarine profile. The presence of woody vegetation does not constitute an impediment to the discharge of floodwater, because there is enough space to cope with the increased flow (Schiechtl and Stern, 1997). The natural or planted shrub and tree may be considered for protection of the coast away from the turbulence.

Impact of shore protective measures on coastal environment : case study from West Bengal coast

The probable impacts of shore protective structures on coastal environment have already been discussed in the preceding sections. Here an example has been provided from West Bengal coast to illustrate the impact of existing and proposed shore protective structures.

Digha is the only sea resort in West Bengal and has been facing severe erosion for last few decades. An armoured seawall, about 3.5 km long was constructed in stages between 1974-1982, by Irrigation and Waterways Directorate (I&WD), Government of West Bengal, with minor modification of the recommendation given by CWPRS, Pune. The seawall was constructed between Jatra Nallah at New Digha on the west and Hotel Sea Hawk at Old Digha on the east. The original profile of seawall as constructed along Digha beach has been shown in Fig. 6. Problem of sand accumulation at the mouth of River Digha, adjacent to Digha coast is also noticed, for which the fishing boats do not get entry to the Shankarpur fishing harbour during low tide. This problem was also addressed at the time of consideration of proposed shore protective structure along Digha coast.

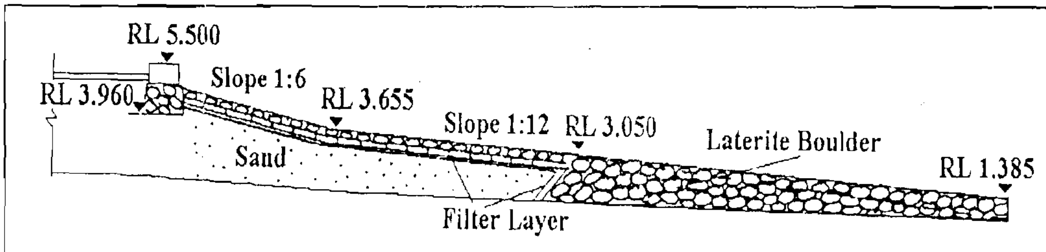

Figure 6 : Seawall cross-section constructed at Digha coast

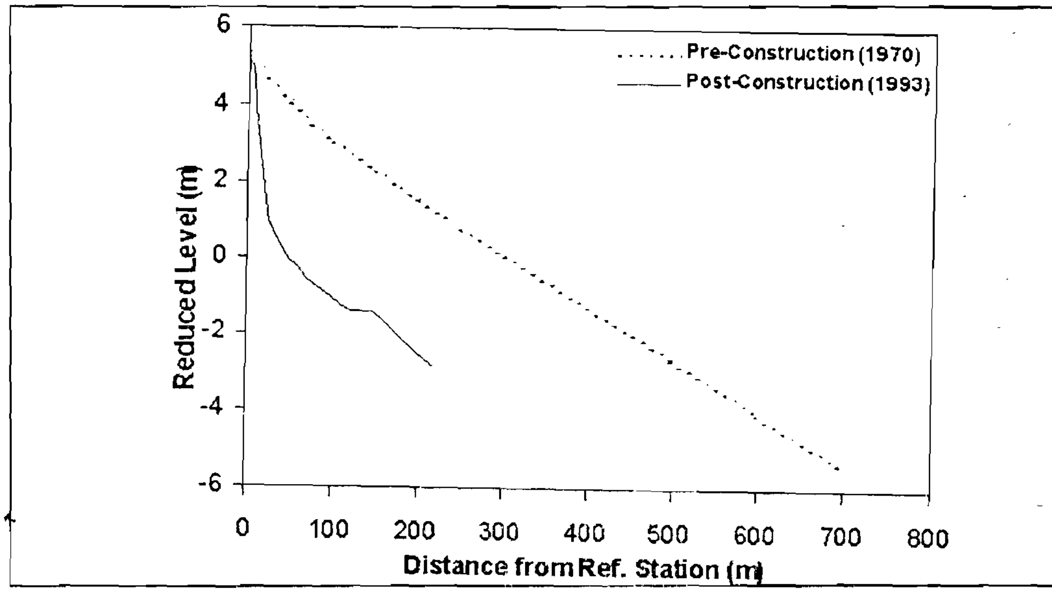

Figure 7: Effect of seawall construction on beach profile

The seawall was able to arrest the beach retreat but the beach lowering could not be protected. It was also noticed that the beach was steepened considerably after construction of seawall compared to the pre-construction period (Fig. 7). The width of the inter-tidal zone also became shorter. Due to existence of seawall, the reflected waves might accelerate the beach lowering. Also, the condition of the existing seawall was deteriorated considerably during the last few years due to moving up and rolling down of laterite boulders by incident and backwash wave action (Plate 1). The slope has become irregular and steeper and the sizes of boulders were reduced considerably due to abrasion from wave action. Daskaviraj and Sarkar (1985) carried out a hydraulic study of the existing seawall. The study revealed that the slope and the reduced level of the seawall (as constructed) was acceptable on the basis of wave height 2.4 m and wave period 11 sec but the study did not reflect anything about the sizes of the armour unit. Toe erosion of seawall due to wave action was also a major problem. In summer and monsoon 1 m to 1.5 m of the toe of seawall becomes exposed (Plate 2) but in winter, sand deposition occurs in front of the toe (Plate 3).

It was reported that there was no overtopping of the seawall upto 1990. But since 1991 there are cases of overtopping at a few places every year, during August and September, when storm coincides with spring tide. It has been reported that waves reach a height of 1.5 m to 2 m above the seawall crest at those occasions.

Plate 1: Natural sand deposition at two of seawall in winter (Digha coast)

Plate 2: Toe erosion of seawall in monsoon (Digha coast)

Plate 3: Instability of armour units of seawall along Digha coast

Plate 4: Wave-cut sand dune indicating severe erosion on predominant down drift end of seawall (Digha Coast)

It was also revealed from the beach profile survey and the report of I&WD, that, severe erosion started on the predominantly down drift end of the seawall (Hotel Sea Hawk end on the east) at post construction period (Plate 4), which is a natural phenomenon of seawall interaction with coastal dynamics. Pattern of shoreline changes has also been presented in Figure 8.

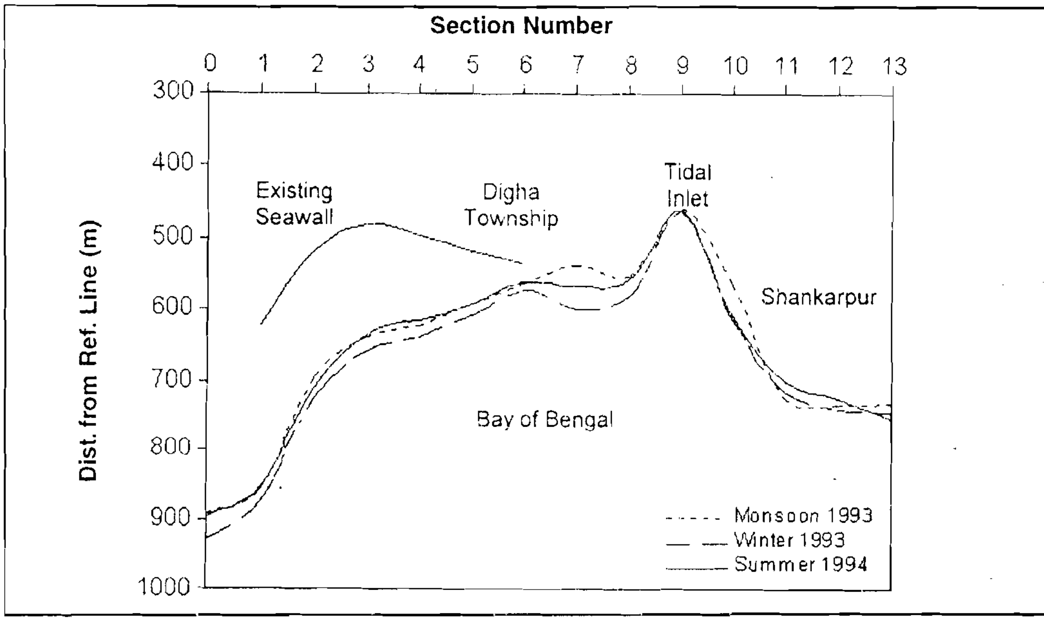

Figure 8: Shoreline change along Digha coast in existing condition

A mathematical model was developed (Bhandari and Das, 2002) to study this disastrous condition of Digha coast. The model was developed to determine the physical coastal environment, subsequently the shoreline changes and to find out probable solution on the basis of obtained physical environment (littoral and wave environment).

The estimated on/off shore and along shore littoral drift as shown in Table 3 (Bhandari and Das, 2002), revealed that Digha coast is dominated by along shore littoral drift. The ratio of along shore littoral drift, Q, to the on/off shore drift, q, is around 10^3. The value of q has been considered '+' for on shore and vice verse and for Q '+' indicates towards east. It also shows that there is a reversal in the along shore littoral drift with the changes of seasons and the predominant direction is west to east. Comparatively low littoral drift is showing towards west during winter.

Table 3: Estimated Values of Sand Movement along Digha Coast

Section No.	Along Shore Littoral Drift ($x10^4$ Cum./Month)			On/Off Shore Drift ($x10^2$ Cum./Month)		
			Season			
	M	W	S	M	W	S
0	+38.0	-19.8	+34.2	-4.98	+2.52	-4.34
1	+28.5	-18.9	+35.3	-3.80	+2.42	-4.50
2	+31.2	-20.2	+39.1	-4.11	+2.58	-4.97
3	+44.3	-23.3	+39.6	-5.77	+2.97	-5.02
4	+43.7	-22.6	+37.1	-5.70	+2.87	-4.69
5	+43.7	-22.5	+36.9	-5.70	+2.86	-4.68
6	+44.8	-23.5	+37.1	-5.88	+2.98	-4.71
7	+44.4	-21.7	+34.1	-5.84	+2.77	-4.34
8	+41.8	-20.6	+37.6	-5.50	+2.64	-4.78
9	+57.5	-26.9	+41.1	-7.52	+3.43	-5.21
10	+60.5	-26.5	+31.1	-7.88	+3.35	-3.92
11	+46.0	-23.6	+30.2	-5.98	+2.99	-3.82
12	+43.6	-24.1	+35.2	-5.63	+3.04	-4.44
13	+48.0	-24.5	+36.4	-6.22	+3.11	-4.61

Since Digha coast is dominated by littoral drift, further extension of seawall may create hazard along the beach stretch backed by seawall and also create erosion along Shankarpur beach (down drift side), which is not desirable. Single groin at Digha Mohana on predominantly up-drift (Bhandari and Das, 2002a) side (Digha side of the river) may create a favourable coastal environment along Digha coast. The single groin would act as sand barrier on Digha side and scour on the down drift side of the groin, which would help to remove the accumulated sand from the mouth of river Digha. The nature of shoreline change along Digha-Shankarpur coast considering the groin along with the existing condition, on the basis of estimated sand movement (Table 3), has been presented in Figure 9. The figure indicating that after considering the groin (hypothetically) in the specific section Digha beach is getting huge sand accumulation and the beach width is also becoming wider, on the other hand the mouth of river Digha is getting scoured, which will increase the navigability of the river without recurring expenses for dredging. The twin problem of Digha can be solved simultaneously by putting a single groin at about 600-800 m west from Digha Mohana.

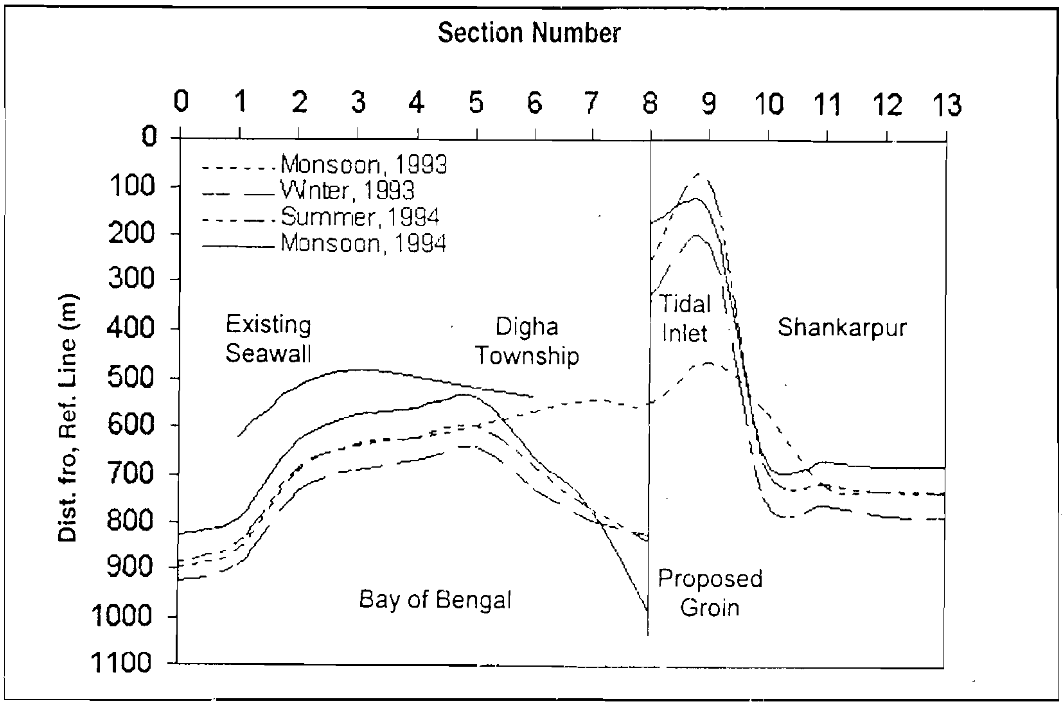

Figure 9: Impact on shoreline change considering single groin at Digha side of tidal inlet along with the existing seawall

Conclusion

The impact of shore protective structures on coastal environment depends on the functional design of the protective measures. It also depends on the beach geometry and other characteristics, like grain size of beach materials, pattern of wave refraction, predominant direction of littoral drift, intensity of on/off shore sand movement etc. in a specific coastal stretch.

As explained above, the groin has accretion fillet on up-drift side and erosion fillet on down-drift side. The erosion fillet may wash out the further down-drift coastal stretch. But twin problem of Digha coast needs scouring at the mouth of river Digha and accretion in Digha beach. Functionally, single groin could provide this solution keeping the groin between Digha beach and river Digha. Exact position, length, direction, height and permeability may be considered in the design aspect.

Shore protective structure should be provided considering the beach characteristics, wave and littoral dynamics and the functional design of the structures. Otherwise, the same may have adverse effect on specific coastal stretch and further up-drift or down-drift. River basin management can be adopted (if the river identified as a major source of sand to the beach) with minimal coastal environmental hazards after a rigorous study of the erosion problem of the beach stretch.

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COASTAL DUNES OF DIGHA, INDIA – A PLEA FOR CONTINUED PROTECTION

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Abstract

An eco-floristic account of the coastal dune environments of Digha is presented. The study records the general features, importance and status of different dune-types with reference to dune-growing plants. The paper also suggests certain viable long-term strategies to protect the dune environment and its precious vegetation particularly the dune-stabilising plants like *Casuarina equisetifolia*, *Ipomoea pes-caprae* and some leguminous plants like *Acacia auriculiformis*, *Leucaena leucocephala* and *Prosopis juliflora* that help supplement nitrogen to the otherwise nitrogen-deficient environment.

Coastal sand dunes which are common in different parts of India, recently identified as highly valued ecosystems in terms of ecology, environment and defence, are threatened everywhere. Besides natural causes, arthropogenic activities are altering these landscapes. And for this, dune systems in many countries are no natural structures today. Notwithstanding geomorphological differences, coastal dunes have some common environmental similarities (Arun *et al* 1999). They constitute a variety of micro-environments due to high substrate mobility and physical processes. Dunes act as natural barriers to protect the coast from the damaging actions of wind, tide and wave, thus assuming a significant role in environmental rescue. Moreover, this landscape, by virtue of its locational uniqueness, is important in terms of the biodiversity it nourishes. Coastal dunes harbour a rich collection of specialised salt-resistant organisms on the one hand and support a good number of adjoining biota of inland origin on the other. This environment, thus, represents a self-contained microcosm wherein biodiversity offers an interesting aspect of life forms and functions. This paper, however, deals with the salient features and functions of sand dunes of Digha in general and dune-growing plants including legumes as they help supplement nitrogen to this otherwise nitrogen-starved environment. The choice for studying the Digha coast hinges on the fact that this area is presently under severe stress, both man-made and natural. Media reports frequently discuss the problems of coastal erosion and

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bare coasts are disturbingly visible. High wind velocity with blow-out sands, eroded shoreline with precariously anchored bushes, poor assemblage of stressed herbs on the eroding edges and storm-stricken defaced bizarre shaped trees speak volumes of adversities that characterise this landscape.

Table 1: Physical features of Digha coast.

Season	Temperature (ºC)		Wind speed
	Maximum	Minimum	
Winter (November – February)	30	10	8 km/hr. NNE
Summer (March – May)	35	17	20 km/hr. SSW
Monsoon (June – October)	35	21	16.5 km/hr. SSW

Source : Goswami (1999).

Digha (Lat. 21º37′N and Long. 87º30′E), an important coastal township of West Bengal, famous for its maritime beauty, is located on a cluster of dunes. The town has a nearly 10 km long shoreline which is mostly alluvial in formation. Physical and climatological features (Table 1) of this terrain is congenial to life, but being a coastal landform, the beachface-dune-complex is a dynamic zone which undergoes constant microlevel changes due to diurnal and seasonal variations in wave-tide-wind energy changes that leave impression in both short and long-term beach/coast morphology changes, rendering the whole area geologically fragile where erosion and accretion not only go hand in hand but also keep shifting (Goswami 1999) which has a telling impact on the structure, function and biogeography of local flora and fauna. Recently, the long-term movement of shoreline obtained from the study of old survey report and new satellite data indicates that there is a continued erosion at Digha proper but accretion at its western boundaries (Bhandari and Das 1999). Between 1877 and 1965, the beach-front-dune complex retreated landward by about 970 m at the rate of 11m per year due to frequent marine transgression. Historical records too indicate that the sandy beach was motorable for the entire stretch and private plane of the erstwhile king of Narajole used to land and take-off safely from the eastern part of Digha till 1964 (Goswami 1968, 1997).

All of these environmental oddities, stresses in biological parlance, of a dynamic environment, in conjunction with soil salinity, water and nutrient scarcity deter plant life to colonise this coast. Yet, there are plants, though few, that survive virtually unaffected. Keeping this in mind, a preliminary ecological work on dune-growing plants of Digha was done by the present author (Bhakat 1999). Since the dune systems are unfailingly ordered by age in relation to their proximity to the sea, the study reveals a gradual and orderly sequence of plant development from seaward to landward side. These are : (1) *Spinifex littoreus* formation on the beach-front seashore, (2) *Ipomoea pes-caprae* development on the mobile dunes, and (3) *Casuarina-Ipomoea-Pandanus* association on the fixed (stabilised) dunes.

Because the coast is very exposed, the unconsolidated substratum of the shorefront is in constant movement. In highly unstable conditions only low-growing *Spinifex littoreus* with deeply penetrating root system survives.

Behind the shore, the freshly deposited dunes, besides being soil and water-starved, are highly porous and prone to removal by the prevailing direction of the wind. In such a changing environment, *Ipomoea pes-caprae* survives and proliferates. Its long creeping stems and much branched surface roots form a network of close-set vegetation on sand surface. In this way, it consolidates and stabilises the freshly deposited, uncovered and mobile dunes. This species later alters the substrate in a way that renders the habitat less favourable for its own survival, but more congenial for the development of other species. Dunes thus fixed by *Ipomoea* invite *Casuarina equisetifolia* and *Pandanus* species, among others. These species, once established, stabilise the shoreline and act as a buffer against erosion, thus accelerating shore development and building new coastlines. This capacity of plants to anchor sand, build soil and help coastal accretion is observed at the duneface of Digha (Bhakat 2000).

Thus, realising the roles of vegetation in the stabilisation of dunes, this study was undertaken to have a glimpse into the eco-floristic aspects of the area, a prior knowledge of which is essential for the judicious management of the coast.

The present day coastline of Digha represents a complex chain of sand dunes lying parallel to the coast, sometimes encroaching 4-5 km into inland areas. On the basis of genesis, development and evolution, these dune clusters can be classified mainly into two categories with an intermediate type in few cases. These are (I) Mobile dunes/Foredunes and (2) Stabilised dunes/Backdunes.

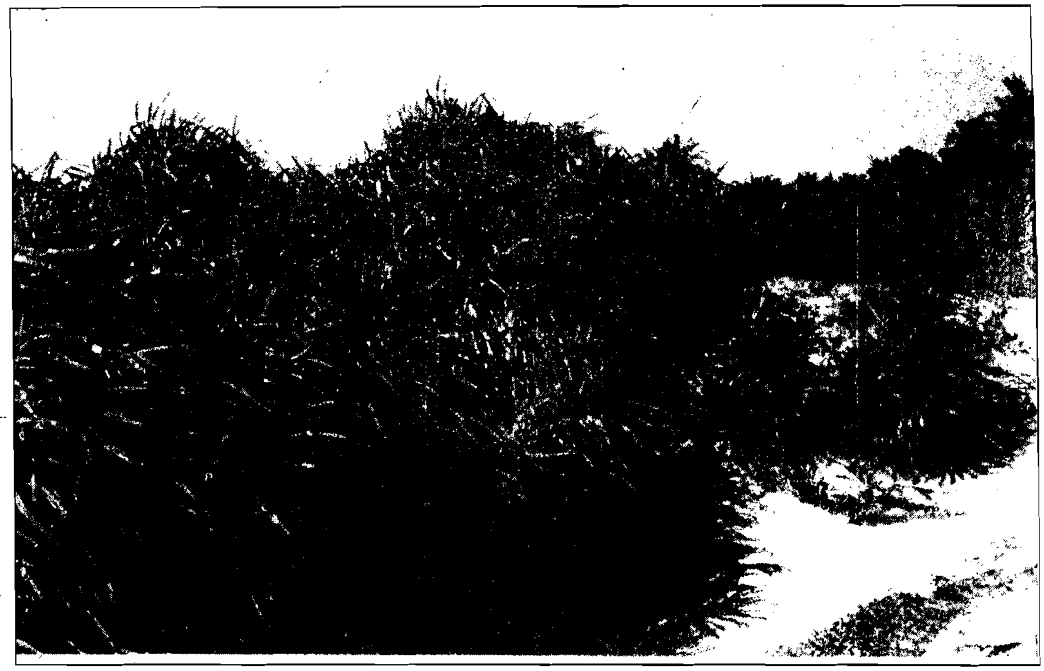

Plate-1 : Stabilised sand dune with *Pandanus* species

Mobile dunes/foredunes

These dunes, chronologically younger in age, correspond to the present sea-front dunes of Digha east. They are of various sizes and shapes, and are also very active, especially during the summer months. Their mobility is controlled largely by the prevailing wind. They have fairly straight fronts and lie parallel to the shoreline often assuming 100-500 m length. The seaward fronts of dunes have characteristics gentle slopes, while the retreating sides are comparatively steeper. The mobile dunes, as they are known, regularly march and shift to inland areas, very often encroaching agricultural lands. The unstable "soils" with very poor fertility status discourages plants to colonise them. Sometimes the mobility of these dunes are restricted by the sparse vegetation growing in a scattered way. The predominant species are *Cynodon dactylon, Borreria articularis, Eleusine indica, Euphorbia thymifolia, Ipomoea pes-caprae, Launaea sermentosa, Sida cordifolia* and *Tephrosia purpurea.* Many of these species very often get buried on the retreating sides by the moving sands. In severe situations, the planted *Casuarina* trees are damaged by cyclonic storms, thus augmenting the sea-front erosion of mobile dunes.

Plate - 2 : Unstabilised sand dune with *Ipomoea* species .

Stabilised/back dunes

Mobile dunes, once fixed by heaths, give rise to stabilised and immobile dunes in course of time. These dunes assume inland position away from the sea. Erosive forces of high winds cannot freely shift sands. The stabilised dunes vary not only in shapes and sizes, but also in micromorphology and microenvironments that differ from base to apex. Further away from the coast, these chains of dune-clusters show inter-dunal depressions or slacks storing runaway rain waters seasonally or annually.

The immobile dunes besides sharing some of the herbaceous species of mobile dunes, harbour ground flora of their own type (Table 2). Sand dune scrubs representing *Calotropis gigantea, Cassia sophera, Cyperus sp., Glycosmis pentaphylla, Lantana camara, Opuntia sp.* and *Pandanus* sp. take their origin on fixed dunes. This scrub formation later gives rise to woodland which represents the (semi) natural near-climax vegetation of the area. Tree dominated inland dunes of Digha coast have *Anacardium occidentale, Casuarina equisetifolia* and *Cocos nucifera.* More recently, two leguminous species *Leucaena leucocephala* and *Prosopis juliflora* are being planted in some areas.

Table 2: Plants growing on different dune-types of Digha

Plant	Mobile Dune	Stabilised Dune	Wet slack	Habit
Acacia auriculiformis	—	+	—	Tree
Anacardium occidentale	—	+	—	Medium Tree
Boerhaavia diffusa	—	+	—	Herb
Borreria articularis	+	+	—	Herb
Calotropis gigentia	—	+	—	Shrub
**Cassia sophera*	—	+	—	Shrub
Casuarina equisetifolia	—	+	—	Tree
Centella asiatica	—	—	+	Herb
Croton bonplandianum	—	+	—	Herb
Cynodon dactylon	+	+	—	Herb
Cyperus sp.	—	+	+	Herb
Drosera burmanni	—	—	+	Herb
Eleusine indica	+	+	—	Herb
Eriocaulon sp.	—	—	+	Herb
Eupatorium odoratum	—	+	—	Shrub
Euphorbia thymifolia	+	+	—	Herb
Evolvulus alsinoides	—	+	—	Herb
Glycosmis pentaphylla	—	+	—	Shrub
Ipomoea aquatica	—	—	+	Herb
Ipomoea pes-caprae	+	—	—	Herb
Lantana camara	—	+	—	Shrub
Launaea sermentosa	+	—	—	Herb
**Leucaena leucocephala*	—	+	—	Tree
Limnanthemum cristatum	—	—	+	Herb
Nymphaea nouchali	—	—	+	Herb
Opuntia dilleni	—	+	—	Shrub
Pandanus sp.	—	+	—	Shrub
**Prosopis juliflora*	—	+	—	Tree
Scirpus articulatus	—	—	+	Herb
Sida cordifolia	+	+	—	Herb
Tephrosia purpurea	+	+	—	Herb
Utricularia sp.	—	—	+	Herb

* Leguminous species; + Present; – Absent.

While the seasonally wet slacks harbour *Centella asiatica, Cyperus* sp., *Drosera* sp., *Eriocaulon* sp. and *Ipomoea aquatica*, the permanently waterlogged pockets support *Limnanthemum cristatum*, *Nymphaea* sp., *Scirpus articulatus* and *Urticularia* sp.

Disturbances

The extent of coastal dune disturbances particularly in Digha can be classified into two categories: natural and biotic, which are defacing the landscape in tandem. While the natural threats like erosion and geomorphological changes are unavoidable (but could be tamed to a certain extent), the biotic disturbances like unplanned urbanisation, escalating tourist load, unregulated disposal of waste, unchecked water exploitation etc. should be tackled on a warfooting. And this includes, of course among others, certain viable long-term strategies to protect the dune system in general and to conserve the precious vegetation in particular. In view of this, the present author recommends certain steps which include: (1) demarcation of space for human activity, (2) enrichment of present dune plants particularly by planting more leguminous species, (3) plantation of more *Casuarina* plants as shelterbelt and (4) fencing of botanically curious insectivorous plants like *Drosera* and *Utricularia*.

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MAN-FOREST RELATIONSHIP: A STUDY IN GEO-HISTORIC RETROSPECTIVE OF INDIA

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Abstract

India has witnessed a long tale of pleasures and pains of its dependent people as far as forest history is concerned. Forests are one of the valuable resources with which the Indians are gifted from the ushering of civilization The forest-fringe people as well as the well-off people were acquainted with this ample amount of flora and fauna and were utilising these resources for effective and comfortable medium of livelihood from time immemorial. The ethos of aesthetics, which men developed with the forests, received a rude shock with the selfish and lusty intervention of human beings themselves, from time to time. The depletion of greenery and the damage of the eco-system is a concern of the thinkers from the Indian as well as from the global point of view, today. The lofty task of today for the social thinkers and the geographers is the restoration of balance in the stock of greenery in Indian scenario.

Introduction

The extensive forest lands of India have not only added to the bio-diversity of the Indian sub-continent, but have also fed millions of Indians and served the basic needs of the forest-fringe people of India from the ancient past. Trees and other forest species like shrubs represent major portion of biomass of this century, herbs and cattle etc. The importance of the very existence of this variety of life on earth is boundless. Our very biosphere is dependent on the metabolism, death and recycling of plants and trees. Various species of forest received enough admiration from the people in general for reasons of religious taboo. Even Fergusson (1875) astonishingly observed that the ancient people considered the

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trees as the *choicest gifts of the Gods* to men. So, there developed an ancient aesthetics between man and forest from the dawn of Indian civilization.

Pre-historic phase

Human history reveals catastrophic changes when compared with what it was during the pre-historic period and what it is now. Human nature was as unpredictable as it is now in certain aspects. One of the characteristic features of human being was his power to adopt himself to the surroundings like animals, which adapt to the surroundings meticulously, which men could do in a slower pace.

The history of human civilization in the Indian subcontinent is substantially old. This land has been blessed with the gifts of the nature in the form of forests, ice, rivers, the blue-sky over-looking them. The pre-historic period had two phases, Paleolithic and Neolithic, in which men had a relationship with the forest, but their attitude towards the forest was conspicuous, different from the attitude prevailing after a few centuries.

The Paleolithic men in India generally lived on the drifts of rivers or lakes and caves; they ate fruits, nuts, roots and the flesh of wild animals. Various kinds of implements were used in this period, *e.g.*, axes, arrow-heads, spears, digging tools, circular stones, hurling choppers, knives, scrapers, hammer stones etc. These implements were held in cleft bamboo, secured by strips of hide or vegetable fiber. Some of these implements had thick butt ends, which were used for digging edible roots or for hand-to-hand fights. Implements of hardwood were also used. Paintings belonging to this period have been preserved in some caverns at Singapur near Raigarh in Madhya Pradesh.

The Neolithic men had their settlements in granite rocks. These rocks gave them natural protection from rain and the sun, and could be conveniently adapted for dwelling purposes. They probably constructed houses made of twigs and thatch materials. The food of the people consisted of fruits, vegetables, roots, nuts, wild pulses, cereals, flesh of animals, fish and milk. Initially, the people for covering their bodies later on used tree bark and skin of animals; clothes of cotton and wool (sheep skin) were used for the same purpose. Hunting and fishing formed their major occupations. People started domesticating animals. Towards the end of Neolithic Period, agriculture became one of the main occupations of the people. A number of superstitions have also been inherited from the Neolithic people. Evidences of their worship and offerings to the spirits and phallus of stone and wood can be traced to the Neolithic Period. Around 6000 B.C., men developed an aggressive attitude towards the environment. They learnt how to grow food crops, to tame wild animals, to make pots and to weave garments. To meet these purposes, they cleared forestlands and cut down the valuable trees for their own benefits. With the increasing selfish interests of human beings, the increasing usage of forest produces grew rapidly in the ensuing centuries.

Classical writers say that the climate of northwestern India was such as it is today; when Alexander of Macedonia crossed the river Indus, perhaps it was little moister. The river valleys were fertile and well-wooded though the coastal strip to the west of the Indus, now called the Makran and much of the Baluchistan were already dry and desolate in 3000 B.C. The whole Indus region was densely forested, providing fuel to burn bricks and food for the wild elephant and rhinoceros and Baluchistan, now almost a waterless desert was sufficiently moist with the presence of perennial rivers. The villagers dwelt in comfortable houses of mud bricks.

The trend of exploitative use of forest for self-comfort continued in the Harappan age. There are evidences that the Harappans used wood from forests for building houses, furniture, ate fruits, made toys for the children like wheeled carts, chairs etc. They domesticated humped bulls, elephants and camels and used them for ploughing the fields. Agriculture must have played an important part in the daily life of the common people and other crops like wheat; barley and cotton were cultivated on a large scale. For trade, ships were used for carrying on maritime trade with distant lands like Sumer, Egypt and Crete. The figures on the seals are mostly those of wild and forest-dwelling animals like unicorn, bull, elephant, tiger, rhinoceros, gharial, antelope etc. Some of the trees like pippal tree and animals like unicorn were regarded as sacred; on the whole, it indicates the deep attachment between forest and people in this period. The study of Vastu Shastra shows the way the forest produces were used, while developing a technology in building these houses was really unique. By observing the structures at Kalibangan, Lothal, Mohenjodaro, Harappa and Chanhudaro, Mackay comments (*cf.* Majumdar, 1977) that the bricks of Mohenjodaro are of excellent quality, well-burnt, practically indestructible and can be used over and over again.

Thus the pre-historic trend shows that human civilization from its cradle years had a deep-rooted relationship with the forests. Human beings, in order to satisfy their various needs, had become automatically dependent on forests and the forests from time to time had provided them with food, shelter, weapons and utensils and with different amenities of life.

Ancient phase

The Aryans who entered India and later settled among the darker aboriginals had a close division in their tribal structure. Their status in the social structure depended on the purity of blood. In the Aryan period, the trees were given a sacrosanct status by the priests. These priests exacted maximum privileges on account of complicated sacrificial procedures and which in turn required a greater amount of forest products. It was through the glorification of sacrifices, an indispensable part of religious procedures, that the priestly class became the only representation of God. The Aryans were basically a wild, turbulent people believing in taboos, which are still prevalent among a few tribes of India. They were addicted to drinks called 'Soma' and 'Sura', which they consumed during times of rituals and occasions of offerings to the god. These were strong liquors made out of corn, barley and extracts of forest trees.

The Aryans gave up their nomadic habits and began to live in fixed dwelling houses. These were made of wood and bamboo and did not differ much from those in Indian villages at the present day. We also hear of removable houses built of wood, which could be taken in parts at different sites. The Aryans followed a mixed pastoral and agricultural economy, which required the cattle as an important element. The importance of cattle wealth in the Aryan society can be judged by the fact that they prayed for increase of cattle as booty, the sacrificial priest was rewarded for his service with cattle. Agriculture was practiced. There are references of ploughing and reaping in the Vedic text. The agricultural implements and tools were of course made of wood, stone and other forest materials. The Aryans cultivated a wide variety of crops, including rice and they also understood something of irrigation and manuring.

The dependence on the forest produces increased in the Aryan community. As can be gathered from the list of occupations practiced by the Aryans, both men and women were engaged in weaving cotton and wool, dyeing and embroidery and leather tanning. The carpenter had an important place in the society and he constructed houses, supplied household articles and furniture. Many of them were skilled in woodcarving and produced delicate artistic articles. The physicians too worked and cured diseases by means of the healing virtues of the plants. The physicians also chased away evil spirits by means of 'Black Magic', which could be practiced in forests only. The sanctity of forest and its value, in the opinion of the authors of the Vedas reverberates in their prayers: *whatever I dig of you, O Earth! May that grow quickly upon you. May my thrust never pierce thy vital points* (Atharva Veda). The Vedic prayers project a robust optimism for living and that too in a congenial environment. From diverse implications it emerges that the word 'Rita' stands for a law of cosmic equilibrium, violation of which is injurious to all components of nature. M. Vanucei holds that the early Indians lived in close symbiosis with nature and in obedience to 'Rita', the natural law.

Buddhism adopted the cult of tree worship from the old tradition and according to legend, Buddha's birth and enlightenment were associated with trees and he received several gardens and groves as representation from his lay followers. In fact, both Buddhism and Jainism promoted prudent use of resources, sanctity of life and protection of various elements of landscape, specifically forests, groves and gardens. This ethics of life preservation originated from pragmatic considerations.

From the sixth century B. C, India witnessed the process of second urbanization with the Ganga plain as the major center of activity. Development of agriculture in the mid-Ganga basin was mainly a rice phenomenon since the area was suited for rice cultivation Ling (1976) suggests that this land had an impact on the population rise, as there is a definite relationship between rice- growing areas and a higher rate of fertility. The increase in population however is indicated by substantial increase in the number of settlements and their general distribution pattern. Various narratives in the early Buddhist literature speak of crowded cities and expansion of settlements, which are an index to population rise. The role of iron technology, according to some scholars, played a significant role in clearing of extensive forests, expansion of agriculture and human settlement.

Expansion under the Maurya State was a more organised effort in the deliberate colonization of river valleys and hill tracts that bounded the Magadhan Empire. Access to the raw - materials appears to have been the prime motivation though control over trade routes and trading points was of no less significance. The initiative taken by the Mauryas in opening new regions to agriculture and trade decisively helped the growth of urbanization (Thapar, 1987). Large scale clearing of forests naturally resulted in easy availability of timber and explains why wood was the chief building material during this period and why Kautilya prescribed several anti-fire and fire fighting measures.

Kautilya's concern (*cf.* Mahajana, 1991) for forests and wildlife can be evidenced by the way he wanted the state to manage it. He categorised forests into four divisions in his 'Arthasastra': a) productive forest, b) elephant forest, c) well-protected leisure forest for the royalty and game forest open to all, d) wild-life sanctuary or abhayaranya. He classified forest produces into ten categories, namely- 1) timber, 2) bamboo, 3) creepers, 4) fibrous plants, 5) plants yielding rope making materials, 6) plants providing writing materials, 7) plants yielding dyes, 8) medicinal herbs, 9) plants providing poisonous drugs and 10) fruit trees. A catalogue of flora is also incorporated in each section. Animal produce minerals, charcoals, menageries of beasts, fire wood and fodder also find enumeration.

Kautilya aptly brought to focus utility and importance of forests for the 'benefit' of mankind; the term 'benefit' may be understood in two ways. In its narrow sense, it means maximisation of production of immediately marketable items and in a wider sense, it evolves conservation of soil and preservation of natural resources and wild life.

Nearchus observed (*cf.* Majumdar, 1977) that Indians wore shoes made of white leather and these were elaborately trimmed, while the soles were variegated and made of great thickness to make individuals seem much taller. The Vinaya texts say (*cf.* Bhattacharya, 1963) that variety of shoes existed, like shoes adorned with skins of lions, tiger, panther, antelope, otter, cat, squirrel and owl. Poorer people used wooden shoes (kharam); shoes made of leaves of palmyra and date-palm and of various kinds of grass.

Daily bathing was not a common practice in eastern India, according to Vinaya texts; special importance was attached to bathing at certain places (*e.g.*, Avanti, Southern country etc.). People used to rub their bodies, thighs, and arms, back against wooden pillars or walls. Chunam was rubbed over the body by means of a wooden instrument in the shape of a hand or string of beads. Certain plant parts were used as 'ruptan' for a healthy skin. The ladies used forest produces immensely for keeping their skin, body, and face healthy and glowing. Ladies for keeping the face glowing and smooth used powdered sandalwood. Special bathing pools or tanks are also referred to. They were floored with brick, stone or wood and had walls or steps of the same material.

After the downfall of the Mauryas, apart from the Kushans and Satabahanas, no great political power arose in India for some time. Under the Guptas, trade prospered and fresh forest areas were encroached. The Guptas had a special officer 'Gaulmika' who were employed to look after the forests and forts. Trade of precious stones, perfumes, drugs, plant extracts, fruits, elephants were done between India and Western countries. The prosperity of trade had greatly enhanced shipping activities and oceanic power of the Indians.

It was from the post-Gupta period onwards that we see the gradual evolution of the wonderful architectural achievements, which were primarily associated with religion. Buddhism was the main source of such artistic endeavour, the results of which are first seen in the modified cave temples at Ajanta, Bagh and Badami. The rock- cut temples as well as the shore temples of Kanchipuram and other places of South India uncover the excellent workmanship of the artisans of the period, who could make their art pieces immortal with the help of adequate amount of forest resources. The extent of archeological remains attest to the glory of urbanization along with massive clearance of the well-preserved forestlands.

The traditional pattern of forest policy was continued throughout the ancient period with little variations. Forests always stood as the epitome of utility for mankind. The Aryans, Kushans, Mauryas, Guptas, Satavahanas, Palas and all other North Indian and South Indian rulers tried to gain maximum benefit for stabilizing the economic situation from time to time. The very notion of utilizing forest products for fulfilling human wants can be traced back to the down days of Indian history. The sentiment for the struggle for human existence found expression in the echoes of green. The very mode of struggle matched with the varying mode of response from forests continued in the next centuries as well.

Medieval phase

With the establishment of empire by the slave king Qutubuddin Aibak, the Muslim dynasty came to the forefront in India with a different set of rules and culture. During the medieval period the country (it was not united at that time) was on the whole ruled under Islamic law. The flourishing trade and the life-style adopted by the nobles, Sultans and the peasants throw light on the luxurious life of some and poverty-stricken life of some others. According to Chopra (1974), the Indian culture in all ages has been fundamentally the same and the differences we notice at different times are those of detail and not of essence.

There was as such no policy towards the forest. The forests were utilized as they were done in the preceding period. The social and economic conditions of the people testify to the fact of ever-increasing dependence on the forests.

The different source materials of this period advocate that rich people spent luxuriously on their dresses. They wore long coats, salwars, and shawls, which were woolen or cotton or silk, depending on the climate. Wool, silk or cotton or any kind of fiber were of course extracted only from the forests. *Ain-I-Akbari* describes eleven types of coats. The workmen and lower classes used cotton langota. The women section wore sari (Hindu women), Salwars and Shirts made of cotton or silk, and brocaded with gold or silver were used by the Mohammedan ladies. They knew the use of hair-dyes, herbal extracts for the cure of baldness, and precious scents were of course items used by rich ladies. The ladies used ghasul, myrobalans, opatanah and pounded sandalwood. *Ain-I-Akbari* gives a long list of scents and their prices. The use of Henna leaves by the women was also very popular. Collyrium was used for the eyes. It was usual for the high-class ladies to use missia for blackening the teeth. Ornaments used by the ladies consisted of Karnaphul, Pipal, and Patti. Khichari was the most popular dish of the common people. Rice, pulses, curd, vegetables, wheat, flour, butter, oil etc were the popular items of food and were mostly related with forests. Different kinds of intoxicants were used during celebrations, *e.g.* wine, bhang, tobacco, betel, tea etc. Wine was extracted from the trees of Mahua, Neem etc. Use of opium was prevalent. Tobacco gained rapid popularity among the common people soon after its introduction in India in 1605 by the Portuguese. These items were all procured through the forest. The forest wood was excessively used to decorate their houses. The Mughal period witnessed construction of huge palaces and architectural monuments. The palaces consisted of *hammams*, *Diwani-Am*, *Diwani-khas*, stables and many other buildings. In Kashmir these houses were built of wood owing to its insulating capacity against harsh winter. In Malabar, these houses were built of teak wood and did not possess more than two storeys. Some houses were built of brick, burnt tiles and lime. The houses of the poor were of thatched roof without any cellar or windows. The floors of the houses were of pounded earth spread over with cow dung.

The houses of the nobles had beautiful furniture like chairs, stools, beds etc. The legs of the chairs were sometimes carved out and the feet were connected by means of wooden planks. Stools made of cane were also used. Mundas of reed and pidis or seats made of suitable wood are also referred in contemporary literature.

Forest traces can be found not only in building construction, furniture but also in the religious ceremonies and customs practiced by the people at that time. The Hindus practiced sixteen principal ceremonies. Six of them were important, namely *Jatakarma* (birth ceremony), *Namakarana*, *Chuda Karma*, *Upanayana* (initiation), *Vivaha* and certain other funeral rites. An interesting thing was that the house in celebration used a chord made of 'Durba' (narrow bladed grass) interwoven with mango leaves, which hung over the main door as a mark of festivity. The Hindus laid even greater stress upon the funeral ceremonies. Different kinds of procedures were adopted for the burial where forest produces were required

Conveyance and transport was another area where requirements of these forest articles were immense. Means of transport in those days were confined to human carriers. Beasts and wheeled traffic on land and boats and small sailing ships on rivers in the coastal areas became prevalent. The poor used ox as their conveyance. Horses, ponies, mules and even donkeys were used for riding purposes. The traditional 'bailgari' or the bullock-drawn cart was much more in use at that time. The rich generally used highly decorated chariots which were covered like the rooms of a house, the windows adorned with glided leather or silk hangings, their mattresses made of silk quilts. Akbar preferred to drive in a two-house chariot *wherein he would sit cross-legged upon a couch covered with scarlet rugs* (*cf.* Blochmann, 1873). Howdahs were also used on elephants; they carried the royal people. The horses and elephants were kept in stables and were well looked after. The nobles and wealthy, however, preferred to travel in palanquins which were covered with cloth. In Bengal, the rich people used *Sukhasan* or *Sukhpal*; a crescent shaped litter covered with camlet or scarlet cloth .In summer khas tatties (screens made of fragrant khas grass) were fixed on all its four sides. Ships and boats were principal means of water transport. There were different kinds of boats for purposes of war, carriage and swift sailing. Larger boats could even carry elephants. The royal people used very artistic boats. All these means of transport needed forest logs and forest materials.

The economy during this period was predominantly agricultural. More than seventy five percent of the population lived in the villages and engaging themselves in cultivation. The country was divided into villages, which were surrounded with cultivable fields. The cultivators followed the traditional methods of cultivation and irrigation. As Babur found no canal did exist. He has written an interesting account of how people irrigated their lands. He writes "At the well-edge they set up a fork of wood, having a roller and tie its other end to the bucket." (*cf.* Banerjee, 1922).

The agricultural products consisted of grain fibers, indigo, sugarcane, poppy etc. The chief fiber crops were cotton, silk, wool, hemp and jute. Hemp and jute were required by the local industries. During Babur's dynasty extensive parts of the country were covered with forests. Babur writes that the country was covered with thorny bush wood. The bush wood was so thick that the people of the parganas relying on these forests took shelter in them. Whenever they revolted against the state by not paying the taxes, they hid themselves in these forests. Extensive forests were there in North-Western Frontier province, Punjab, Uttar Pradesh, Bihar, Bengal, Orissa, modern Madhya Pradesh, Rajastan, Gujarat and Southern India. These forests were full of trees and ferocious animals like tigers and even in some parts there were lions. In Bengal the forests were infested with wild animals, including very many tigers, as observed by the travellers. Abul Fazal mentions (*cf.* Banerjee, 1922) that one had to traverse a thick forest during a journey along a southern bank of Gharghara. William Finch (*cf.* Majumdar, 1977) found a thick, continuous and dense forest while travelling from Jaunpur to Allahabad.

The forests in the Mughal age provided employment to a large number of wood-cutters, sawyers, carters, carriers, craftsmen and other working people who cut wood and cleared the forests. The forests provided numerous varieties of timbers for building conveyance, residential houses, furniture, boats etc. The main wood came from teak, seasame, babul and mango trees. The rich used costly furniture made of costly wood like sandalwood.

Historian Moreland observed (*cf.* Nilkanta Sastri, 1962) the sufficiency and extensive use forest wealth of the country by all sections of people. Akbar abolished duties on the leaves of *Dhak* trees and on barks of babul trees brought from jungles for sale. The duties on grass and fuel wood too were also abolished. The produces from the forest, such as timber, fuel, bamboos, leaves, fibers, grass, gum, sandalwood and other fragrant wood and drugs formed the chief raw-materials from the forests.

British phase

The Portuguese were the first to come to India for trade. People followed them from other countries were the Dutch, French and then the British. It was the British who changed the whole scenario of administrative system in India. They influenced the Indian society at all fronts. The colonial rule was responsible for a massive deforestation. But it was during this rule, that the concept of proper forest management took roots.

The most powerful effect and sustained consequences of the British rule in India was the intellectual development of people in a totally new direction and consequent changes in their political, social, religious and economic outlook. The impact of British rule was first felt in Bengal where British rule had been most deep-rooted than in other parts of India. Although the British became virtually the rulers of Bengal after the Battle of Plassey in 1757, people could not initially understand their motive behind this. It took some years for the people to understand the real nature of the rulers. The initial period of the Indian National Congress proved that the Indians believed in the generosity and ethics of the British rule. These unreal assumptions about the Britishers strengthened the Britishers' exploitative policies. This policy was not only in the field of forestry but in the field of economic activities also. They broke the traditional relationship of the people with the forest. They broke the traditional economy of the villages. The people who were directly affected, *i.e.* the common man and even the middle class did not give any serious attention to this change from political point of view. The economic consequences were of course disastrous for the people and they suffered terribly but there was not any organized outcry against the alien rulers till the second half of the 18th century.

The British rule was exploitative in material terms as well. The British came to India to trade and establish monopoly on Indian trade with the West. At first they tried to extract concessions from the rulers not forcefully but by appeasing them with their services. The Mughal rulers gave these concessions in the form of firmans. The first such firman was the firman of Faruqshiyar in 1717. But they did not stop the immoral acts of denying the rightful amount of revenue to the Bengal Nawab. During the rule of the later Mughals, the English had to pay custom taxes at many points. They wanted to avoid the paying of taxes at every point. So they took the help of these orders in order to fulfill their selfish interests. When they realized the deteriorating condition of the Mughal rule, they thought to take advantage of the situation. It did not take them long to realize that if they want to have profits from the trade, they have to extort as much money as is possible. That land was the best revenue-generating asset became clear to them in very short span of time. So, whenever they could grab land after winning a war, they demanded the Diwani of lands. The Battle of Plassey paved the path of giving the Diwani in 1765 of Bengal, Bihar and Orissa to the British. With this, the rule of greed and exploitation began. The evils of the new revenue system put tremendous pressure on the natural resources of the country. The heavy pitch of assessment continued to be steadily enhanced at each recurring settlement to the maximum paying capacity of the cultivator. The land revenues virtually crushed and impoverished the cultivating classes. The heavy assessment sometimes amounted to confiscation of private property (in land) and the peasant was virtually transformed into a serf. The evils of land- revenue system also compelled many to desert their lands. Thus the Government was denied of the actual expected land revenue. They then started employing means and ways to compensate the loss. Forest resources became a very valuable asset for generation of revenue.

The British turned their evil eye on the forest resources on several other purposes. The ruin of traditional Indian economy and disruption of small-scale industries were other reasons. Before the advent of the British, the Indian villages were self-sufficient units. In times of normal monsoon, the lands produced sufficient food-grains for the people's subsistence. Other needs of the people were few and the village artisans met them. The agricultural surplus went to the Zamindar in the form of land revenue and the peasants after paying the government, had little surplus left with him for purchasing goods.

The disruption of traditional economy resulted in increase in the number of unemployed persons. The end of royal dynasties, the demand of raw-materials by the English, the discouragement of production of finished goods were the chief factors for the unemployment of the artisans. The pressure of agriculture increased, as these artisans now became landless labourers. This resulted in further enhancement of poverty, which forced many to join the group of anti-socials. Realizing the worth and value of forestry products, these people forced by poverty, tried to earn their living by selling the woods of different trees. This led to increase in deforestation.

The modern industries, which came to India as a by-product of the British rule, further, escalated the process of ruining the forests. Till the 1860s the modern methods had been introduced either by the East India Company or the private British merchants. They had produced nothing but had quickened the process of a commercial revolution in India. Instead of machine-made goods and machines being imported from Great Britain, a handful of specialized industries were being built and Indian manufacturers were destroyed in that process. The Indian industries were fortunate in gaining foreign capital, they were all export-oriented and even railways were built with commercial profit as the ultimate goal. Indian enterprisers were fully financed by British capital. The different industries surviving during that time were of indigo, sugar, tea, coffee, jute, cotton, steel, coal etc. The main obstacle in these enterprises was that they were all financed by British money. The Britishers invited money from Britain in the form of investments on which interests had to be paid which amounted to crores of rupees. Thus there was increasing expenditure of the government; the British had to pay the home charges, the return on interest, the salaries of the people working in India. All this they did with Indian capital. Forests became money-producing banks from which they continued extracting money.

The project of railways was another field where they not only invested capital from Britain but also created new avenues of forest exploitation. India had a long tradition of state activities for the promotion of public works, before the East India Company established its political supremacy. Different parts of the country were interconnected by road and water transport for commercial and other purposes. With new political changes in the West as well as in India, there was naturally a demand for improved and external means of communication about the middle of the 19th century. It was in 1843-44 that the earliest proposals were made for construction of railways in India. In 1855, the total length opened was not much. But most of the other railway companies started functioning after 1858. The construction of railways facilitated the export of food-grains, raw materials and other industrial goods. But the most drastic consequence was that it led the British to the interior, unexplored areas of India, which amassed valuable natural resources like forest wood. The railways gave a boom to the policy of deforestation. The exploited forest resources were carried to the ports and then were exported to Britain. The construction of railways itself required large quantities of wood for the coaches and tracks Large tracks of forests were cleared for the spread of railway tracks.

By the time the British established their rule, there was total deforestation in India. The forests of India also acquired a special significance to the rulers for meeting their timber needs, particularly for shipbuilding. In the early British period, the British needed large quantities of teak for the Royal Navy as well as expanding railway network Both teak and timber were required for construction purposes which were exported in large quantities.

Modern phase

The methods adopted by the British led to depletion of specific trees, which were in great demand by the British. This forced the government to enact different forest policies. Forests were declared as 'reserved forests' and 'protected forests'. The village communities, the tribals who were for centuries attached with the forest, were debarred from using them. But in the pre-colonial phase we find that the tribals were themselves aware of the usages of forest produces in some parts of the country. The policy of deforestation continued till the time the reins were in the hands of government. The unscrupulous use of forest resources not only left its impact on the nature but also on the common man. The depletion of forests was conducted for commercial gain of the Britishers only. In 1855 Brandis (*cf.* FRI Publ., 1960) was appointed as the first Inspector General of Forests. In order to legitimise the restrictions regarding the uses of forests by the local people, the first Indian Forest Act was passed in 1865. It was Dr. Brandis who enunciated fundamental principles of sustained yield fixation. The first Act to give effect to the rules for the management and the preservation of forest was passed in 1865. An Act of 1878 classified forests into 1) Reserved Forest, 2) Protected Forest, and 3) Village Forest. Certain Acts like trespass and pasturing of cattle was prohibited in the reserved forests. The local Governments were given rights to notify any forest or land as protected forest after ascertaining nature and extent of rights of government and of private persons over the forestland or wasteland. In 1894, the British Government declared its Forest Policy, which specifically emphasized the commercial use of the forests. The colonial laws led to 97% of India's forestland under alien rule. But these Forest Acts were not meant for conservation of forests at all, though they were the steps, which later on led the Government to modify Forest Acts and emphasize on forest conservation. The general Forest Policy of the government of India had been developed in stages. In 1894, the Department was properly organized. The government of India issued a resolution, which was further strengthened in 1904. The Resolution classified the areas under the control of Forest Department as follows: a) Forests, the preservation of which is essential for protection and environmental purposes. b) Forests, which are kept, reserved exclusively for the supply of useful timber, the commercial purposes and general construction. c) Minor forests, which would supply small quantity of wood, fodder and other produces for local consumption especially for agricultural communities. This was also meant for grazing purposes to a limited extent. d) Pastoral land or grazing grounds managed by Forest Department.

The British left India in 1947, but left some permanent scars in Indian soil. Among many gruesome gifts, Independent India received as a gift over-exploited forests. She also inherited an environment of hostility between foresters and forest-dwellers because of the restrictions put on freedom enjoyed for generations and also because of inhuman and sometimes unjustified enforcement of the forest laws. She also inherited an administration, which was insensitive and unresponsive to the people. Since Independence the forestry activities of the country have been marked by some trends followed by the policy-makers. They can be summarily listed according to decades as follows:

- In the 1950's vesting of all private forests to state. Consolidation of the same for protected and unclassed state forests.
- In the1960's Introduction of the fast growing exotic especially eucalyptus.
- In the 1970's planting of more commercial and industrial species and establishment of State Forest Corporation to attract institutional finance and speedy convention of indigenous forests.
- In the 1980's Extension of Forestry activities outside forest through Social Forests
- In the 1990's participatory management in forests.

The Independence brought a degree of confusion too among the rural and the forest-fringe people. They could not understand the future policies of the government.

Since Independence, the forest policies were formulated by the Government of India and these were followed over certain periods. During the period of 1952-1975 forests were to be used only for production of timber. During 1976-1987 the main focus of the management policies was to continue with the production of timber and creation of social forestry. More funds were allotted for social and farm forestry outside forestlands. From 1988 onwards, a revolutionary venture called the *Joint Forest Management Project* was launched. The New Forest Policy of 1988 is radically different from earlier two policies (*i.e.* 1952 and NCA 1976). This is an epoch making period in the history of forest management. The forest policy tried to conserve the natural heritage of the country by preserving the remaining natural forests. Forests maintained the balance of environment and hence could meet the subsistence required by the local people. The priority and objective changed. The forest policy gave more importance to the environmental stability than the economic benefits. It gave preference to mixed forest and encouraged poly-culture. The main focus was on ecological balance. It also tried to strengthen the tribal economy by satisfying the need of the people. The *Non Timber Forest Produces (NTFP)* was stressed upon. Production and Processing of these items contributed to the boost in rural economy by generating employment and income. It gave due importance to people's participation in forest protection. This forest policy encouraged the participation of forest-fringe people in saving the forest. In order to strengthen the man- forest relation ship, it gave the rights to the protecting communities over the forest produces. The *Non Government Organizations (NGOs)* were attracted and were invited to act as intermediaries between the people and the government. The encroachment of forestland for non-forestry purposes and also the use of forestland for any personal use by the forest dwellers were strictly prohibited. The villagers were encouraged to participate irrespective of their sex. The women were encouraged to come to fore front for resuscitation of forests. Advancement of research and technology were encouraged in order to increase productivity in forestry .The new strategy of forest policy adopted by the government needs a strong political will to implement it properly. The forest-fringe people involved in this project are being economically benefited. The NGOs involved in this programme are working as a medium between government and foresters. The future trend of JFM would indicate success or failure in the forest policy pattern of the government and the Forest Department.

Conclusion

After analysing the man-forest relationship in different phases of Indian history, it can be found that geographical environment had a deep impact on the historical trends of India. Human civilizations were carved out of geographical setting of which forests played an extraordinary role in shaping the destiny of man and mankind in India. Man-forest relationship had an inherent aesthetics, which was slowly destroyed due to the accelerated selfish interests of human beings for the struggle for existence and better living. The nature of dependence on forests took a crude turn with the intrusion of the Britishers from the middle of the 18th century. The luster of green was totally demolished by the greedy interference of the aliens It was from mid 19th century onwards that drastic deforestation took place in India and severely disrupted the geographical and ecological balance in the entire Indian Sub-continent. The thought of restoring the eco-balance by revitalizing the greenery is a current phenomenon. An extra thought has been given for revamping the economic standard of the forest-dependent people by various progressive means. Now, let this century and the next century ahead watch whether the geographical scenario and the historical scenario would act in accord in order to bring back the ancient harmony between man and forest.

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Short Communication

CONSERVATION BY THE PEOPLE, FOR THE PEOPLE AND OF THE PEOPLE

How people conserve natural resources

One of the lexical meaning of the word "conservation" runs like this: "the official care, protection or management of natural resources"(Webster's New World Dictionary, 1988). Kindly note the word "official" which connotes a formal organization, power structure and authority. Historically speaking, conservation of natural resources did not originate from formal and hierarchic social organizations but out of the sheer need for survival through prudent use of natural resources. Descriptions of the lifestyle of so called "primitive" peoples all over the world by the anthropologists contain plethora of evidence regarding the conservation of plants, animals and inanimate natural resources through various kinds of cultural norms, taboos and prohibitions. Recently, Professor Madhav Gadgil and his team at the Indian Institute of Science, Bangalore have done a seven-state study in India which clearly demonstrated how biological diversity of our country is being protected by the poor people without any kind of help from the government (Gadgil, 1998).

Tribal and peasant communities throughout the globe worship various kinds of plants as well as animals and observe taboos, which prohibit the cutting down of, and the killing of animals. Among the tribes who subsist on gathering and hunting, an almost universal prohibition on the killing of pregnant animals shows a kind of *bioethics* for the preservation of the different animal species, which also provide important sources of protein for the people. The ecologists have interpreted the classic case of prohibition against the killing of the totemic animals by the clans of the same tribe among the Australian aborigines as an example of resource management through customs rather than by any formal bureaucratic structure. The different clans of the same tribe worship their respective totemic animals although, the members of one clan may hunt the totemic animal of other clans and vice-versa, which ensures food security as well as conservation of natural resources within a given area. Most of the forest dwelling communities in the tropical regions of the world consider themselves as "children of the forest". They talk, play, sing and dance with the trees. In a recent field based study conducted by an anthropologist among three forest dwelling communities of Zaire, Malaysia and India revealed a kind of *cosmic economy of sharing* among these groups. The Mbuti, of Zaire for instance, depict the forest as a "womb" from which they have originated (Bird-David, 1992). If we just compare this cosmic economy of sharing where natural resources have to be shared and loved with that of the technological ethics of the modern period, then the contrast can be observed very easily. While the people who depend directly upon natural resources for their daily sustenance show "love" and "respect" towards nature, the people who can purchase whatever they want from the market try to "conquer nature" with superior technology. And it is the latter group of people who hold greater power in societies and blame the former for putting immense pressure on the natural resources by their larger number. So when the question of conservation of the natural resources arise, the educated people of our country think in terms of this dominant ideology which views the poor people (tribals, dalits, landless labourers, artisans etc.) as a kind of burden upon the natural resources who should be prevented from overusing the land, water and forests for food, fuel and fodder. This technology and market oriented ideology is also reflected in the National Forest Policy, 1988 which is regarded as a major breakthrough in forest management policy and conservation of natural resources. In the following section we would make an attempt to analyse National Forest Policy from this angle.

National Forest Policy: conservation for whom?

The National Forest Policy (NFP) can be regarded as one of the most idealised text issued from any government department since the independence of our country. The most value loaded statement of this policy can be found under the section entitled **"Basic Objectives"** wherein, it is stated that one of its objectives would be to "create a massive people's movement with the involvement of women" for achieving conservation and regeneration of our natural environment and "to minimize pressure on existing forests". (National Forest Policy, 1988). How far and to what extent our governments, with the help of their forest departments, would be able to create this "massive people's movement" for conservation of the natural resources is an open question. But even a casual reading of the newspaper shows that conflict over natural resources between states, forest departments and people as well as between different communities have increased over the years. Neither the Central nor the State governments have any system of keeping any record of conflicts, let alone systematic policies for minimizing them. The recent protest campaigns launched by the voluntary organization against the World Bank funded eco-development project reflect this conflict in prominent manner (The Statesman, 5 December, 1988).

It is interesting to look into the contradiction of this national policy when it comes to the question of conservation through protection. Under clause 3.3 it is stated: "For the conservation of total biological diversity, the network of national parks, sanctuaries, biosphere reserves and other protected areas should be strengthened and extended adequately". But just after a few paragraphs the same policy document under clause 4 mentioned quite emphatically: "The life of tribal and other poor living within and near forests revolves around forests. The rights and concessions enjoyed by them should be fully protected". It is not clear how these two kinds of "protection" viz. (1) protection of nature parks and the (2) protection of the rights of the poor people on forests can be effectively carried out without the empowerment of those people through legislation and their effective implementation by the State Government and the panchayats. The National Forest Policy does not contain any statement regarding the necessity of such legislation for the empowerment of the poor people living in and around the protected areas. How can one protect and regenerate forests without involving the people living within them?

The clause 4.10 of the Policy is quite interesting as it clearly expressed the paternalistic attitude of its makers. This clause states: "Forest conservation programme cannot succeed without the willing support and cooperation of the people." So far so good. But just in the next line the policy document stated without any hesitation: "It is essential, therefore, to inculcate in the people, a direct interest in forest, their development and conservation, and to make them conscious of the value of trees, wildlife and nature in general". But who are these "people"? Are they tribals who consider themselves children of the forest or educated city dwellers that consider the tribals as burden on the nature parks, which should be protected as national assets? Nowhere in the national policy on forest is there any reference to the traditional conservation practices followed by the people. For the policymakers, conservation is always 'official' and should be initiated by the government. Not a single line in the text is devoted to the importance of learning from the experience of the tribals and the poor people of our country. The attitude of the government towards the forest users become very much clear when the question of grazing is dealt with. Under the rubric, "*Damage to Forests from Encroachments, Fires and Grazing*" the policy statement categorically mentioned "Grazing in forest areas should be regulated with the involvement of the community. Special conservation areas, young plantations and regeneration areas should be fully protected. Adequate grazing fees should be levied to discourage people in forest areas from maintaining large herds of non-essential livestock". Several questions immediately arise as to the scientific basis as well as practical feasibility of this policy prescription. There is no concrete management plan about how to involve the community in the regulation of grazing at the same time discourage them to enter into the forest areas. Secondly the phrase "non-essential livestock" is an imposition by the policymakers upon the poor villagers for whom cattle serves manifold purposes in their struggle for existence in agricultural and pastoral economies. If cattle becomes really non-sustainable for the overall ecological balance in a region, but at the same time essential for the poor, then it is the duty of a democratic government to make alternative arrangement for those people through poverty alleviation schemes before preventing them to graze their cattles within the forests.

Our foregoing discussion on the National Forest Policy shows its paternalistic and contradictory approach towards conservation and it can hardly be called a down-to-earth and people-oriented policy statement.

Two suggestions in lieu of a conclusion

Under these circumstances, universities have a great role to play in changing the approach of our governments and its bureaucratic organizations. To begin with, some action-oriented research can be taken up at the local and regional levels which are enumerated below:

1. Recording and documentation of the biodiversity of the locality in which a university is situated. For doing this, expertise of several disciplines is required. For example geography, botany and zoology can prepare inventories of biodiversity in some selected areas in the vicinity of the university campus. The Vidyasagar University has immense potential for drawing biodiversity maps of some selected areas and/or villages near its campus. In fact, the Vidyasagar University campus itself is a wonderful setting for the preparation of this kind of biodiversity map. The students of the aforementioned disciplines may be assigned to prepare small project works on this very important aspect of environmental studies.

2. The sheer recording and documentation will not be sufficient to generate action research which may have some bearing on policy formulation in future. It is also necessary to collect concrete data on the various conservation practices adopted by the people themselves. For the collection of these type of data, the anthropological method of direct and

intensive fieldworks may be adopted. A seven days fieldwork in a peasant village may bring out rich data on the various practices of the people related to conservation and regeneration of the flora, fauna and the inanimate natural resources in and around the village. For example, if a group of students of the anthropology department just observe and record the number and types of trees planted by members of each household in a small village then it would yield a wealth of material on the diversity of trees in that village. And if information on the nature of those trees and the taboos and rituals associated with them are collected then it may generate valuable baseline data on conservation by the people.

This kind of database on conservation of the natural resources would also help us to develop fruitful national and international network with other universities, research institutes and voluntary organizations that have already started to work in this line.

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Book Review

Landscapes and Lives: Environmental Dispatches on Rural India by Mukul Sharma : Oxford University Press, New Delhi, 2001, pp. Xi + 234, Rs. 475/-

We are experiencing and passing through a new revolution – the environmental revolution. Of all the political, economic and social movements of the last century, none has so fundamentally changed human values and behaviours as the environmental conflicts and revolutions have done. Environmentalism has since spawned a mass movement with plethora of followers, generated new bodies of law, hatched new political agenda, encouraged a thinking of economic and social priorities, and made inroads into central issues in international relations. Above all, it has changed the way we look at the world, and forced many of us to change our attitude and lifestyle. For the first time humanity has awakened to the ground realities about the interrelatedness of and fragility of the biosphere. At the same time, humanity has been alerted to the basic truth that nature is finite, and that mismanagement of the environment ultimately jeopardises our own survival and existence.

In India, thanks to the pioneering work done by the Delhi-based **Centre for Science and Environment** which has been instrumental in disseminating the contemporary environmental affairs and in awareness-building initiatives through its periodic *Citizens Reports*, fortnightly *Down To Earth* and other publications for the last two decades. And since then ecological concerns have carved out a permanent niche in Indian social sciences and public discourses alike. As a result, more and more people are getting involved in environment related affairs, more specifically in decrying government and private efforts to short-term economic development at the cost of environment. The Chipko movement in the Himalayas led the pathway in early seventies. The Tehri Dam agitation and the Narmada Bachao Andolan have brought to the fore the unknown and little known but dedicated activists. And environmental conflicts are now almost routine headlines of major media. Drought and flood, the impact of industrial by-products, the problem of unabated mining, and green destruction – it seems that no one has remained untouched by such issues. Yet the mainstream media has increasingly shied away from in-depth and on-the-spot analysis of many of such issues, especially those which are rural in origin. Notwithstanding this, there are exceptions of course, and this is where the work of Mukul Sharma, a journalist, stands out. And herefrom the sensitive and ecologically serious journalism crops up.

The significance of the book under review emerges clearly from its simple and lucid introduction. "*Landscapes and Lives* is about the unfolding of environmental issues and movements in rural India during the 1990s. It makes no claim to a comprehensive coverage of the field. The reports in this book appeared originally in a number of publications, including the *Economic and Political Weekly, Frontline, Down to Earth, Inter Press Service, Gemini News Service, Navbharat Times*, and *Udbhavana*. They are concerned with issues which received little or no attention in the mainstream media. The focus of the book is on how rural people, movements, organizations, governments, and non-government organizations are confronting, or evading, the question of the ecology of land-scape. It deals with some marginal to marginal ecologies like *diara, khadar*, and ravines, where from the mid-1980s to the mid-1990s alone, thousands of acres of land and hundreds of lives have been lost, leaving once-prosperous villages devastated and isolated, and several families near-destitute. Yet this crisis, a festering sore on the landscape, rarely figures in any environmental agenda because these areas have little political clout and, perhaps, because the decline here is not sudden, dramatic, or imposed from above. It is a slow, everyday phenomenon (and therefore, perhaps, more pervasive), which does not fit into a neat category of crisis perpetuated by the modern developmental models."

Landscapes, as described by the author, have both natural and social environments. As the author writes, "They bear the marks, not of a fixed relationship with humanity, but of changes brought about by the impact of shifting political, economic, and social actors upon them. In them we see the effects and the process of, say, land erosion, deforestation, desertification, or pollution. At the same time, we can grasp the political and economic pressures which generate, exacerbate, or reduce these problems. We can see how the majority of people – tribals, small-scale farmers, fishing communities, boatmen, and labourers – have struggled to retain control over their environment, often in struggle against the state or business and, as we can see from the examples, they are by no means always the vanquished in these conflicts."

What is interesting about the book is that it narrates both everyday and episodic stories. "The way people, society, state, and the market function on a day-to-day basis is responsible for pollution, deforestation, waterlogging; while floods, the shifting of riverbeds, landslides, which are massive occurrences over long time-periods, are episodic. But there is a relationship between the two and sometimes, as in the case of diara region of Bihar, the khadar region of Haryana, the ravines of Madhya Pradesh, and the coastal belt of Kerala, we see the episodic becoming the everyday. With floods, landslides, and erosion becoming almost regular occurrences, impoverishment and trauma have become everyday reality for many people. It is essentially the poor and the weak who bear the brunt of these disasters. These processes of ecological and economic marginalization are leading to extreme forms of criminalization, violence and conflict."

Adivasis, Dalits or peasants must not, however, be seen only as helpless and hapless victims. They have repeatedly organised themselves to fight the injustice and exploitation of oppressors and their representative forces. The fisherfolk of Bihar, for example, have formed the *Ganga Mukti Andolan* to free the ferry ghats and waters of the Ganga where they have to pay cess to the profit-seeking landlords who have had a sway over the river. And the government remains a silent spectator because it is pathetically starved of resources needed to intervene. A similar situation exists in relation to the thousands of other waterbodies with traditional mallahs and dalits engaged in serious conflicts, often leading to gory endings, with the powerful upper castes, money-lenders, sometimes the government who control these waterlogged resources.

We often hear governments addressing land reform issues but rarely about water reforms (recently the government is thinking of such agenda). As a result, the lives and livelihood of a cross-section of poor people whose life-styles revolve around such wetlands are in jeopardy. With the legal status of these environments remaining unclear, the possibility of state take-overs frequently haunts the communities managing these resourceful ecosystems. And the Kolkata-based Mudially Fishermens' Cooperative Society is a case in point. This Society consisting of a group of skilled fishermen, has nicely developed a resource-generating Nature Park-cum-Sewage-fed Fish Farm out of a derelict waterlogged landscape of Kolkata Port Trust. But in the recent past there had been several attempts by the Trust to repossess the wetlands for its own uses. Sensing the threats of eviction, the Society had sought the Left Front government's and various NGOs' intervention as last succour. This wetland movement in the line of "Save East Calcutta Wetland" spearheaded by the present users (fishermen) is not only an attempt to save a precious waterlogged wealth, but is a struggle for survival and traditional rights over the area.

Equally horrific is the situation prevailing in the diara and khadar lands formed by the unpredictably meandering and shifting rivers. These landforms, ephemeral and seasonal though, are extremely fertile, and therefore are chosen fields for seasonal vegetable cultivation and fish culture. As a result, these sites often turn out to be the breeding grounds of violent conflicts on the one hand and places of instability caused by the erosion and floods on the other.

Grassroot environmental resistance of people are not merely reactive and fuelled by protests against oppression by others. They can also build new institutions, construct new structures, and find new and novel ways of living to escape poverty and injustice, thus enjoying the freedom that is everybody's birthright. In this act of resistance, alienation and isolation, they invent new survival weapons to counter the state forces. The unofficial cooperation defying the political restrictions among the Indian, Pakistani and Srilankan fishermen is a pointer in this direction.

In yet another instance in the four contiguous districts of Rajasthan, the survival instinct of tribals has led them to protest against the Forest Department's action to fence off forests, thus destroying the livelihood of forest fringe dwellers. In a positive thinking, "their demands included regularization of all pre-1980 encroachments on forest lands based on the notifications of the central and state governments, a special time-bound campaign for the identification and regularization of encroachments, recognition for the *Jungle Jamin Jan Andolan* (People's Movement for Jungle Land), comprising tribal, environmental, social and non-governmental organizations, and citizens, to plan, implement and monitor the campaign, recognition of the *gram sabhas*' opinion for identifying encroachments in the absence of written records and an end to all eviction procedures and harassments by officials until the process of identification and regularization was over."

Similarly, in Madhya Pradesh, the villagers of Jhabua district have used *halma*, a traditional agrarian institution for collective labour, to construct civil works that cater to the needs of local inhabitants, with financial support from the government under the Integrated Rural Development Programme scheme. Another telling tale of environmental reform by common people comes from the village Ralegan Siddhi, Maharastra where disciplined villagers under the leadership of Anna Hazare (known popularly as 'Annasaheb' – the elder brother), who once threatened to return Padmashree award, have transformed a dry unproductive terrain into a prosperous oasis. Ralegan and Anna Hazare are synonymous today. Their land and water management and skills in rural development, decentralised planning, among others, have caught the nation's attention. In the words of Mukul Sharma, "It (the village) professes to combine materialism with spiritualism, religion with patriotism, and environment with development."

Environmentalists and social activists in India cry now and again against large dams, yet in remote corners some dedicated Indians have used small dams or bunds (recall the pioneering work of Rajendra Singh) to store rain water or run-off from hill slopes, and used them for different purposes like irrigation, soil conservation and afforestation. The Sato example of Bihar will suffice to reestablish the fact that people's own indigenous skills and local necessity can make a dent on the future course of environmental management in general and watershed development in particular.

The villagers of Sato in Gumla district (near Ranchi) celebrate 28th October every year as their "Independence Day" since on that day in 1988 they completed a small-scale dam on a hilly waterfall. After the several unsuccessful efforts, when the dream turned into reality, it was really a matter of joy and great celebration the like of which merits comparison with 15th August.

In an even more interesting case in Mahuatoli of Vishnupur region in Chotanagpur, the tribals have formed a "parallel" *Tinsimani Sarkar.* With six other ministers and a Prime Minister, Bhiku Urao, a labourer and "Forest Minister" of the "government", looks after the forest, water and land of the region. The government formed by the coming together of people of three adjoining villages has its own agenda in addressing the local issues, and accuses the state government of illegal felling of trees. The latter, of course, denies it and helds the tribals responsible for breaching the peace in the region and not allowing the administration to perform its duties.

Further up in the Himalayan Uttar Pradesh (now Uttaranchal) where women under the leaderships of Sunderlal Bahuguna and Chandi Prasad Bhatt started the Chipko agitation, villagers have still to continue the struggle against deforestation, unscrupulous contractors and indifferent administration. The women of Bacher, a village away from Gopeshwar, the district headquarters of Chamoli and a cradle of Chipko movement, has formed a Mahila Mangal Dal to ban the tree-felling in both the government and private lands. But in this case, it was not an issue of forest any more. The villagers had for long been demanding the State Electricity Board to provide electricity to the village. When the Board failed to do so even after repeated requests, it was the womens' agitation that galvanised the state into action.

Sharma's reports on the struggles of traditional fisherfolk in the coastal landscapes, although seem to be less surprising possibly because of protracted agitation, but strive to remind one that dialogues between the dispossessed and the state will remain alive and likely to continue in the days to come. What is abundantly clear by the time one finishes the book replete with numerous less-known and untold stories is that the struggles, mostly local and dispersed though, are teaming up with new activists and using newer strategies including taking resort to the Hon'ble Supreme Court for redressal and justice as happened in the case of factory workers suffering from the industry-induced disease silicosis in

Chinchurgeria village near Jhargram in Midnapore district of West Bengal.

Lastly, if the present reviewer cares to humble submission, it is very difficult to either discuss or comment on the many fascinating aspects of the book. What is attracting and equally important is the fact that at a time when the environment as an issue becomes to a subject of academic exercises and or an issue for donor funding, the author of the book tries to link the fate of earth with the lives of its creatures, particularly the existence of human being. Therefore, this treatise deserves recommendation for reading in ecology, sociology and politics. It is also important for academicians, policy makers, researchers, NGOs and social and environmental activists.

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